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Welcome Address

Dear Dr Feto Esimo, Director General, IQQO;

Invited Regional and Federal Bureau heads, directors from various regional and Federal Research centers, respected official from Universities, representatives from donor partners, delegates from Oromia Regional State president office, delegates from Oromia regional house of representatives and standing committee for Agriculture, regional and federal AGP-II coordinators, honored stakeholders from zonal to Federal government offices and CGIAR centers, respected staffs of IQQO from center to the institute level, Ladies and Gentlemen;

It is indeed a privilege for me to make a welcoming address on this remarkable workshop where almost all Agricultural Research and Development partners working in Oromia Regional state and also representatives from Dire Dawa and Harari regions are assembled to discuss and advise forthcoming proactive actions on Agricultural Production Constraints identified in the regions. The Government of Ethiopia has been implementing a five year Agriculture Growth Program II (AGP- II) from 2015 to 2020 with the support of the World Bank and several other donor partners committed to assisting the development endeavors of the country. The Program is aimed at increasing agricultural productivity and commercialization of small holder farmers in the selected potential districts in the country, where Agricultural Research are expected to play a major role in generating, demonstrating and multiplying demanded agricultural technologies. Understanding farmers' socio-economic situation, their environments and agricultural production constraints and opportunities are prerequisites to implement this kind of multifaceted research and development intervention. To this end, Oromia Agricultural Research Institute (IQQO) Agricultural Growth Program (AGP-II) conducted survey of Agricultural Production Constraints from 13 representative districts of nine selected zones of Oromia Regional State, two districts from Harari Regional State and two clusters from Dirre Dawa City Administration during 2016. Community Level Participatory Planning (CLPP) and Participatory Research Approach (PRA) tools were employed.

The identified Agricultural production constraints are so monumental and multidimensional that needs interventions of all entities working in Agriculture and related sectors. Majority of them requires development intervention and some others are researchable. Today, the results of the identified production constrains across all the study areas will be presented, commented and enriched. Besides, the general overview and management of some of the disastrous and priority Agricultural production constraints such as fall army worm, wheat rust, maize lethal necrotic disease, soil acidity, termite and mango scale insects will be presented and discussed.

I take this opportunity of paying tribute all donor partners to AGP-II for generous financial support in conducting field survey, data analysis, article preparation and organizing such a wonderful stakeholder’s workshop. This workshop would not have been materialized had it not been technically and logistically supported by IQQO, the established committee and IQQO AGP-II coordination units. I wish to express my sincere hope that we all have to show commitment and collaborate to avert the multiple agricultural production constraints that our small holder farmers have been fronting year after year.

Dear Dr Feto, it is with greater pleasure, honor and privilege that I now invite you to officially open this workshop.

Dagnachew Lule (PhD)
Oromia Agricultural Research Institute (IQQO)
Agricultural Growth Program Coordinator

Opening speech

Honorable officials from Oromia, Dire Dawa and Harari regional administration offices; esteemed Zonal, Regional and Federal Bureau heads, Directors from various research centers working in the region, Presidents and vice Presidents from the Universities in the region, invited guests and IQQO staffs, Ladies and Gentlemen;

On behalf of myself and the institute I am heading, I would like to thank you for your commitment to participate on this cutting age stakeholders' workshop, assembled to discuss on Agricultural production constraints prevailing in the regions and to set strategic and collaborative interventions.

Agriculture plays a crucial role in the life and livelihood of most Ethiopians and has also a key role in poverty reduction for most poor farmers, who largely depend on it. However, agricultural productivity in the country remains low due to several biotic and abiotic constraints. Even though several Agricultural technologies have been generated during the last 5 decades, its impact on livelihood of farmers and overall economy is not significant.

Oromia Agricultural Research Institute, IQQO, was established 20 years back to conduct problem oriented and demand driven Agricultural research so as to maximize productivity and modernize the sector to accelerate Agriculture lead Industrialization economic policy. Accordingly, the institute, through its 17 research centers, has been conducting multidisciplinary research on crops, livestock, natural resource, Agricultural Engineering, socio-economics, food science and seed technologies in the various agro-ecologies of the mandate area. As a result, hundreds of improved technologies were released and recommended during the last two decades. However, climate change and other emerging natural and human induced calamities are exposing the sector to numerous production constraints year after year obliging advanced research and development interventions through collective and collaborative actions of the stakeholders.

Dear participants:

Oromia Agricultural Research Institute (IQQO) Agricultural Growth Program (AGP-II) identified the major Agricultural Production Constraints in Oromia, Harari and Dire Dawa city administration and the results of these identified production constrains across all the study areas will be presented, commented and enriched today with your active partaking.

I would like to take this opportunity to express my sincere thanks to the organizers and in particular AGP II coordination unit of our institute. All our staff members at headquarter have been working very hard since the inception to date, even though they are both very busy with other routine activities. I truly appreciate your dedication.

Ladies and Gentlemen:

Finally, I am fully confident that your input will be significant and opportune time to declare the official opening of this workshop.

Feto Eismo (PhD)
Director General, Oromia Agricultural Research Institute (IQQO)

Key note presentation

Dear Dr Feto Esimo, Director General, IQQO, invited officials & scientists from the various research and development institutions, ladies and gentlemen;

The ever increasing population of the World in general and Ethiopia in particular, necessitate to double and triple agricultural productivity to meet Food requirements. The vertical increase in land productivity can be achieved only by using agricultural research technologies. Research is a systematic investigation of unknown things to solve practical problems or poses new questions for future research to explore. It is about systematic gathering of data and information and its analysis for advancement of knowledge in any subject. Research plays a fundamental role in generating, adapting, and adopting improved technologies, information, knowledge and practices to be disseminated to increase productivity. Research is also a key factor for efficient learning, promote practical learning, and enhancing ability to solve practical problems.

Research management is about managing the work force, financial resources, programs/projects, relationships with stakeholders, ethics and integrity, accountability mechanisms. The pressing challenges of our country includes Climate change, energy crisis, water crisis, pandemic pests and diseases, desertification, biodiversity issues, market access & returns, risks & unfair trade and urbanization & displacement. Close collaboration and integrity is much more obligatory than before at least to minimize these multiple challenges. The Government take the lion-share to create conducive policy environment, assign competent leadership, provide adequate financial support, qualified human resource, modern facilities, research infrastructure, create conducive working environments and develop sustainable incentives mechanism. The ability to build and maintain result-focused stakeholder engagement is the key to bring a change in the sector. Farmers, sectoral bureaus, private sectors like seed companies, NARS, higher learning institutions, national and international research and development institutes, policy makers, financial institutions and traders are the major stakeholders who plays a crucial role in tackling the multifaceted production constraints.

Several researchers conduct research that is relevant for a wide range of disciplines. Some are interested in disseminating their results to policy makers, beneficiaries and media audiences, while some other researchers are less interested. There is no reason to do research if results are not communicated to end users. Use appropriate language to each audience, scientific communities or local farmers, both clear and memorable. Research can also be communicated through media, leaflet, field days and experience exchange visits. Recognize that communicating to the users encourages users to act immediately and adopt the technology.

Policy and strategic documents, emerging issues, beneficiary demands, and production constraint analysis is the basis for proposal development. Oromia, being the biggest State in Population, land size, Productivity, Intellectuals, Contribution to GDP, export, food security, diverse agro-ecological zones and biodiversity, requires close collaboration between each stakeholders working on Agricultural research and development entities to enhance the economic capacity of the country. Collaboration can also avoid duplication of efforts, save the limited resources and maximize benefits of the community.

Abera Deressa (PhD)
Senior Researcher and Advisory for Oromia Agricultural Research Institute (IQQO)

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Participatory Agricultural Production Constraint Analysis in Oromia: A Guiding Tool for Strategic Research and Development Interventions *Case Study In East And North Shoa, Oromia Regional*

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Executive Summary

Although agriculture plays a crucial role in improving the life and livelihood of most Ethiopian smallholder farmers, it is characterized by low productivity due to inadequate research and development. Thus, the Government of Ethiopia (GoE) has prioritized sustainable transformation of the sector through implementation of projects and programs related to research for development. Amongst others, Agriculture Growth Program II (AGP II) has been implemented from 2015 to 2020 with the aim of increasing agricultural productivity and commercialization of smallholder farmers in the selected areas of the country. Understanding farmers' socio-economic circumstances, production practices and the environment in which smallholders producing, constraints to and opportunities for agricultural production is crucial in order for the project to invest in a sustainable manner. Thus, this report presents the assessments of agricultural production systems emphasized on crop and livestock production, natural resources and socio-economic aspects. The assessment is based on information collected through different Participatory Rural Appraisal (PRA) tools includes Focus group discussions (FGDs), key informant interviews, seasonal calendars and pairwise ranking as well as information collected from secondary sources. The study stressed to assess agricultural production systems with special emphasis on crop and livestock production, natural resources and socio-economic aspects of the target community in order to understand the existing heterogeneities in agricultural production and socio-economic contexts. Three representative districts Dugda, Lume and Yaya Gullalle were selected where each district was represented by three kebeles; representing lowland, midland and highland agroecology in the district.it was noted that, large variations exist in agriculture management practices between district, Peasant Associations and zones in terms of access to agricultural inputs such as seed, fertilizers, access to irrigated land, improved cattle breed, and farm equipment's. Intensive vegetable production exists in irrigated areas of Dugda and Lume district of East Shoa zones. The main production constraints to crop productivities were identified in categories of inputs, crop management knowledge, market and climate-related constraints. Low quantity of improved seed supply, untimely supply, and un-preferred varieties was among the key restraints regarding input supply. Crop management practices were a traditional practice not supported by research and extension. Market variables like access to the market, marketing institution, credit facility, and transportation, processing, and quality management were found varying among districts. In general marketing of agricultural

products were found very poor. Lack of reliable rainfall both in amount and distribution and in some highland districts chilling injuries were noticed climate variables that constraint agricultural produces.

The part of the report concerning to livestock and fishery production describes livestock production system, productivity and management, livestock production constraints and assessments related to fisheries and aquaculture. The assessment indicates that mixed crop-livestock system which is dominated by indigenous breeds and low producing animals was most common. However, poultry production using improved chicken breeds and honey production from modern bee hives have been expanding. Low productivity of indigenous breeds coupled with constraints to including poor management of animals, decline in grazing areas due to expansion of crop cultivation arise from increasing population, feed and water shortage, and other inputs and services makes the sector to remain stagnant. Although fishing is not practices as a full time activity, in areas near Lake Ziway unregistered fishermen were perceived to illegally harvest using different fishing materials and thus fish resources have been overexploited. Major problems including, among others, absence of fishery regulation, lack of transportation facilities, and poor processing practices have been challenging fishery production. This calls for interventions aimed at improving the sector in way that is economically, socially and environmental sustainable manner through capacity building, input and service provision, and policy implementation. In general constraints identified in the report were used to set research priorities which will be directed towards the improvement of sustainable agricultural production.

Introduction

The agriculture sector plays a crucial role in the life and livelihood of most Ethiopians, where about 12 million smallholder farming households account for an estimated 95 percent of agricultural production and 85 percent of all employment (FAO, 2011). Agriculture has also a key role in poverty reduction for most poor farmers who largely depend on it. However, agricultural productivity in the country remains low due to inadequate investment on research and development in agriculture. Higher investment in agricultural research and development could bring a sustainable impact on food security and poverty reduction. The development in agriculture and improvements in food security in turn strongly influence other sectors of the economy and are seen as essential components of sustainable development (Kleemann, 2012).

To achieve its national development objectives, the Federal Government of Ethiopia (GoE) has prioritized the transformation of agricultural sector on an economically, socially and environmentally sustainable manner. This approach is outlined in the first five year Growth and Transformation Plan (GTP I; 2010/11-2014/15) and its successor, the 2015-2020 GTP II. As a contribution to the GTP II to achieve its objectives, GoE has been implementing a five year Agriculture Growth Program II (AGP II) from 2015 to 2020 with the support of several partners committed to assisting the development endeavors of the country. The Program is aimed at increasing agricultural productivity and commercialization of smallholder farmers in the selected areas of the country. It is also aimed at supporting key public and private sectors (institutions) that have multiplier effect on the growth of the agricultural sectors along the value chain. Moreover, the project contributes to the higher-level objectives of poverty reduction, improved nutritional outcomes by diversifying and improving dietary consumption and climate change mitigation and adaptation of climate smart agriculture initiatives.

According to Notenbaert *et al*., 2009, for investments in agriculture to have a sustainable impact on food security and poverty reduction through increasing productivity, decisions have to be made with respect to the smallholder and their natural environments. It is thus crucial to understand farmers' socio-economic circumstances, production practices and the environment in which smallholders produce, constraints to and opportunities for agricultural production. As elsewhere in developing countries, many forms of agricultural production co-exist in all regions of Ethiopia. Some geographical areas are endowed with agro-ecological conditions suitable for rain-fed cropping, while in others agricultural activities are limited to irrigation or grazing. Some regions have a well-developed road infrastructure, whilst others suffer from lack of access to market and other services. Understanding of such conditions offers a basis for designing and implementing pro-active, more focused and sustainable development that could bring impact on food security and poverty reducyion through enhanced agricultural productivity. Therefore, the aim of this study was to assess agricultural production constraints with special emphasis on crop and livestock production, natural resources and socio-economic aspects of the target community in order to understand the existing heterogeneities in agricultural production and socio-economic contexts. The study provides evaluation of constraints to and opportunities for agricultural development in order for the governmental or non-governmental organizations make decisions regarding research and development interventions and designing the likely interventions.

Methodology

Selection of the Study Locations

Multistage sampling design was used to select the study locations and the community from which the information is collected (Table 1). Both East and North Shoa zones of Oromia Reginal State were selected as target areas of project. Dugda and Lume from East Shoa and Yaya Gulele from North Shoa zone were purposively selected, as representative district for the study (Fig 1). Three *kebeles* (the lowest administrative unit) were also selected purposively from each district following the discussion made with subject matter specialists (SMS) and development practitioners from different offices of the respective districts and their departments. The offices are; Office of Agriculture and Environmental Protection (OAEP), Office of Livestock and Fisheries Resource Development (OLFRD), Office of Rural Land Administration and Utilization (ORLAU) and Office of Irrigation Development (OIDA). Criteria such as representativeness of the *kebeles* for the three main climate zones (highlands, midlands and lowlands), agricultural production practices (rain-fed *versus* irrigation based), and the proximity of the location to the main and access to roads were used to select a total of nine *kebeles* (Table 1).

According to the traditional classification system cited in Deressa *et al*. (2010), Ethiopia has five climatic zones: Wurch (upper highlands; 3200 plus masl), Dega (highlands; 2300-3200 masl), Weynadega (midlands; 1500-2300 masl), Kola (lowlands; 500-1500 masl) and Berha (desert; under 500 masl). However, the altitude meters above sea level (masl) of some kebeles included in the present study is not consistent with the traditional agro-ecological classification. The reasons are; first, agro-ecological classification of the kebeles based on different methods is lacking; second, the districts fall under only one or two climatic zones, thus agro-ecological representation of sampled kebeles is based on their features relative to others.

Table 1. Altitude and agro-ecologies distribution of the sampled districts and kebeles

Zone	District	Sampled *kebeles*	Altitude (masl)	Agro-ecological representation
East Shoa	Dugda	Koto Biliti	1969	Highlands
		Tuchi Sumeya	1659	Midlands
		Welda Kelina	1640	Lowlands
	Lume	Nanewa	2193	Highlands
		Tade Dildimo	1858	Midlands
		Dhugugi Bekele	1628	Lowlands
North Shoa	Yayya Gullelle	Dede Tigi	2813	Highlands
		Kuchi Dengego	2536	Midlands
		Buyema Kuwat	2441	Lowlands

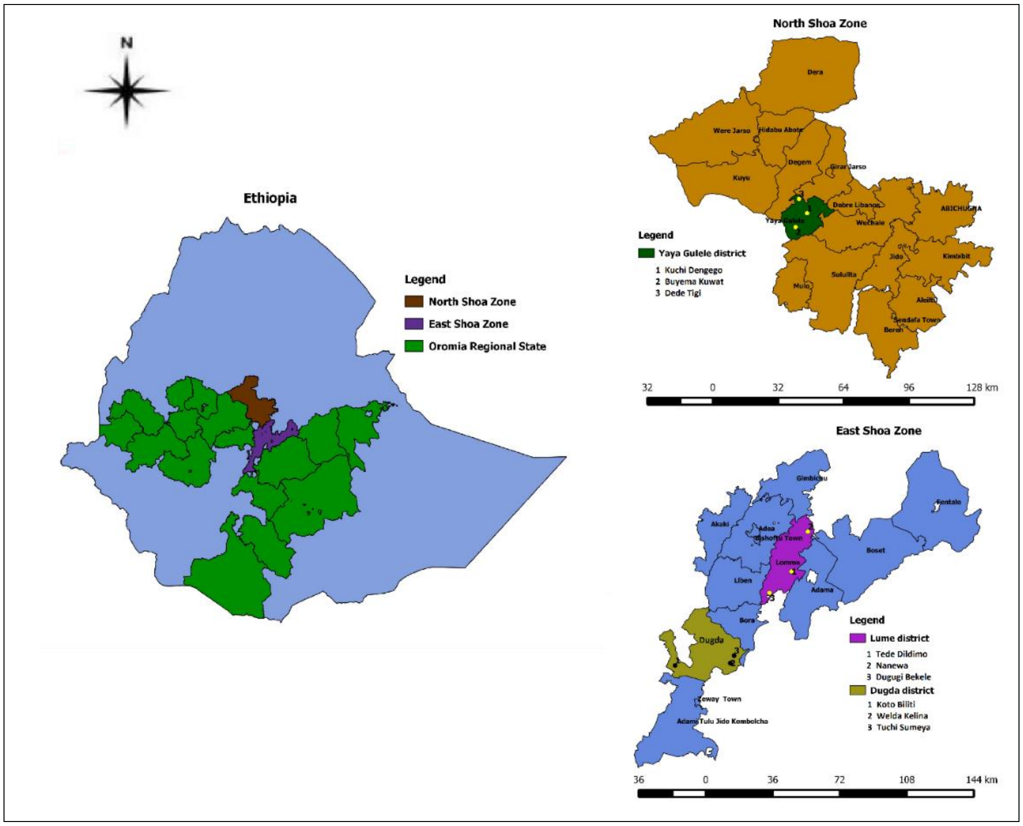

Fig. 1. Locations of the study Districts

Description of the study Districts

Dugda district

Dugda district is located in the center of Ethiopian Rift Valley under the administration of East Shoa Zone. The district is bordered by Bora district in the North and Northwest, Arsi zone in the East, Adami Tulu Jido Kombolcha district in the South and Gurage zone of SNNPR in the West. Awash River serves as a boundary between Dugda and Bora districts. The district is also crossed by Meki River. Both rivers play a significant role in expansion of irrigated agriculture along these riverbanks. Meki, the capital town of the district, is located at 134 km South of Addis Ababa and 88 km West of Adama town on the highway to Hawassa town and at an alatitude and longitude of 8°01’ N and 38°31’ E, respectively. The district has a total of 40 kebeles of which 4 are urban and 36 are rural kebeles.

The topography of the district is mainly flat plain (95 percent of the area) which ranges from 1600 to 2020 meter above sea level (masl) with the highest point at Mount Bora. The district consists of 45% midland and 55% lowland.The average daily minimum and maximum temperatures of the district are 22 and 28^0C, respectively. The rainfall of the district is highly variable and unpredictable with a mean annual rainfall ranging between 650 and 850 mm. Rainfall distribution is bimodal, the main rainy season (*Ganna* or *Meher*) is extending from

June to September and the shorter rainy season (*Arfasa* or *Belg*) is extending from March to May. However, rain-fed crop production is only limited to the main rainy season.

Lume district

Lume district is located under the administration of East Shoa Zone, Oromia Regional State, and has a total area of 752 km^2 (Fig. 1). Beside Moji River that crosses the district, Awash River forms a boundary that separates the district from Bora district. Both rivers and Lake Koka have been used for small-scale irrigation. The capital town of the district, Modjo, is located at 73 km Southeast of Addis Ababa and 25 km West of Adama town on the highway to eastern parts of the country and Djibouti. The district is geographically located between 08^0 24’30’’ to 08^0 49’30’’ North and 39^0 01’00’’ to 39^0 17’00’’ East. The district has a total of 42 kebeles of which 7 are urban and 35 are rural kebeles.

The topography is mainly flat and undulating plains with an elevation ranges from 1590 to 2512 and the highest point is at Mount Boru Taro and characterized by semi-arid and sub-humid climate. The district consists of 30% highland, 45% midland and 25% lowland.The average daily minimum and maximum temperatures of the district are 20 and 28^0C, respectively, with a mean annual rainfall ranging between 500 and 1200 mm.

Yayya Gullelle district

Yaya Gulele district is located in North Shoa Zone, Oromia Regional State, and has a total area of 368.62km^2 (Fig. 1). The district is bordered by Debre Libanos district in the East, Girar Jarso and Degem district in the North, Degem and Adea Berga district in the West and Sululta district of Oromia special zone in the South. Fital, the capital town of the district, is located 114 km North West of Addis Ababa and 26 km South West of Fiche town.The town is located out of the highway to Bahir Dar, thus it can be accessed at 24 km West of Debre Tsige town which is located on the asphalt road at 90 km North of Addis Ababa. The district has a total of 19 kebeles of which 2 are urban and 17 are rural kebeles.

The topography of the district is mainly flat (56 percent), mountains (33 percent) and undulated plains (11 percent) with an elevation ranges from 1500 to 2800 masl. The district consists of 27% highland, 41% midland and 32% lowland.The average daily minimum and maximum temperatures of the district are 16 and 20^0C, respectively, with a mean annual rainfall ranging between 800 and 1200 mm and bimodal rainfall pattern.

Data collection techniques

Participatory rural appraisal (PRA) method was used to quickly and systematically collect information from a target community on agricultural production constraints with special emphasis on crop and livestock production, and natural resources. The survey related with fisheries and aquaculture was only under taken in three *kebeles* (Welda Kelina, Dugugi Bekele and Buyema Kuwat) of the selected districts because fish production is practiced by farmers who reside in only limited areas. Focus group discussions (FGDs), the main and widely used PRA tool in this survey, consisting of elders, youngsters, both men and women farmers, and *kebele* leaders were arranged per *kebele* in consultation with development agents

(DAs). Then, a total of nine FGDs (one at each *kebele*), each consisting of 16 to 24 discussants, who are composed of different age and sex groups, and DAs were conducted using a PRA checklists prepared by multidisciplinary team of researchers from various disciplines. The checklists consist of both close and open questions.

The survey was conducted by a multidisciplinary team of researchers from crop production, livestock production, fishery and aquaculture, natural resources management and socio-economics disciplines. Participatory rural appraisal techniques such as seasonal calendars and pairwise ranking were also used during FGDs in several ways. First, different constraints related with crop (e.g. pest of major crops, major farming and production constraints) and livestock production (e.g. livestock diseases and production constraints), and natural resources management (e.g. constraints to forest, water and soil conservation and management) were identified and prioritized through pairwise ranking. Second, seasonal colanders were constructed in order to capture seasonality in farming activities. Third, gender analysis was used to assess workloads, levels of involvement, gender roles and responsibilities in livestock and crop production, and natural resources management, and access to and control over resources. Key informant interviews were also conducted with head, focal persons for AGP project, SMS and development practitioners from different offices of respective districts and their departments. Furthermore, secondary information were gathered from OoAEP, OoLFRD, OoRLM and OoIM of respective districts so as to evaluate the profiles of each district. The study was conducted during June and July 2016.

Data management

Numeric data gathered through close questions and secondary information were entered into Microsoft Excel® spreadsheet and analyzed. The results (means or averages) were presented using tables, graphs and texts. Information collected during FGDs using open questions and non-numeric secondary information were summarized and narrated.

Results and Discussions

Demographic Characteristics of the study Districts

The Demographic characteristics of the study Districts, urban and rural population and number of households are indicated in Table 2. Dugda district has a total population of 157,818 with 51 and 49 percent males and females, respectively, which are distributed in 4 urban and 36 rural *kebeles*. The rural population accounts for about 75 percent of the total population of the district. Alike the total population, number of male is greater than female in the rural parts of the district. The total household of the district is estimated at 19,729. In terms of age distribution, 62% the population belongs to 15 to 60 age category. Population below the age of 15 and above 60 years accounts for about 38 and 3%, respectively. The crude population density and average household size of the district were, estimated to be 164 persons per square kilometer and 6 persons respectively.

Lume district has a total population of 110,245 with 52 and 48 percent males and females, respectively, which are distributed in 7 urban and 35 rural *kebeles*. The rural population accounts for about 89% percent of the total population of the district. The total household of the district is estimated at 14,514 of which 85 % are male headed. The crude population density of the district was estimated to be 146 persons per square kilometer.

Yaya Gullale district has a total population of 155,233 with 52 and 48 percent males and females, respectively, which are distributed in two small towns and 17 rural kebeles. The rural population accounts for about 93 %, of the total population of the district. Alike the total population, male dominates female in the rural parts of the district. The crude population density of the district was estimated to be 421 persons per square kilometer.

Table 2. Demographic characteristics of the study Districts

Parameter	Sex distribution	Dugda	Lume	Yaya Gullalle
Number of house hold head	Male headed	16877	12310	NA
	Female Headed	2852	2204	NA
Urban population	Male	20531	11055	5404
	Female	18925	953	5683
	Total	39456	12008	11087
Rural Population	Male	60655	51539	75850
	Female	57707	46478	68296
	Total	118362	98017	144146
Total Population	Male	81186	57753	81254
	Female	76632	52492	73979
	Total	157818	110245	155233

NA = data is not available.

Land use pattern and land holding of the study districts

According to the secondary information gathered from the districts, lands under cultivation is the major land use patterns with the proportion of 65.2, 74.13 and 69% for Dugda, Lume and Yaya Gullale districts respectiviely. Fairly large area of cultivable land in Dugda district and 15 % of cultivation land in Lume district has been used for irrigation (Table 3). Grazing lands are important land use patterns in Yaya Gullale (11.7%) followed by 8.3% for Dugda and 0.5% for Lume districts

Table 3. Land use pattern of Dudga, Lume and Yayya Gullelle district

Land use pattern	Dugda		Lume		Yayya Gullelle	
	Area (km^2)	Percentage	Area (km^2)	Percentage	Area (km^2)	Percentage
Land under cultivation	625.85	65.2	557.57*	74.13	254.59	69
Grazing or pasture land	79.87	8.3	3.63	0.5	43.22	11.7
Forest land	34.11	3.6	23.64	3.14	20.58	5.6
Area closures	4.14	0.4	NA	NA	28.03	7.6
Others**	215.48	22.5	167.36	22.2	22.20	6
Total	959.45	100	752.20	100	368.62	100

Key: *=of the total land under cultivation in Lume district, about 15 percent has been used for irrigated agriculture. **=others includes water bodies, residential areas and lands which have been used for different purposes, NA = data is not available.

Data on land holding was available only for Lume district. From this it can be observed that, landholdings by the farmers varies from less than 1 ha to more than 5 ha with an average of 3.3 ha per household. Number of households in terms of their landholdings is indicated in Table 4.

Table 4. Number of households in terms of their landholdings of Lume district

Landholding size	Number of households	Percentage
1 ha and less	47582	76.73
1-2 ha	1457	2.35
2.1-3 ha	7288	11.75
3.1-4 ha	4371	7.05
4.1-5 ha	1021	1.65
5 ha and plus	293	0.47

Crop Production in the study districts

Farming system and major crops of the study districts

Dugda district is characterized by mixed farming system. A number of cereals, pulses, vegetables and fruits had been cultivated in the district. Rain-fed crop production is mainly dominated by the cereal-based production system with a small proportion of pulses. The major cereal crops of the area are maize, teff, wheat, barley, and sorghum; while haricot bean, chickpea, field pea and lentil were among pulse crops of the area. Vegetable and fruits take major share of crop production with about 23% of the total cultivated area of the district. Onion, tomato, head cabbage, Ethiopian kale, green pepper, and papaya were the most commonly produced vegetables and fruits in the district. Tomato and onion were dominant and collectively constitute more than 95% of vegetable produced in the district. In general, Dugda district is known by its high production and productivty of onion, tomato, head cabbage and other horticultural crops.

Similarly, Lume district has mixed farming system with a number of cereals, pulses and vegetable crops produced for both household consumption and market. In both lowland and midland ago-ecologies, maize, teff, wheat, barley, faba bean and chickpea are produced largely. In addition to the cereals and pulses, horticultural crops like tomato, onion and hot pepper are produced under irrigation. On the contrary, typical kebeles in the highland parts of the district dominantly produce teff, wheat and onion under rain-fed conditin.

Like the other two districts, Yaya Gulalle is also regarded as mixed farming system. The current study revealed that the major share of crop production is taken by cereals and pulses, and very little proportion by vegetable; mainly onion and potato. Among field crops, teff, wheat, barley, faba bean and chickpea are produced in all agro-ecologies while maize and onion are localized to the lowland while little proportion of potato is produced in the highland kebeles.

Cropping system of the study districts

Rain-fed cropping system

Dugda district receives a rainfall which extends from May to September. Maize, as a staple food crop is one of the dominant field crop produced for home consumption and market in the area. As a result of farmland shrinkage and because of being major grain for home consumption; maize is cultivated year after year on the same plot of land. Thus, mono-cropping (Cultivating the same crop year after year on the same plot of land) is the main feature of meher season for maize production with a little proportion of crop rotation. Some farmers with low land holding practice mono-cropping of teff and wheat. All other AGP crops were produced in crop rotation pattern which consists of at least two to three either cereal or pulse crops.

Similarly, Lume district receives rainfall similar to Dugda district where Meher season extends from May to September. Out of 35 kebeles in the district, 20 (57%) produce crops under rainfed while 15 kebeles (43%) produce crops under both irrigation and rain fed. In the lowland kebeles, teff and maize are dominantly grown in mono-cropping pattern while in the midland kebeles only maize is cropped in mono-cropping pattern. Unlike the lowland, in the midland kebeles, relatively rotation cropping pattern is widely adopted for all major crops. In general, sole cropping is dominant in rain fed cropping system; while multiple cropping is practiced in irrigation production system.

Unlike Dugda and Lume, Yaya Gulalle district has a bimodal rainfall pattern where farmers produce crop twice a year. In the district, maize is cropped around homestead. Crop rotation is majorly practiced for all field crops and rarely for maize in the lowland areas of the district. In the midland kebeles of the district, teff and wheat are grown in mono-cropping pattern while faba bean, chickpea, barley and other crops are grown in crop rotation which encompasses at least two crops.

Irrigation production system

The bulk of vegetable and fruit supply for the central market is majorly from the rift valley lake regions where Dugda and Lume districts are located. Dugda district has both modern and traditional small-scale irrigation scheme with about 1313ha and 14763ha of land, respectively. Tomato, onion, hot pepper, Ethiopian kale and head cabbage are the major crops produced. In addition to horticultural crops, farmers produce maize under supplemental irrigation. Selection of the crops majorly depends on economic capacity of the farmers. Accordingly, local farmers are pushed from the production of tomato and hot pepper as these require higher initial investment. In general vegetable farming system in the district is mainly market-oriented where improved varieties, mechanized farming (eg. use of tractors), application of nutrients (use of fertilizers), and application of chemicals for pest control are highly employed.

Potential of irrigation in Lume district is mainly from Koka dam and catchment of Modjo River. In the district tomato, onion, hot pepper and watermelon were grown on a considerable acreage of land. A vegetable farmland is cultivated mostly twice ayear. On the other hand, some farmers hardly achieve triple cropping. Similar to Dugda distict, crop selection is mainly dependent on the initial investment. Cropping pattern is mostly rotational due to the fact that most vegetable production is market dependent, fear of disease and insect pest and chilling temperature that occurs during November to January.

A number of rivers such as Aleltu, Chakka, and Moger catchments are the sources of irrigation in Yaya Gullalle district. In this district, vegetable crops like shallot, onion and potato are produced. Irrigable crops are also produced in double cropping pattern using irrigation from the Rivers. The production of these crops is not intensified to the level of the rift valley districts (Dugda and Lume) as the production technologies in the district mainly depend on traditional management assumptions: low input, local cultivars and low market orientation.

Area Coverage of major crops and crop productivity

Area coverage and productivity of rainfed crop

The average productivity of major crops, both for local and improved varieties, from the year 2010 to 2015 G.C for Dugda and Lume districts (data for Yaya Gullale was not available) is indicated in table 6. In Dugda district, maize, wheat and teff had greater share in area coverage and yield during main rain season/meher. In recent years wheat showed increasing trend while teff, maize, faba bean and chickpea showed constant in area coverage over the last five years (Fig 2). According to FGD the reason for increasing trend in wheat area coverage was basically due to an introduction of combine harvester that simplified harvesting, threshing and marketing activities. In the district crop productivity showed non-consistent trend and all crop except chickpea was showed the highest yield in 2014 meher season. According to the information obtained from the district office of agriculture and environment, the average productivity of teff, wheat, barley, maize, faba bean and chickpea over the last six years is 1.73, 2.82, 2.02, 4.20, 1.58, and 1.73tones per hectar (t/ha) respectively. As compared to CSA (2015) report, productivity of Teff, wheat and maize in the district was found to be above the national and regional average yield while that of faba bean and chickpea was below both the national and regional average. On the other hand, barley productivity was found to be comparable with the national average and lower than that of regional average.

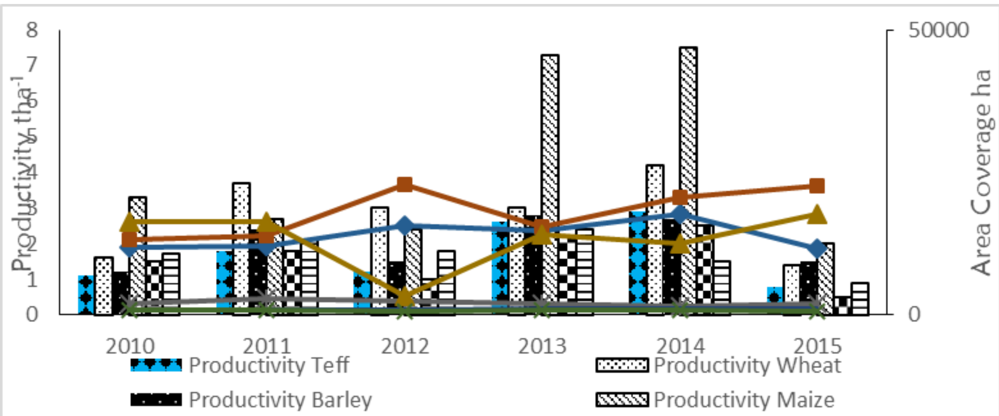

Fig. 2. Area coverage, productivity of major AGP crops at Dugda district

According to secondary data of Lume district office of agriculture and environmental protection (OAEP); teff, wheat and chickpea had the largest area coverage while barley, faba bean and maize take the lowest share. During 2015 Meher season, teff covered about 52% followed by wheat (28%) and chickpea (15%). Whereas barley, maize and fababean covered only 6% of the total cultivated land (fig 3). Conferring the district OAEP and CSA (2015), the productivity of teff, wheat and barley was observed to be above the national and regional averages. On the other hand, maize, faba bean and chickpea productivity were found to be below both the nation and regional averages. In fact, focus group discussion (FGD) revealed that farmers use early maturing varieties of maize like Katumani which give very low yield as compared to other hybrid varieties (Table 5).

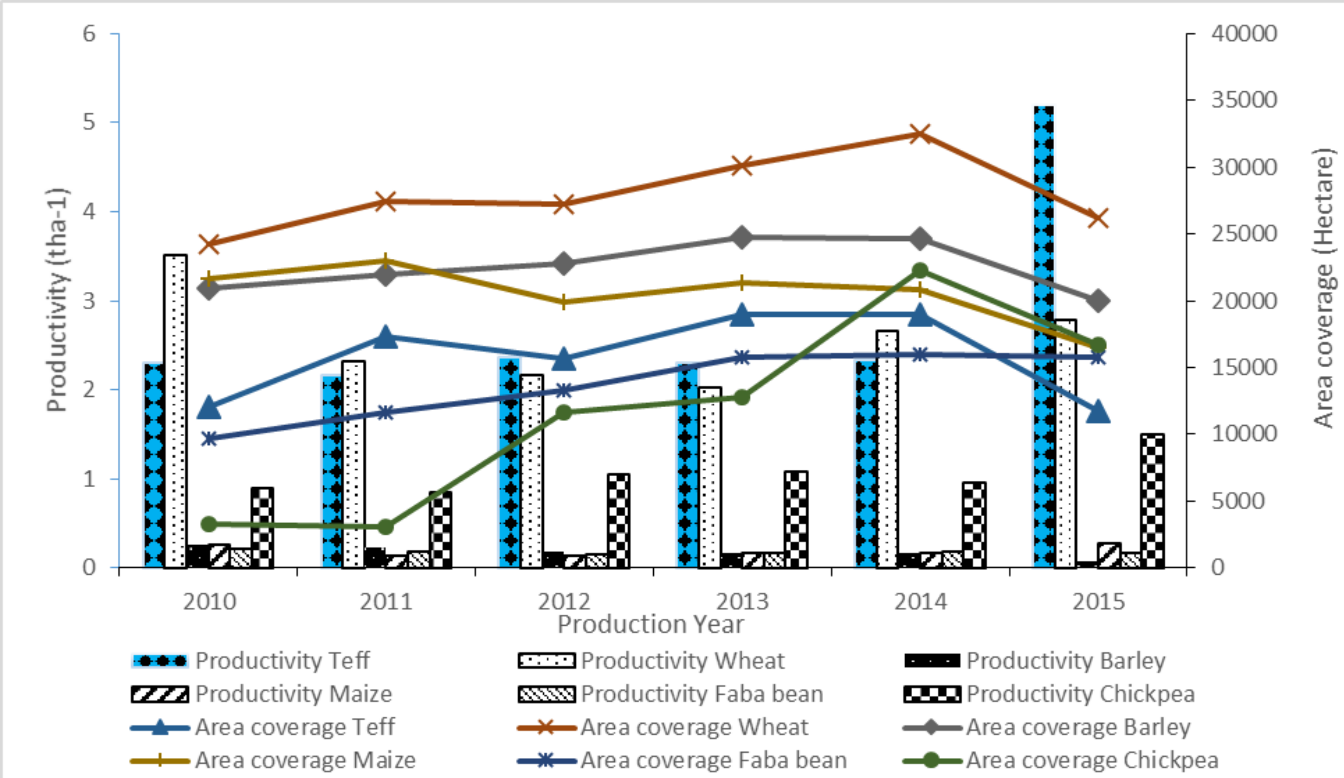

Fig. 3. Area coverage, productivity of major AGP crops at Lume district

Table 5. Productivity of major rain fed crops in Dugda and Lume districts

District	Crop	*Meher* production season											
		2010		2011		2012		2013		2014		2015	
		Improved	Local	Improved	Local	Improved	Local	Improved	Local	Improved	Local	Improved	Local
Dugda	Teff	17.0	10.8	22	14.4	15	12	35	20.5	35	31	**	**
	Wheat	21	16	40	29.2	35	30	45	24	48	40	**	**
	Barley	**	12	**	25	**	15	**	**	**	**	**	**
	Maize	53	19	55	30	30	**	85		85	**	**	**
	Faba bean	**	**	**	**	**	**	18	14	**	12	**	**
	Chick pea	**	**	**	**	**	**	**	20	**	**	**	**
Lume	Teff	23	16	27	20	26	22	32	28	29	20	18	17
	Wheat	39	34	42	40	42	40	51	45	50	47	40	39
	Barley	**	31		33		34	**	37	**	37	**	30
	Maize	33	33	35	34	28	30	36	32	32	28	25	25
	Faba bean	**	15	**	18	**	20	**	24	**	24	**	24
	Chick pea	**	21	**	25	**	30	38	35	**	33	41	10

NB **=data not available

Area coverage and productivity of iirrigated crops

Dugda district has a high potential for irrigation. During the 2015/16 cropping year, a total of 16076ha of land was under irrigation of which 1313ha and 14763ha was irrigated with modern scheme and traditional, respectively (Table 6). According to district office of irrigation development, major share of irrigated land was devoted for tomato and onion production. Dawit (2015) estimated that 95% of irrigated land was devoted for tomato and onion cultivation in the district. According to the Dugda district Irrigation Development Office, average productivity of vegetable is highly variable depending on factors such as soil type, agronomic practice, use of improved seed and outbreak of diseases. The maximum annual productivity reported was 31t/ha which is very low as compared to the national average which is 37t/ha (CSA, 2015). Tomato yield during 2013 was extremely low mainly due to a very damaging insect known as tomato leaf minor (*Tuta absoluta*) (Dawit, 2013). Regardless of the report of Irrigation Development Office; data from FGD revealed that the productivity of tomato and onion in the district was increased drastically after the introduction of hybrid varieties and agro-chemicals.

Lume is another potential district for irrigated crop production in east Shoa zone. The district has a total of 6479ha of traditionally irrigated land (Table 6). Same to Dugda district, the highest percentage of irrigated land is devoted for tomato and onion production. The productivity of tomato and onion was found to be below the national and regional averages.

Similar to the above two districts, Yaya Gullalle has also a great potential for irrigated crop production in the north Shoa zone. However the level of intensification in irrigated crop production was found far behind Dugda and Lume district. The district has 5811Ha of land traditionally irrigated land from Mogour catchment, bore hall, and other rivers. The highest percentage of irrigated land was devoted for potato, shallot and onion production. Tomato production occupies the least percentage of irrigated land in the district. According to FGD, the productivity of potato, tomato and onion was found to be below that of Dugda, Lume, national and regional averages. This is mainly due to the low level of production intensification in the district.

Crop management practices

Crop Nutrient management

Farmers in Dugda district use commercial inorganic fertilizers, compost, organic manure and crop rotation to maintain soil fertility. According to FGD, farmers in the lowland kebeles of the district use only urea fertilizer for maize production while DAP/NPS is applied for teff andwheat at different rates. On the other hand, midland and highland farmers use both urea and NPS/DAP for the production of teff, wheat and maize. As compared to field crops, higher rate of fertilizer application was noted for vegetable crops in the district. Tomato was fertilized with 318 kgha-1 of NPS/DAP and 288 kgha-1 of urea whereas onion was fertilized with 346kgha-1 NPS and 408kgha-1 urea (Table 7).

Likewise, Lume district uses inorganic fertilizers, compost, organic manure, crop rotation and bio-fertilizers to maintain soil fertility of the land. Overall farmers use a combination of urea and DAP/NPS for the production of cereal grains like teff, wheatand barley. Maize is produced in the backyard where soil fertility is easily managed using compost/animal dung (Table 7).

Unlike the two districts, inYaya Gullalle district, soil fertility management technique incorporates the use of bio-fertilizer for faba bean production. The combination of DAP/NPS and urea has been used to maintain soil fertility for field and horticultural crops in the district. Furthermore, higher rate of inorganic fertilizer use is noted in the district as compared to the two districts. In general soil fertility management of each district deviates from both the BoAEP and research recommendations.

Table 6. Irrigated crops area coverage, yield and productivity at Dugda, and Lume districts

District	Crops		Year				
			2011	2012	2013	2014	2015
Dugda	Potato	Area (Ha)	**	**	**	**	4
		Yield (t)	**	**	**	**	342.8
		Yield (tha^{-1})	**	**	**	**	7.8
	Tomato	Area (Ha)	894	1647	4329	4996	4812
		Yield (t)	114180	150386	176632	277847	205491
		Yield (tha^{-1})					
	Onion	Area (Ha)	3276	2656	5356	6178	6228
		Yield (t)	161621	83341	177807	206436	184283
		Yield (tha^{-1})					
Lume	Potato	Area (Ha)	28	**	**	**	**
		Yield (t)	588	**	**	**	**
		Yield (tha^{-1})	21	**	**	**	**
	Tomato	Area (Ha)	1922	**	1382	1341	1549
		Yield (t)	59582	**	33168	40280	12180
		Yield (tha^{-1})	31	**	24	30	8
	Onion	Area (Ha)	1884	**	2981	2828	2902
		Yield (t)	88884	**	62601	77770	32917
		Yield (tha^{-1})	47	**	21	28	11

** Data not available and For Yaya Gullalle not data available

Giving a plant the right nutrient at the right time and place will not only increase the yield, but also improves quality and profit and prevents from damage by diseases and pests (Brady and Weill, 2008). As a general rule, farmers use DAP/NPS fertilizers at sowing as initial source of N and as a main source of P for the whole growing period. Broadcasting is a commonly used method of fertilizer application in all districts and for all crops except maize. Row application of NPS/DAP fertilizers at sowing and top dressing of urea after 21 days of sowing is a common practice for maize producers.

Table 7. Type, rate and method of fertilizer application for AGP crops in Dugda, Lume and Yaya Gulalle district

District	Kebele	Fertilizer types	Fertilizer application for Teff			Fertilizer application for Wheat			Fertilizer application for Maize		
			Rate ($kgha^{-1}$)	Method	Application time	Rate/ $kgha^{-1}$	Method	Application time	Rate/ $kgha^{-1}$	Method	Application time
Dugda	Walda Kalina	DAP/NPS	40-60	BC	0 DAS	40-60	BC	0 DAS	100	Row	100kg at 0DAS
		Urea							100	Row	100kg at 21DAS
	Tuchi Sumayan	DAP/NPS	50-100	BC	0 DAS	50-100	BC	0 DAS	100	Row	100kg at 0DAS
		Urea	25-50	BC	0 DAS	25-50	BC	0 DAS	50	Row	50kg at
	Koto Biliti	DAP/NPS	80-100	BC	0 DAS	80-100	BC	0 DAS	100	Row	100kg 0DAS
		Urea							68	Row	40kg at 40DAS
Lume	Tade Dildimo	DAP/NPS	100	BC	100kg at 0 DAS	100	BC	100kg at 0 DAS			
		Urea	50		25kg at 0 DAS 25kg at 21 DAS	50		25kg at 0 DAS 25kg at 21 DAS			
		Compost								BC	Before sowing
	Dungugi Bekele	DAP/NPS	100	BC	100kg at 0 DAS	100	BC	100kg at 0 DAS			
		Urea	100	BC	100kg at 20 DAS	100	BC	100kg at 20 DAS			
		Compost								BC	Before sowing
	Nanawa	DAP/NPS	100	BC	100kg at 0 DAS 50kg at 0DAS	100	BC	100kg at 0 DAS 50kg at 0DAS			
		Urea	100		50kg at 21 DAS	100		50kg at 21 DAS			
Yaya Gulalle	Buyama and Kuat	DAP/NPS	100	BC	100kg at 0 DAS	100	BC	100kg at 0 DAS	100	BC	100kg at 0DAS
		Urea	50		50kg at 40 DAS	50		50kg at 40 DAS	50	BC	50kg at 40DAS
	Kuchu and Tengego	DAP/NPS	150	Row	100kg at 0 DAS 50kg at 14 DAS	150	Row	100kg at 0 DAS 50kg at 14 DAS			
		Urea	100	BC	50kg at 0 DAS 50kg at 14 DAS	100	BC	50kg at 0 DAS 50kg at 14 DAS			
	Dede Tigi	DAP/NPS	100	BC/Row	100kg at 0DAS	100	BC/Row	100kg at 0DAS			
		Urea	200	BC/Row	200kg at 40DAS	200	BC/Row	200kg at 40DAS			

NB. DAS= Days after sowing; BC=Broadcasting

Table 7. Type, rate and method of fertilizer application for AGP crops in Dugda, Lume and Yaya Gulalle district cont'd

District	Kebele	Fertilizer types	Fertilizer application for Barley			Fertilizer application for Faba bean			Fertilizer application for Chickpea		
			Rate ($kgha^{-1}$)	Method	Application time	Rate ($kgha^{-1}$)	Method	Application time	Rate ($kgha^{-1}$)	Method	Application time
Dugda	Walda Kalina	DAP/NPS									
		Urea									
	Tuchi Sumayan	DAP/NPS									
		Urea									
	Koto Biliti	DAP/NPS	40	BC	0 DAS	25	BC	25kg at 0 DAS			
		Urea							68	Row	40kg at 40DAS
Lume	Tade Dildimo	DAP/NPS									
		Urea							50	BC	50kg at 0DAS
		Compost								BC	Before sowing
	Dungugi Bekele	DAP/NPS	39	BC	39kg at 0 DAS						
		Urea	39	BC	39kg at 20 DAS						
		Compost								BC	Before sowing
	Nanawa	DAP/NPS	100	BC	100kg at 0 DAS						
		Urea	100		50kg at 21 DAS						
Yaya Gulalle	Buyama and Kuat	DAP/NPS	100	BC	100kg at 0 DAS			100kg at 0 DAS	100	BC	100kg at 0DAS
		Urea						50kg at 40 DAS	50	BC	50kg at 40DAS
		Bio-ferti				4 packet	Seed trt				
	Kuchu and Tengego	DAP/NPS						100kg at 0 DAS 50kg at 14 DAS			
		Urea						50kg at 0 DAS 50kg at 14 DAS			
		Bio-ferti				4 packet	Seed trt		4 packet		
	Dede Tigi	DAP/NPS	100	BC/ Row	100kg at 0DAS	60	Row	60kg at 0DAS			
		Urea	200	BC/ Row	200kg at 40DAS	60	BC/Row	60kg at 0DAS			
		Bio-ferti				4 packet	Seed trt				

NB. DAS= Days after sowing; BC=Broadcasting

Table 7. Type, rate and method of fertilizer application for AGP crops in Dugda, Lume and Yaya Gulalle district cont'd

District	Kebele	Fertilizer types	Tomato			Onion		
			Rate of application ($kgha^{-1}$)	Method of application	Application time	Rate of application ($kgha^{-1}$)	Method of application	Application time
Dugda	Walda Kalina	DAP/NPS	400	Row	200kg at 0DAT 200kg at 35DAT	200	Row	100kg at 0DAT 100kg at 35DAT
		Urea	300	Row	100kg at 0DAT 100kg at 35DAT 100kg at 60DAT	560	Row	160kg at 0DAT 200kg at DAT 200kg at DAT
		KNO3	25	Row	10kg at 55DAT 7kg at 85DAT			
	Tuchi Sumayan	DAP/NPS	400	Row				
		Urea	400	Row				
		KNO3	17	Row				
Lume	Dungugi Bekele	DAP/NPS	400	Row	400kg at 0 DAT	600		400kg at 0 DAT 200kg at 30DAT
		Urea	400	Row	100kg at 0DAT 300kg at 60DAT	400		250kg at 21DAT 150kg at 30DAT
		Ecogreen	100$ltha^{-1}$	Foliar spray	100lt at 45DAT	33ltha-1		33lt at 55DAT
		Orga	200	BC on soil	200kg at 0DAT			
		Ucan	4lt^{-1}	Foliar spray	2lt at 35DAT 2lt at 70DAT			
	Nanawa	DAP/NPS				100	Row	100kg at 0DAT
		Urea				100	Row	100kg at 21DAT
Yaya Gulalle	Buyama and Kuat	DAP/NPS				50	Row	50kg at 0DAT
		Urea				50	Row	50kg at 40DAT
	Dede Tigi	DAP/NPS						
		Urea						

NB. DAS= Days to after sowing; BC=Broadcasting

Seed sources for the study districts

Sources of seeds and crop varieties used in the study districts are indicated in table 8. In Dugda district, farmers use both improved and local seeds from different sources. Almost all farmers use improved seeds of teff, wheat and maize crops. The major source of improved seeds is Bora Dembel union while that of local seeds are either the vicinity market or own saved. Dominant and most preferred varieties of teff in the low and midlands of the district is Dz-Cr-37 followed by Kuncho. Kuncho is the most preferred variety in the highlands of the district. Improved wheat varieties such as Pavan, Digelu, Kakaba and Hawi are majorly supplied by Bora Dembel Union, but in recent yearsHawi and Digelu are becoming out of market even though farmers' preference for the varieties is still very high. The most supplied varieties of maize in the districts are BH-540, BH-543, Shone, MH-1v fc38, Limu and Melkassa-2 (Table 8). Preference of the varieties depends on the onset of rainfall. If the onset of rainfall is early May farmers preferred BH-543 followed by BH-540. Sometimes when the onset of rainfall is in June farmers preferred Melkassa series due to their early maturing characteristics. Unlike teff, wheat and maize no improved varieties are supplied for Barley, faba bean and chickpea and farmers depend on the local varieties for the production of these crops.

Lume Adama union and Biftu seed multiplication cooperative are the major source of improved seed in Lume district. According to FGD, farmers use improved varieties of teff, wheat, maize and chickpea while the production of faba bean and barley mainly depend on local varieties. Farmer group discussion revealed that Kuncho and Boset are among the improved varieties widely used in Lume district while Hadho, a local variety, is used at Dungugi Bekele kebele. Pavan, Kakaba and Danda varieties for what and Kathumani and Melkassa-4 for maize are the improved varieties used in the district. Shasho, Arerti and Habru are improved Chickpea varieties under production in the district. Generally, farmers' preference for the varieties depends on whatvarieties the union offers.

On the contrary, in Yaya Gulalle district, supply of improved crop varieties is mainly performed by office of agriculture and environmental protection and in current years by Holeta Agricultural Research Center. The improved seeds supplied are mainly for teff, wheat, maize and faba bean while barley and chickpea production mainly depend on the local varieties. According to FGD, improved varieties supplied for teff are Magna, Kuncho and Dukem; for wheat are Kakaba and Dandaa; for Maize BH-540 and for faba bean Walki. Wheat varieties like Digelu and Kubsa were still very popular among farmers. The local wheat variety, Koticho is produced solely on black soils in the district.

Table 8. Crop varieties used at Dugda, Lume, and Yaya Gulalle district

District	Kebele	Teff varieties		Wheat varieties		Maize varieties	Barley varieties	Faba bean varieties	Chick pea varieties	
		Improved	Local	Improved	Local	Improved	Local	Local	Improved	Local
Dugda	Walda kalian	DZ-Cr-37, Kuncho		Hawi, Pavan, Digelu, Kakaba		Shone, BH-543, BH-540, Limu	Local			local
	Tuchi Sumeya	DZ-Cr-37, Kuncho		Hawi, Pavan		BH-543, BH-540		Local		
	Koto Biliti	DZ-Cr-37, Kuncho		Hawi, Pavan		BH-543, Shalla, Shone, Melkassa-4, Jibat, MH-140	Local	Local		
Lume	Tade Dildimo	Kuncho, Boset		Pavan and Kakaba		Katumani Melkassa-4			Shasho, Arerti, Habru	
	Dungugi Bekele	Kuncho	Hadho	Pavan, Kubsa		Melkassa -4			Shasho	
	Nanawa	Kuncho and Boset		Dandaa and Kakaba			local	local	Shasho, Arerti, Habru	
Yaya Gulalle	Buyama and Kuat	Magna, Kuncho		Digelu, Danda'a, Kakaba		BH-540	Biiraa	Local		Dube
	Kuchu and Tengego	Kuncho Dukem		Kakaba Dandaa	Koticho		Local	Local		Dube
	Dede Tigi	Kuncho		Kakaba Dandaa Digelu			Biiraa	Walki		

Land Preparation and Planting methods

Land preparation practices followed in the three districts are summarized in (Table 9). In Dugda district, draft animal power is used for land preparation using traditional implements. Only few farmers how undertake small small scale irrigation for horticultural crop production use tractors for land preparation. Plowing frequency ranges from 2 to 3 times depending on the crops to be cultivated. Land for teff, maize and faba bean is plowed three times while for wheat, barley and chickpea plow frequency is 2 times. On the other hand the plow frequency for irrigated crops like onion and tomato is at least 4 times. Most farmers in the district use row planting for the production of maize while broadcasting is practiced for wheat, teff and other cereal and pulse crops. Few farmers also use row planting for faba bean, what and teff cultivation.

Similar to Dugda, use of traditional implements and draft animal power is the most known practice for land preparation in Lume district. But very few farmers use tractor for plowing small scale farms. According to FGD farmers of Lume district plow farm lands for teff, wheat, maize, barley, faba bean and chick pea 4, 4, 3-4, 3-4, 2-3, and 2-5 times, respectively. For horticultural crops like tomato and onion, plots are plowed 5 times in the district.

According to the (FGD), farmers in Yaya Gullalee district use draft animal power with normal iron tool for light soil and broad bed maker (BBM) for black clay soil. Broad bed maker (BBM) was used for preparation of land for wheat, barley, faba bean and chickpea while teff, maize and onion fields are prepared with normal tool (Maresha). Teff is plowed four times, wheat and maize three to four times; barley 3 times; faba bean 2-3 times; chickpea 1-3 times; potato 4-5 times and onion four times. In general legumes need less plowing frequency as compared to other cereals and horticultural crops.

Table 9. Land preparation practices in the study districts

Crop type	Districts	Rain fed								Irrigation		
		Teff	Wheat	Maize	Barley	Faba Bean	Chickpea	Onion	Potato	Tomato	Onion	Potato
Power source	Dugda	Draft animal	Draft animal	Draft animal	Draft animal	Draft animal	Draft animal			Tractor & draft animal	Tractor & draft animal	
	Lumme	Draft animal	Draft animal	Draft animal	Draft animal	Draft animal	Draft animal	Draft anima	Draft animal			
	Y. gullale	Draft animal	Draft animal	Draft animal	Draft animal	Draft animal	Draft animal			Draft animal	Draft animal	
Plowing frequency	Dugda	3	2	3	2	3	2			4	4	
	Lumme	4	4	3-4	3-4	2-3	2-5	5			4	4
	Y. gullale	4	3-4	3-4	3	2-3	1-3		4-5	4-5	4-5	
Seed type	Dugda	Improved &local	Improved & local	Improved								
	Lumme	Improved /local	Improved/local	Improved/local	Local	Improved/local	Local	Unknown			Improved	Local
	Y. gullale	Improved & local	Improved & local	Improved & local	local	Improved & local	Improved & local		Improved & local	Improved & local	Improved & local	
Seed source	Dugda	BD Union	BD Union	BD Union						Trader	Trader/M B U	
	Lumme	LAU, Own saved	LAU, own saved	LAU, own saved	Local market	Local market and own saved	Local market and own saved	Trader			Trader	Trader
	Y. gullale	BoAEP, world vision	BoAEP, world vision	BoAEP, world vision	Local mrkt (degem)	Holeta ARC, farmers	Farmers		Local mrkt (Degem)	Local mrkt (Degem)	Addis Ababa trader shop	
Drainage of excess water	Y. gullale		BBM, BBM		BBM	BBM	BBM		BBM	BBM		

Seeding Rate

Seeding rate is one of the most important parameter in agricultural production. Having the proper plant density is important because it affects the overall health and the vigor of the plants (Yan *et al.,* 2017). Seeding rate varies depending on the varieties, soil fertility and climatic condition of the area. Seeding rate of each major crop shows a discrepancy from research recommendation. In this study it was noted from the FGD that seeding rates used varies widely among the districts and the crop types. Although research recommendation are not site specific farmers use higher seeding rate as compared to national recommendation for each crops.

In Dugda district for example, seeding rates for Teff, wheat, maize, barley, faba bean,and chickpea ranges from 36-48kgha^{-1}, 112-200kgha^{-1}, 25-33kgha^{-1}, 200kgha^{-1}, 28-80kgha^{-1}, and 32kgha^{-1}, respectively (Table 10). It was only in the case of faba bean and chickpea that the farmers' seeding rate was found to be below the national recommendations. From FGD, it is noted that farmers in some kebeles of Lume district use seeding rates which is below national recommendation. In the case of teff, for instance, they use seeding rates ranging from 12 to 56 kgha^{-1} whereas the national recommendation is 20-30kgha$^{-1.}$ Samilar trend was observed at Yayya Gullallee district.On the other hand seeding rate of faba bean and chickpea was found below the national recommendations. Excessively high plant densities cause plants to compete for available food and water, whereas extremely low plant densities may provide the opportunity for weed invasion (Yan *et al.,* 2017).

Table 10. Agronomic practices used for the major crops in the study districts

Crop type	Districts	Rain fed								Irrigation		
		Teff	**Wheat**	**Maize**	**Barley**	**Faba Bean**	**Chick pea**	**Onion**	**Potato**	**Tomato**	**Onion**	**Potato**
Sowing method	Dugda	Broadcasting	Broadcasting & row planting	Row	Broadcasting	Row and BC	BC			Row	Row	
	Lumme	BC	Broadcasting and row planting	Row	BC	Row and BC	BC	Row			Row	Row
	Y. gullale	Broadcasting and row	Broadcasting and row planting	Row	Broadcasting and row	Row and BC	BC				Row	
Varieties	Dugda	DZ-Cr-37, Kuncho,	Hawi, Pavan, Digelu, Kakaba	BH-543, Shalla, Shone, Limu, Melkassa-4, Jibat, MH-140	Local	Local	Shasho, Arerti, Habru			Roma-VF,		
	Lumme	Kuncho, Boset, Hadho	Pavan, Kubsa, Dandaa, Kakaba	Kathumanni, Melkassa-4	Local	Local	Shasho, Arerti, Habru	Bombay Red			V9, Roma VF, Kochoro	Bombay red
	Y. gullale	Magna, Kuncho and Dukem	Digelu, Dandaa, Kakaba and Koticho	BH-540	Local (Biiraa)	Local and Walki	Dube and local	Bombay Red	Jalenne, Gudannie and local (Shashamane)	Jalenne, Gudannie and local (Shashamane)	Bombay red and unknown	
Seed rate (kgha^{-1})	Dugda	36-48	112-200	25-33	200-250	28-80	32				12-16	
	Lumme	12-56	50-200	24-60	100-400	80-200	48-240	8-14				
	Y. gullale	10-60	100-200	12	160-300	60-200	30-140	14	12000			
	Research recommendation	20-30	125-150	25	85	200	110	3.5				
Row planting technology	Dugda		Highland/Jarkin	Hand drilling		drilling				Hand planting	Hand planting	Hand planting
	Lumme		Highland/ Jerkan	Hand dropping		Hand dropping		Hand planting			Hand planting	Hand planting
	Y. gullale	Highland	Highland)	Hand drilling		Hand drilling			Hand planting	Hand planting	Hand planting	
Cropping system	Dugda	Mono cropped & rotated	Mostly rotated	Mono cropped or rotated	Rotation							
	Lumme	Crop rotation	Crop rotation	Mono cropping	Crop rotation	Crop rotation	Crop rotation	Mono cropping			Crop rotation	Crop rotation
	Y. gullale	Mono cropped and rotated	Mostly crop rotation	Mono cropping	Crop rotation	Crop rotation	Crop rotation		Crop rotation	Crop rotation	Crop rotation	

Pest and pest *control measures* in the study districts

Weeds and weed control measures

Weed species on different crops and their control measures in the study districts are indicated in Table 11, *Galansigo parviflora, Parthenium hysterophorus, Cypersuss rotundas, Guizotia scraba, Xanthium spp., Black jack, Datura stramonium, Fira Gidi, Dase setena, Shishi, and Gurii are the* commonly occurring weed floras in Dugda district. Based on their importance, farmers prioritized *Parthenium hysterophorus, Guizotia scarba, Xanthium spp, and Galansigo parviflora* as the most occurring and problematic weeds in the district.

With regard to weed control, farmers use a combination of different measures depending on weed type abundance. The most common weed control measures in cereals such as teff, wheat and barley are 2, 4-D application followed by hand weeding at least 2 times during cropping cycle. According to Razenne (2008) the critical weed competition period for teff is approximately between 3-7 weeks after crop establishment. This is the time when farmers in the district apply their control options.   . Application of 2, 4-D may be repeated depending on weed abundance. Hand weeding is mainly practiced for control of *Snowdenia polystachya, Avena fatua, and Phalaris paradoxa* since these weeds are not controlled by 2, 4-D application. Maize fields are hand weeded once, but hoeing (kutkato) and shilshalo are also supportive for the control of weeds even though both techniques are meant for aeration and nutrient application. Both faba bean and chick pea are hand weeded twice, wheras Irrigated commercial crops such as tomato and onion are weeded 6-8 and 4 times, respectively.

Weed species diversity in Lume district is almost similar to that of the Dugda district. The control options used by farmers in this district include physical, chemical and crop rotation. In the highland kebeles of the district, farmers use a combination of Palace herbicide and at least two times hand weeding for teff, wheat and barley production. On the other hand, 2, 4-D followed by one time hand weeding and hoeing is used for the control of weeds in maize fields. FGD revealed that a chemical known as Gallant super is used to control faba bean weeds, whereas chickpea weeds are controlled by the application of Palace at 3 leaf stage. In general farmers in this district are effective in adopting herbicides for production of their field crops.

The composition of weed flora in Yaya Gullalle district includes *Phalaris paradoxa, Balami, Shaye, Avena fatua, Snowdenia polystachya, Guizotia scarba, Plantiago lenceolata, Convulvulas arvensis, Migira saree, Macaree, Trifolium arvensis, inkirdado, , Gezotia scraba, Cynodia ploystachya, Rumex spp, Plantego lencoleta, gafarsa, Argemon mexicana.* Weed control measures in the district mainly depends on hand weeding and 2, 4-D application, the former one being the most widely used method. According to FGD, weeds on crops such as teff, wheat and barley are controlled predominantly by herbicide application followed by hand weeding (1-3 weeding frequency), while weeds on faba bean are majorly controlled by hand weeding. On the other hand dominant weed in chickpea field is commonly affected by *Argemon Mexican,* which is very difficult to control by hand wedding. In general some weeds which are categorized as important ones *(Phalaris paradoxa, Snowdenia polystachya, Lolium temulentum and Avena fatua) in the* district cannot be controlled by 2, 4-D application.

Table 11. Weed species on different crops and their control measures in the study districts

Districts	Teff	Wheat	Maize	Barley	Faba bean	Chick pea	Tomato	Onion	Potato
Weed species available									
Dugda	*Galansigo parviflora, Cendelon dactilon Guizotia scarab, Amaranthus hybrid* Black jack, *Datura stramonium*, Fira Gidi, Dase setena, Shishi, Gurii , *Parthenium hysterophorus, Xanthium spp.*	*Black jack, Galansigo parviflora, Guizotia scarab, Cynodia ploystac, Parthenium hysterophorus hya, Fira Gidi, Fox tail, Galium aparine*	*Cynodia ploystachy, Striga spp, Parthenium hysterophorus*	*Cynodia ploystachya, Galium aparine, Parthenium hysterophoru s*	*Galansigo parviflora, Guizotia scarab, Kakaba Black jack, Fox tail, Balamola, Saaraa, Shishii, Kiloo, Parthenium hysterophorus*	*Goose horse foot*	*Partheni um hysterop horus, Orobanc he spp*	*Cuscuta spp., Partheni um hysterop horus, Cyperuss rotundus, Galium aparine*	
Lume	*Setaria pumila, Jaree, Gurii, Cyperuss rotundas, Tiloo, Phalaris paradoxa, Wabeloh, Guizotia scarba, Galansigo parviflora, Alumaa, Machara, Snowdenia polystachya*	*Avena fatua, Setaria pumila, Jaree, Cyperus rotundus , Tiloo, Wabeloh, Phalaris paradoxa, Snowdenia polystachya*	*Bokusaree, Phalaris paradoxa, Parthenium hysterophorus, Snowdenia polystachya, Plantago lanceolata Dehanekay, Parthenium hysterophorus, Datura stramonium*	*Avena fatua, Setaria pumila, Jaree, Tiloo, Cyperus rotundus , Gurii, Avena fatua, Haluma, Bromus pectinatus, Snowdenia polystachya*	*Guizotia scarba, Datura stramonium, Bokuu saree, Jaree, Mech, Datura stramonium, Snowdenia polystachya*	*Bokuu saree, faramsiisa a, Fincan loonii, Basoo bilaa saree, Tiloo, Gabisaa, Asaandab oo, Cyperus rotundus*	*Partheni um hysterop horus, Boku saree, Cyperus rotundus, Gabisaa, Fincan loonii*	*Cyperus rotundus, Fincanii loonii, Partheni um hysterop horus, Lamunce e, Cuscuta spp.*	
Y.Gulale	*Phalaris paradoxa, Balami, Shaye, Avena fatua, Snowdenia polystachya, Guizotia scarba, Plantiago lenceolata, Migira saree, Macaree, Trifolium arvensis, inkirdado, amakito, Gezotia scraba, Cynodia ploystachya, Rumex spp, Plantego lencoleta, gafarsa,*	*Avena fatua, shaye, Phalaris paradoxa , mujaa, hadaa, kortobe, Lelium temulentum , amakito, Rumex spp, shaye, mamako, Galium aparine*	*Hadaa, Amakito, Datura stramonium, Brassica spp striga*	*Sinara, Muja, asendabo, shaye, hadaa. Kortobe, inkirdda, Shulti, Galium aparine*	*Gizotia scarba, kortobe, Brassica spp., amakito, muja, asendabo, kortobe, mamako, Rumex spp., maxxane,*	Macaraa, Bonanlati, Asandabo, migira saree, hadaa, Argemon mixicana			*Asand abo, rumex spp Anano o,*

	Convulvulas arvensis, Argemon mexicana								
Weed control measures ***a) Frequency of weeding (for hand weeding)***									
Dugda	2 (30DAE, 60DAE)	1-2	1 and 1 time hoeing	2	2 (14DAE and 30 DAE)	2	6-8 (as per required)	4 (every two weeks)	
Lume	2-3	2	2 (1x hoeing and 1x weeding)	2-3	2-3	2-3	6-7	8x	
Y.Gulale	1-3	1 and hoeing	1 and hoeing	2	1-2				2-3
b) Type of Chemicals used (for Chemical control)									
Dugda	2, 4-D (21DAE)	2, 4-D (30 and 60DAE); topic(30DAE)	2, 4-D	2, 4-D					
Lume	2, 4-D; Palaca	2, 4-D, Palace	2, 4-D	2, 4-D, Palace	Gallant Super	Palace at 3 leaf stage			
Y.Gulale	2, 4-D at 40DAE	2, 4-D (60DAE)	2, 4-D	2, 4-D					

Insects and Insect control measures

Prevailing insects in the three districts and their control measures are summarized in Table 12. According to farmers group discussion (FGD) the most prevailing insects in Dugda district were shoot fly and grass hopper on teff, stalk borer on maize, shoot fly on wheat and barley, pod borer and aphids on faba bean and pod borer on chickpea. Of a number of insects and pests reported to attack tomato, tomato leaf minor (*Tuta absuluta*), aphid, white flies and tomato fruit worms are identified to be the most important ones. Farmer's put thrips and worms (*Raamoo Bulee*) as the major insect damaging onion in the district.

Regarding control measures, very few farmers stated that they use 2, 4-D to control shoot fly on teff. This low use of the chemical is likely to be because of the effect of shoot fly inducing more tillers which can be become productive (Bayeh *et al.*, 2008). On the other hand no control options were employed for barley shoot fly in the district. According to FGD, the major challenge with wheat production is birds (Girissa) attack. Farmers attempt to control this through removal and thining of branches of trees (majorly Acacia) which exist in the fields. To control stalk borers, which occur during longer dry period and just after rainfall drops, some farmers apply malathion. This chemical used in control of other insects such as red mites, pod borerand aphids which attack different crops. To control tomato leaf minor, which attacks tomato, farmers use recommended insecticides such as ampligo 150 ZC, coragen 200 SC and tracer 480 SC with four to six times spray per season. Karate 50% EC, thionex 35% EC, profit 72% EC, endosulfan, selecron, kocide 101 and many other insecticides has been to control thrips. plant leaves at any stages of the crops. Similar types of insects existing in Dugda district are found in Lume ditrict. Here farmers farmers are found not attempt to control insects except that they hardly try to control faba bean and chickpea insects by use Malathion and Karate used to control.

Table 12. Important insect and their control measures in the thre districts

Districts	Teff	Wheat	Maize	Barley	Faba bean	Chick pea	Tomato	Onion	Potato
Insects									
Dugda	Shoot fly, Grass hopper, smudge	Girissa (Birds)	Stalk borer (Tuse)	Shoot fly	Termite; Stem maggot, pod borer	Aphid, pod borer, black aphid	Tuta absulota, aphid, white fly,	Thrips, raamoo bulee	
Lume	Shoot fly, black teff beetle, grass hopper	Grass hopper, ramoo, shoot fly	Stalk borer	Shoot fly	Aphid, pod borer	Aphid, pod borer	Tuta absulota, aphid, white fly,	Thrips	
Y.gulele	Shoot fly, Grass hopper, smudge	White worm with black head; Maski (very difficult)		Shoot fly, caterpillar	Worm (lumuxii), caterpillar	Green worm, pod borer, cater piller			Mixii didmitu u
Control									
Dugda	Farmers apply 2, 4-D for the control of shoot fly	Tree removal and branch thinning	Malathion; managed by rainfall	No management practice	1X Malathion application at podding	3x Malathion, or 2x karate application	Coragen, tracer, endosulphan, Selecrone, agrolambasin,	Selecro ne, Helarat, profit, karate,	
Lume	No management	No management	No management	No management	3X Malathion application or 2x karate application	3x Malathion, or 2x karate application	Coragen, tracer, endosulphan, Selecrone, agrolambasin,	Selecro ne, profit, karate,	
Y.gulele	No treatment	Sheep walk on the field and hoeing; endosulphan tried but not controlled		Sheep walk and 2, 4-D application and unknown liquid insecticide	Sheep walk on the field and hoeing	Application of mancozeb			No treatme nt

Disease and disease control practices

Some crop diseases and their control measured applied in the study districts are given in Table 13. Diseases of teff, wheat, maize, barley, faba bean and chickpea were found to be root rot (*hunde shamsa*), rust, root rot, chocolate spot and fusarium wilt, respectively. On the other hand, tomato and onion are affected by diseases such as Bacterial spot, down mildew, powdery mildew, late blight, early blight and a number of viral diseases. Down mildew and purple blotch are the most important diseases of onion in both Dugda and Lume districts.

Farmers carry out control measure only against diseases of wheat and chickpea. All field crops diseases were not managed in Lume district. According to FDG, farmers inboth Dugda and Lume districts use chemicals such as Ridomil gold MZ 68 WG, matco, Mancozeb 80 WP, agro-laxyl mz 63.5 wp, agro-fos 400 SL, bacticide and many others to control both tomato and onion diseases. Both FDG and secondary data revealed that farmers exercise cocktail application of at least two fungicides and one insecticide at a time as they believe that this is a perfect way of managing both diseases and insects.

According to FGD conducted in Yaya Gullalle, very few diseases identified as economically important ones. are, rust on wheat and barley; black root rot and chocolate spot on faba bean; fusarium wilt on chickpea and late blight and leaf rust on potato are important once. No attempt is made in the district to control the diseases except little effort made by some farmers to control rust using insecticides. This is majorly due to lack of awareness and the difficulty to get the chemicals.

Table 13. Important crop diseases and their control measures in the three districts

Districts	Teff	Wheat	Maize	Barley	Faba bean	Chick pea	Tomato	Onion
Diseases								
Dugda	Hunde shamsa /damping off/ (during heavy rain)	Rust (leaf and stem) (occurs after heavy rain followed by strong sun)	Hunde shamsa	Rust	Chekolet spot	Fusarium wilt	Leaf spot, early and late blight, bterial spot, viral	Damping off, Purple blotch, Downy mildew
Lume	Rust	Rust (leaf and stem)		Scald	Chocolate spot	Fusarium wilt	Leaf spot, early and late blight, bacterial spot, viral,	Damping off, Purple blotch, Downy mildew
Y.Gulele	No disease; chilling injury	Rust		Rust	Black root rot, chocolate spot	Qora, Fusarium wilt	Wagii (ni dammesaa), late blight	
Control methods								
Dugda	No management	Ridomil Gold 60%WP	No management	No management practice	No management	No management	Mancozeb, unizeb, matco, ridomil, bacticide, agromycolyxl,	Mancozeb and ridomil at least 10 times
Lume	No management	No management		No management	No management	No management	Mancozeb, matco, ridomil, bacticide,	
Y.Gulele		Liquid chemical applied for rust		Chemical applied for shoot fly works	No treatment	No control	No treatment	

Post-harvest management

Harvesting techniques

In all districts, farmers use sickle for harvesting teff, wheat, maize, barley, and faba bean. Chickpea is harvested by uprooting at full maturity. About 15% and 9% of farmers in Dugda and Lume district respectively stated that they use combined harvester for harvesting and threshing wheat. Tomato is picked by hand, sorted and packed at farm gate. Onion is harvested manually by uprooting and then separating the bulb by cutting. Both tomato and onion are packed in wooden box and directly transported to the final market destination.

Storage, Processing and transportation

In all districts after cleaning process, grains are either put in sacks and stored in inside a living house or are stored in special sores. Means of both crop and grain transportation in Dugda and Lume district is Donkey cart whereas donkey backs are used in Yayagulele district. Grain storage duration varies from place to place depending on the economic wellbeing of farmers. In Dugda and Lume districts, because of their high temperatures, crops are stored for few periods as compared to Yaya Gullalle district. In all districts, farmers use storage pesticides to enlenghten storage period. In all districts there is no crop processing practices including for horticultural crops because of lack of processing facilities, improved transportation and well established value chain.

Knowledge management

Office of agriculture and environmental protection is the major institution that gives training to farmers in the districts on the use of improved agricultural technologies. In Dugda and Lume districts, it was known that different projects such as ILRI/Lives project and institutions such as Melkassa and Adami Tulu Agricultural Research Centers provide both training and information on the use of improved agricultural technologies. In Yaya Gullalle district, OoAEP, Holleta agricultural research center and World vision participate in extension services. Though market was found to be the most important constraints to small scale irrigation, especially in Dugda, and Lume districts, no market linkage services were supplied by any institution in all districts.

Table 12. Harvest and post harvest practices in the three districts

Crop type	**Districts**	**Rain fed**								**Irrigation**		
		Teff	**Wheat**	**Maize**	**Barley**	**Faba Bean**	**Chickpea**	**Onion**	**Potato**	**Tomato**	**Onion**	**Potato**
Harvesting methods	Dugda	Manually by sickle	Combined harvester & manually by sickle	Manuall y by sickle	Manually by sickle	Manually by sickle	Manually by hand			Hand picking	Manually uprooting	Manuall y uprootin
	Lumme	Manually by sickle	Combined harvester and manually by sickle	Manually by sickle	Manually by sickle	Manually by sickle	Manually by hand	Manua lly			Hand picking	Manual uprooting using hand tools
	Y. gullale	Manually by sickle	manually by sickle	Manually by sickle	Manually by sickle	Manually by sickle	Manually by hand		Manually uprooting	Manually uprooting	Manually uprooting	g
Threshing technique	Dugda	Animal trampling	Animal trampling	Animal trampling	Animal trampling	Animal trampling	Animal trampling		Farm gate			
	Lumme	Animal trampling	Animal trampling and combined harvester		Animal trampling	Animal trampling	Animal trampling					
	Y. gullale	Animal trampling	Animal trampling	Animal trampling	Animal trampling	Animal trampling	Animal trampling					
Storage technique	Dugda	Madabari ya	Madabariya	Madabar iya	Madabariya	Madabariya	Madabari ya					
	Lumme	Madabariya	Madabariya	Madabariya	Madabariya	Madabariya	Madabari ya	N.A.			N.A	N.A
	Y. gullale	Madabariya	Madabariya	Madabariya	Madabariya	Madabariya	Madabari ya					
Storage duration	Dugda	Upto 10 month	1 year	10 month	1 year	7 month	7 month					
	Lumme	Up to 1 year	Max 6 month	Max 6 month	1 year	Max 6 month	Max 6 month	N.A			N.A	N.A
	Y. gullale	Up to 2 years	Up to 2 years	Up to 2 years	Up to 2 years	Up to 10 month	Up to 1 years			Farm gate	Farm gate	
Product cleaning	Dugda	Tradition al	Lameda	Lameda	Lameda	Lameda	Lameda					
	Lumme	Lameda	Lameda	Lameda	Lameda	Lameda	Lameda					
	Y. gullale	Traditional	Lameda	Lameda	Lameda	Lameda	Lameda					
Transportati on	Dugda	Donkey cart	Donkey cart	Donkey cart	Donkey cart	Donkey cart	Donkey cart					
	Lumme	Donkey cart	Donkey cart	Donkey cart	Donkey cart	Donkey cart	Donkey cart					
	Y. gullale	Donkey back	Donkey back	Donkey back	Donkey back	Donkey back	Donkey back		Donkey back	Donkey back	Donkey back	

NB: BD union= Bora Dembel Union; LA union= Lume Adama Union

Crop production constraints

Rain-fed crop production constraints

Constraints related to agriculture production inputs such as seeds, fertilizers and pesticides was indicated in table 13. The major constraints related to improved seed supply are poor quantity of seeds, untimely supplyand miss match of variety preference. According to FGD at Dugda, Hawi is the most preferred wheat variety whereas most seed suppliers deliver varieties such as Pavan-76, Jafarson, and Digelu. The same is true for teff where koncho was supplied instead of farmers' preferce for Dz-Cr- 37 (Tseday).

Table 13. Fertilizer and pesticide supply for the study districts during the period of 2008 to 2015

District	Inputs	2008	2009	2010	2011	2012	2013	2014	2015
Dugda	DAP	10831	8700	12973.5	6465	20016	18124.7	15374	2383.5
	NPS	0	0	0	0	0	0	0	20729.5
	Urea	1350	2323.5	5801.5	2855.5	7603	9879.5	16908	11596.5
	2 4-D	1740	2154	2000	3034	3444	85	150	2120
	Topic	0	0	0	0	0	0	67	460
	Palas	0	0	0	0	0	0	0	346
Lume	DAP	**	**	31679.0	28170.5	25909.0	2`7654.5	29560.5	199.0
	NPS	**	**	0.0	0.0	0.0	0.0	0.0	32331.0
	Urea	**	**	17102.5	15157.5	15171.0	15017.5	17323.0	16581.0
Yaya Gullalle	DAP	**	**	**	1538.5	1368.5	2438	2754	22
	NPS	**	**	**				1050	2901.5
	Urea	**	**	**	3134	3091	4202	4381	5422.5
	Bio-fertilizer	**	**	**	1365	110	66	89	600

** = data not available

According to FGD, except for the ever increasing cost of fertilizers, no noticeable constraints were raised by farmers across all districts. In Dugda and Lume districts, farmers raised affordability and efficacy as the major constraints related to agro-chemicals. In Yaya Gullale constraints regarding agro chemical supply were majorly poor supply and lack of knowledge on appropriateness of the chemicals. In general, Input supply and services at Yaya Gullalle were relatively poor as compared to that of Dugda and Lume district.

In the study areas, access to market is rated as a good in Dugda and Lume district and as medium in Yaya Gullalle. There is no marketing institution in the three districts that facilitate marketing system for enhanced bargaining power of farmers. No credit facilities available for farmers at product harvesting stage. Credit is given only for fertilizer and other input purchases at the time of sowing. Climate is becoming the main challenge to crop production. In the rift valley, where rainfall is not reliable, both in amount and distribution, crop production is affected due to low soil moisture, whereas, the highlands are affected by chilling injury and snows.

Irrigated crops production constraints

Major problems in irrigated agriculture are poor input supply system, prevalence of disease and pests, poor credit system and market being dominated by middle men and brokers. Problems related to tomato seed supply were high cost and less availability. For onion, there is no certified seed that farmers rely on. Its production mainly depends on the nationally released onion variety known as bombey red.

Price fluctuation is the major constraint facing horticultural products marketing. This happens as everybody produces the same product for the same market. A given plot of land is used twice per year, from September to January for onion production and during rainy season for tomato production which not only affects product prices but also declines the fertility of the soil.

Other challenges related to horticultural crops production is lack of fertilizer and pesticides application knowledge. Whereas DAP is not applied as splits for annual crops, the farmers in rift valley areas apply DAP in two to three splits. Some farmers apply over doses while others apply below the crop requirement. According to FGD at Dugda and Lume, farmers use a minimum of 400kg DAP/NPS ha^{-1} and 400kg Urea $ha^{-1,}$ the rate which is above the national recommendation made for crops in Ethiopia. According to Edossa *et al.* (2013) more than 30% of farmers in the rift valley use this rate. Time of application and fertilizer placement methods also needs attention. Problems related to pesticides include storage, use and safety. The rate of application, frequency and place of application of pesticides also requires practical skills.

As the result of focus group discussion revealed, farmers witnessed that there is no extension services provided for farmers engaged in vegetable production. Farmer to farmer information exchange was the only means of technical information exchange among farmers.

Matrix ranking

The problems in crop production were listed and ranked using pair-wise matrix ranking method (Table 14). Accordingly, market problem ranked first in irrigated crop production followed by disease and insect pest at Dugda and Lume districts. This was not found to be challenging in Yaya Gullalle district as irrigated crop production in the area very limited and the demand for vegetable crops is from far central markets.

In lowland kebeles of all district shortage of rainfall and its poor distribution were ranked first except in Dungugi Bekele. Chilling and snow were found to be challenging in the highland kebeles of Yaya Gullalle district. Lack of improved seeds with sufficient quantities and of good quality was other challenges in Yay Gullalle district were extension was very poor.

Table 14. Matrix scores and ranking for crop related constraints at Dugda, Lume and Yaya Gullalle districts

Constraints	Dugda				Lume				Yaya Gullalle			
	Walda Kalina		Tuchu Sumeyan	Koto Biliti	Dungugi Bekele		Tade Dildimo	Nanawa	Buyama and Kuat		Kuchu and Tengego	Dede Tigi
	RC	IC			RC	IC			RC	IC		
Disease and Insects	4 [2]	2 [2]	1 [3]	1 [5]	3 [2]	1 [3]	2 [2]	2 [5]	1 [5]	2 [3]	3 [3]	0 [5]
Rainfall shortage and distribution	5 [1]	xx	2 [1]	4 [1]	2 [3]	xx	4 [1]	0 [7]	1 [5]	4 [1]	0 [7]	xx
Adverse climate (chilling and snow)	xx	xx	xx	xx	Xx	xx	xx	xx	xx	xx	6 [1]	3 [2]
High cost of inputs (fertilizer, chemical, etc)	xx	1 [3]	xx	4 [1]	2 [3]	2 [2]	2 [2]	3 [4]	4 [1]	xx	1 [6]	2 [3]
Chemical availability	xx	xx	2 [1]	xx	Xx	xx	1 [4]	2 [5]	2 [4]	xx	3 [3]	1 [4]
Lack of required quality and quantity seed supply	2 [5]	0 [4]	1 [3]	2 [3]	4 [1]	0 [4]	1 [4]	4 [1]	3 [2]	3 [2]	5 [2]	4 [1]
Market problem	4 [2]	3 [1]	Xx	2 [3]	1 [6]	3 [1]	xx	4 [1]	xx	0 [5]	3 [3]	xx
Credit facility at harvest	xx	xx	Xx	2 [3]	3 [2]	xx	xx	4 [1]	3 [2]	1 [4]	3 [3]	xx

Numbers given in and out of brackets, respectively indicate scores and ranks; xx = represent that it is not included as constraint; RC = Rain-fed crop production and IC = Irrigated crops production.

Summary and recommendations

Crop production is constrained by diverse biotic and abiotic factors. Lack or limited access to improved seeds, prevalence of diseases and insect pests, are the major challenges to crop production in the study areas. Poor crop management practices, lack of marketing system and information, poor market linkages, low institutional support, lack of value chain development are also important to ensure participation and benefit of the smallholders.

Based on the findings of the study, the following recommendations are given:

- Improve the technical knowledge and skill of farmers and development agents by providing training on improved production and husbandry practices and on the use of quality inputs of the required amount Develop efficient seed and agro chemical supply sytem with technical guidance
- Carry out extensive crop response to multiple sources of fertilizer and develop soil test based fertilizer recommendations for specific crops.
- Strengthen knowledge of agricultural extension staffs on soil fertility management for specific crop (rate, time and space of application)
- Capacitate farmers on pest scouting and application of integrated pest management techniques and enhancing farmer's knowledge on safety during chemical application.
- Arrange credit facilities during harvesting time to reduce risk of selling products at low price .
- In areas where chilling injures is a problem, development and introduction of resistant or tolerant varieties to overcome frost damage is important.
- Develop farmers' knowledge crop intensification especially in areas like Yaya Gullalle where production depends on low input use.\

Livestock production

Livestock types and population

Information from secondary data of each study district was reviewed to understand the types and population of livestock and the results are presented in table 15. In all the study districts; cattle, sheep, goat equines, poultry and bee production have been carried out in varying proportions. Dugda district had the highest population of all livestock types followed by Lume and Yaya Gulele districts. This might be due to relatively the larger grazing land the district has. The district is also identified by having larger number poultry and honey bee colonies. However, the discussants mentioned that agro-chemicals are becoming a threat to their honey bees as the area is dominated by the production of horticultural crops which demands higher uses of pesticides. Livestock in all the study districts were dominated by indigenous breeds. For instance, as a proportion of total cattle population, only few crossbred cattle of different exotic inheritance level, particularly Friesian breed, were registered at Yaya Gulele (6.1 percent), Lume (1.8 percent) and Dugda (0.1 percent) districts.

Table 15. Livestock population of the study districts

Livestock types	Dugda	Lume	Yaya Gulele
Cattle	229,354 (+118*)	131,405(+2,367*)	58,549 (+3,587*)
Sheep	70,263	38,985	50,286
Goat	62,705	40,305	23,592
Donkey	20,017	29,357	8,729
Horse	5,193	892	2,202
Mule	2,166	934	182
Poultry	615,170	105,411	51,201 (+8700*)
Honey bee colony (total)	18,028	3,338	4,692
Traditional hives	8,028	2,273	3,461
Transitional hives	6,000	715	723
Modern hives	4,000	350	508

**Number of crossbred or improved animals*

Livestock production systems

Livestock production systems in developing countries varies from extensive pastoral systems dominated by smallholders and semi-subsistence production to intensive mixed crop-livestock systems where large scale commercial oriented industrial production is practiced (Herrero *et al*., 2012). In the current study extensive mixed crop-livestock production system in which farmers manage their livestock under poor feed resources such as grazing and crop residues is practiced in all the districts. In all the three districts, mixed-intensive systems has been practiced by few farmers who particularly have improved dairy and poultry breeds. Mixed semi-intensive system was significant in Yaya Gulele district where fairly large number of farmers practice improved dairy production using improved breeds. Farmers were provided with purchased concentrate feeds such as linseed and noug seed cakes and wheat bran, and green feeds harvested from the boarder of croplands, from within the crop. Semi-intensive fattening was also practiced by some farmers who have ample sources of the necessary feeds.

Livestock productivity

Daily milk and annual egg production from both indigenous and improved breeds of cattle and chickens as well as annual honey production from different types of hives is indicated in table 16. Average dairy milk yield of indigenous breeds varies from 1 to 3 liters, with a low, medium and high production at Dugda, Lume and Yaya Gulele districts, respectively. Relatively higher productivity for Lume and Yaya Gulele, could be related to the management levels and feed availability in the areas. In many cases, the lowland areas are characterized by relatively low milk productivity.

Average milk production from improved breeds of different exotic blood levels ranged from 8 to 10 liters. The mean annual egg production of indigenous and improved breeds was 50–75 and 120–300, respectively. Generally, the results indicated that livestock productivity has been decreasing over time as compared due to shortage of feeds resulted from diminishing of grazing lands and expansion of crop farming. However, FGDs at Yaya Gulele district indicated that milk production from both indigenous and crossbreed cattle is in the state of increasing due to improvements in management, breeding and awareness of the farmers even though the use of improved breeds is limited.

Although it varies from place to place, in many cases honey could be harvested twice a year during August to December (main harvesting season) and May (minor harvesting season). The results indicated that 5-8 and 10-32 kg of honey is annually harvested from traditional and modern hives, respectively. Review of secondary information, on the other hand, indicated that the average productivity per hive was 4, 8 and 15 kg, respectively, for traditional, transitional and modern hives per year. When districts are compared in terms of honey production, annual harvest was highest in Yaya Gulele followed by Lume and Dugda districts.. Alike the difference in quantity, honey collected from traditional, transitional and modern hives had different quality. Secondary information from Yaya Gulele indicated that the quality of honey from traditional hives was characterized to be lower and mixed with wax. Both yield and quality of honey vary seasonally based on the availability of flora type.

Unavailability of bee forages due to deforestation and increased losses of honey bees by improper use of agro-chemicals are the most important factors affecting honey production. In the contrary, discussants from Yaya Gulele district believed that honey production has shown an increasing trend over time due to changes in attitude and awareness, and improvements in management and technology intervention which enabled them produce in improved ways.

Table 16. Productivity of cattle, chicken and honey bees in kebeles of the study districts

Livestock types	**Dugda district**			**Lume district**			**Yaya Gulele district**		
	KB	WK	TS	TD	DB	NA	KD	BK	DT
Cattle, indigenous (kg, milk)	1.00	1.00	2.00	1.75	1.00	2.00	3.00	1.00	3.00
Cattle, improved (kg, milk)	-	-	-	8.67	-	-	8.00	-	10.00
Chicken, indigenous (N, eggs)	75.0	52.5	60.0	60.0	70.0	50.0	75.0	60.0	67.5
Chicken, improved (N, eggs)	165	150	120	180	280	180	240	150	300
Honey bee (kg, honey)									
Traditional hives	5.0	12.0	-	7.0	-	-	12.0	5.0	8.0
Transitional hives	-	-	-	-	6.0	-	-	-	10.0
Modern hives	-	18.0	10.0	24.0	-	-	32.5	-	22.0

KB = Koto Biliti; WK = Welda Kelina; TS = Tuchi Sumeya; TD = Tade Dildimo; DB = Dugugi Bekele; NA = Nanewa; KD = Kuchi Dengego; BK = Buyema Kuwat; DT = Dede Tigi.

In all the study districts, age at first lactation varied from 4 to 5 and 2 to 2.5 years for indigenous and improved or crossbred heifers, respectively. It is stated that cow can give birth for up to 8 to 10 times during her life time. Age at work (plough) for indigenous bulls was about 4 years with a service length of 6 to 8 years while it was 2 years for crossbred bulls. FGDs confirmed that crossbred bulls are mostly suitable for fattening. The average lactation length for indigenous cows at Dugda district was as long as 12 months, while it was 6 months at Lume and 4 to 5 months at Yaya Gulele districts. However, lactation length for crossbred cows was estimated to be 7 to 10 months, which is relatively longer than that of the indigenous cows.

Age at weaning (month) and age at which livestock types in the study districts get old are indicated in table 17. Both FGD and the secondary information results indicated that the average waning age for indigenous cattle in the three districts is comparable and varies between 6 and 12 months. The variation is likely to be due to variation in availability of feeds both for the dam and the offspring, management levels and breed differences. Improved breeds of cattle are weaned relatively earlier than indigenous breeds. Age at weaning for sheep and goats was comparable and varies between 3 to 6 and 2 to 6, respectively.

With regard to age at which different livestock get old, variations were observed among the different livestock species and the study districts. Discussants perceived that improved breeds of cattle and chicken get older at earlier age than their indigenous counter parts.

Table 17. Age at weaning (month) and age at getting old (year) for livestock types in the study districts

Livestock types	**Age at weaning**			**Age at getting old**		
	Dugda	**Lume**	**Yaya Gulele**	**Dugda**	**Lume**	**Yaya Gulele**
Cattle, indigenous	9-12	6-12	7.5-12	15-20	11-12	13-16
Cattle, improved	-	7.0	5-12	-	15	7-12
Sheep	3-6	3-4	3-5	6-12	5-6.5	7-10
Goat	3-6	3-5	2-5	8-12	6.5-8	7-10
Chicken, indigenous	1.5-2.5	1.5-1.75	2-4	3-5	2-5	3-6
Chicken, improved				3-5	2-3	2-4.5
Donkey	5-12	6-12	6-12	25-27.5	15-20	18-20
Mule				6-40	20	40-70
Horse	6	-	8.5-10	15-40	10	20-30

Livestock management

Livestock feeds and feeding

Major livestock feed sources available in the study districts and their extent of utilization was given in table18. Even though it is on the state of shrinking due to increase in crop land, open grazing is the main source of livestock feeds both during the dry and wet seasons in all the study districts. During wet season, the farmers fed their livestock on private grazing land near the farmers' homestead and small plots of grazing lands at the edge of croplands. Besides, animals were primarily fed on weeds harvested from within the cropland, green grasses and thinned out crops, as it is also confirmed by the secondary information. Farmers in urban and peri-urban areas use concentrates and industrial by-products for dairy and fattening. Industrial by-products and feed concentrates have not been used by farmers in most study areas during wet seasons asother feed resources abundantly available during this time.

Crop residues, mainly teff, wheat and barley straws, and maize and sorghum stovers, and pulse crop residues are utilized in all study districts. In rural areas of Lume district and urban and pre urban areas of Dugda district, supplementation of crop residues with industrial by-products such as *Atala* (by-product from local alcoholic beverage) and concentrates (eg. wheat bran, oil seed cake and molasses) is practiced for fattening, lactating cows and plowing oxen during dry seasons. In Lume district molasses is being provided to the farmers by OLFRD on payment bases but it is rarely used due to its unaffordable prices. Farmers residing in areas located at far distance from main market centers and towns had no access to industrial by-products and hence use such feeds rarely. Farmers in Yaya Gulele district are examples.

It has observed that forage was not cultivated by majority of the farmers in the study areas due to several reasons. First, in areas where irrigation agriculture has long been practiced, farmers were not willing to allocate land for forage production. Instead, they are interested to use their land for crops which are used to generate income. Secondly, most farmers are not producing forages under rain-fed due to lack of inputs, services and know-how. This might be related to the poor extension services to bring a change in farmers' attitude towards the importance of forage production for improved livestock production. Though on the state of extinction due to deforestation, some important traditional browse trees were used as feed resources. Different *Acacia* species were perceived to be an important local browse trees in the Ethiopian Rift Valley areas, where Dugda and Lume districts are located. Besides, local browse trees such as *laaftoo, adaaddii, ebiicha, qilxuu, oodaa, doddotii, garbii, badannoo, ittica, hindhesa, alellaa* were identified during FGDs at Kuchi Dengego and Buyema Kuwat of Yaya Gulele district as important feed sources for browsers.

Table 18. Major livestock feed resources in the study districts and their extent of utilization

Major feed sources	**Dugda district**		**Lume district**		**Yaya Gulele district**	
	Wet season	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**
Pasture land	Smaller area	Wider area	Smaller area	Wider area	Limited	Some area
Crop residues	To some extent	Communal land	In some extent	Communal land	Limited	Communal land
Weeds, thinned out crops and vegetable wastes	Commonly used	Limited to irrigation based areas	Commonly used	Limited to irrigation based areas	Commonly used	Limited to irrigation based areas
Industrial by-products	Used only in urban and peri-urban areas for dairy and fattening	Used mainly in urban and peri-urban areas, and rarely in rural areas	Commonly used for dairy and fattening	Commonly used for dairy and fattening	Not common	Not common
Concentrate feed	Used only in urban and peri-urban areas for dairy, poultry and fattening	Used mainly in urban and peri-urban areas	Used in urban and peri-urban areas for dairy, poultry and fattening	Used for poultry, dairy and fattening	Not common	Not common
Sown Hay/ forage	Not used	Not used	Not used	Not used	Used	Used

Water sources for livestock

Rivers (Meki and Awash), Lake Ziway and bore holes were the three main important water sources for livestock in Dugda district both during the dry and wet seasons. In addition to these sources, rain water harvested from roofs and water accumulated in holes or trenches are used during the wet season. In Koto Biliti *kebele* of Dugda district, Meki River was the only source of water during the dry season, however, farmers stated that it takes them three hours on-foot to reach the river. As a result, they were forced to take their animals for watering every other day. Similarly, water from Lake Zeway and bore holes is used for livestock in Welda Kelina and Tuchi Sumeya *kebeles* of the district both during dry and wet seasons. However, farmers stated that the water from the bore holes, which is currently used for both human and animal consumption, has a higher fluoride content which thought to have a negative impact on health.

Farmers in Tede Dildimo and Nanewa *kebeles* of Lume district are using water for their animals from seasonal rivers, rain water harvested from roofs and water accumulated in holes during the wet season, FGDs at these kebeles indicated that they bring water from nearby areas such as Modjo town during the dry season, however. Awash River has mainly been their water source both during the dry and wet seasons.

Several areas under Yaya Gulele district had an access to rivers which have been used as sources of water for livestock. Farmers in Kuchi Dengego and Dede Tigi use rivers for their livestock both during the dry season and wet seasons. Muger River which separates Yaya Gulele district from West Shoa zone has been used as a water sources by farmers of Buyema Kuwat Kebele and other areas closer to the river both during dry and wet season. Discussants also indicated that they use spring water both during dry and wet seasons and any available water during the wet season.

Animal health management

Major livestock diseases parasites identified in study districts, as summarized from the secondary information, are given in table 19. Both internal and external parasites, bacterial and viral diseases are known to affect animal health in the study districts. Bovine and Ovine pasteurellosis were the two most common dry seasons bacterial diseases in all the three districts. Blackleg was reported as a common cattle disease during the main rainy season in Dugda and Yaya Gullele districts. Anthrax in cattle and cholera in poultry were also reported as common bacterial disease in Yaya Gullele district.

Lumpy Skin Disease (LSD) and foot and mouth disease (FMD) in cattle, pox and PPR in sheep and goats during short dry season, Newcastle disease in poultry during both dry and wet seasons, African Horse sickness (AHS) in horses were the most common viral diseases in all the study areas. Rabies is also reported as the most important viral disease in Dugda. Even though vaccines are available for all these viral diseases, incidence of the diseases was a challenge due to the presence of unvaccinated animals, especially the indigenous chickens, in the remaining flock or flocks in the surrounding areas.

Higher rates of infestation by internal parasites such as nematodes, trematodes and protozoan parasites were reported in cattle, sheep, goats and chicken during periods after short rainy season. Although the availability of drugs to treat the parasites is not a challenge, liver fluke was found to widely affect cattle and sheep grazing on wetlands in all the three districts.

Secondary information from the districts showed the presence of livestock external parasites such as ticks, lice and mites mainly occurring in short rainy season, around April. The animals were usually treated in several ways including chemical spray and injection based on types of the parasites.

Table 19. Major livestock diseases and parasites identified in study districts

Major diseases	Dugda district	Lume district	Yaya Gullele district
Bacterial diseases	Bovine Pasteurellosis	Bovine Pasteurellosis	Blackleg
	Blackleg	Ovine Pasteurellosis	Bovine Pasteurellosis
	Ovine Pasteurellosis		Ovine Pasteurellosis
			Anthrax
			Cholera (poultry)
Viral diseases	LSD	LSD	LSD
	Sheep and Goat pox	Sheep and Goat pox	Sheep and goat pox
	PPR (ruminants or ovine rinderpest)	PPR	African horse Sickness
	African Horse Sickness	Newcastle Disease	Newcastle disease
	Newcastle Disease	African horse sickness	Rabies
	FMD	FMD	FMD
	Rabies		
Internal parasites	Live fluke	Nematodes	Liver fluke
	Round worms	Trematodes	Round worms
		Protozoa (Coccidiosis)	
External parasites	Tick	Tick	Tick
	Mites	Lice	Mites
	Lice	Mange mites	Lice
	Flea	Demodex mites	Flea

Housing management

Both separate and group housing for all types of livestock are used by the farmers in the study districts. It was indicated that cattle and equine are managed under fenced traditional loose enclosures without any shade whereas, small ruminants and calves were kept in barns with shade and walls. Animals in the enclosure may be tied on poles using ropes or may be allowed to freely move in the traditional barns. Housing for poultry was varied from place to place which includes, among others, perch in kitchens and in family dwellings. Housing for small ruminants and calves may be within the houses of the owners as is the case for some farmers. In most cases, separate houses are constructed by sharing part of their walls with the family residences. On the other hand, in areas such as Tede Dildimo of Lume district and where improved dairy breeds are managed, farmers use separated houses for their cattle also.

Breeding management

Except for the locations closer to the capital town of the districts where OLFRD is found to give insemination (AI) services, smallholder farmers across the study areas are faced with challenges of not getting AI services. This forced them to use bulls of any breed available in their own or in other herds for breeding purpose without any selection. On the other hand farmers in some areas, for instance, farmers in some *kebeles* of Lume, and Yaya Gulele districts are using controlled breeding in order to avoid mix up of their improved dairy breeds. As indicated during the

FGD in Kuchi Dengego, currently, majority of the farmers are using controlled mating and AI system as the extension system helped them to bring changes in their attitude. Farmers in Dede Tigi are also bringing their dairy cattle in heat to improved bulls in their village. Breed improvement through mass synchronization was recently being implemented by OLFRD in collaboration with other development partners but farmers claimed that it was not that successful.

Product handling and processing

Methods and materials used for milk and honey processing were entirely traditional in all the study areas. However, storage and transportation materials (different plastic and aluminum cans) for cheese, butter and honey were considered as modern although they are not intentionally manufactured. Farmers use clay pot to store fresh milk where it is naturally fermented to give *ergo*, traditionally fermented yoghurt which is then churned to produce butter and *arera*. Farmers have been using different traditional preservation methods such as putting garlic and *tenadam* in cheese in order to improve the shelf-life of dairy products.

***Livestock* production constraints**

Major livestock production constraints prioritized by farmers in their respective district and kebeles are summarized in the table 20. The major constraints identified were input constraints such as breed, feed, disease, technological constraints, and livestock and livestock product marketing.

Breed

Low productivity of the indigenous breeds and lack of access to improved breeds were the major limiting factors for livestock production and productivity in all studied districts. Even though farmers intend to change their local breeds to improved ones, the accessibility is very low. When available at very limited private farms, their prices were not affordable by smallholders. Such breed related constraints was ranked as second important constraint at Koto Biliti and Tuchi Sumeya *kebeles* and first most important problem at Welda Kelina *kebele* of Dugda district (Table 20). The results indicated that breed related constraints were severe at Dugda district as compared to Lume and Yaya Gulele districts. This challenge was perceived to be related to lack of institutions which support in terms of providing improved breeds of poultry and dairy animals in affordable prices, infrastructure, and modern technological packages like AI and bull services. Feed shortage and disease are the other most important challenges for improved chicken and dairy cows to adapt and efficiently produce.

Feeds

Feed shortage particularly during the dry season, limited access to concentrates and industrial by-products, and shortage of improved forages both in terms of quantity and quality were major feed constraints facing livestock production in the present study districts. As a result feed ranked first in most and second in limited kebeles of the study districts (Table 20). Coupled with the shrinkage of both communal and private grazing lands due to expansion of crop cultivation which is being driven by population expansion and demand for food crops, shortage of forage production is highly affecting livestock production in the area. Besides, lack of knowledge, insufficient institutional support and poor extension services are major constraints for improvement of the sub-sectors.

It was observed that areas located relatively closer to towns and market centers had an access to industrial by-products though its price was not always affordable. Some farmers started to use industrial by-products such as oil seed cakes, wheat bran and molasses, particularly for their dairy animals, draught oxen and for fattening purpose as they are aware that these feeds are important to enhance livestock production and productivity. Farmers buy these feeds from private feed processors or small retailers in urban areas. Farmers stated that variations in quality and prices of the feeds exits among feed processors as well as retailers which might be related to differences in processing techniques, storage facilities and types of raw materials used. For instance, farmers at Tede Dildimo of Lume district indicated that the price of feeds from Genesis farm in Bishoftu town was relatively higher than the price of feeds from Alema farms in the same town.

During FGDs, most farmers indicated that they have been informed either through training or other means about the benefits of using sown forages to enhance the livestock productivity. However, they had no access to seeds and cuttings of the forages. In the contrary, discussants in Tede Dildimo and Nanewa kebeles of Lume district and indicated that research centers are providing them with the forages, but shortage of land is a major limiting factor for them to grow the forages. Similarly, farmers in Kuchi Dengego and Dede Tigi kebeles of Yaya Gulele district that they have the same problem, even if they get seeds of the improved forages from OLFRB offices. As farmers indicated, some important bee forages are in the state of extinction as result of deforestation and hence cannot support bee colonies for efficient production. In addition to this, farmers are lacking experiences in looking for alternative and additional feed sources for their colonies.

Animal health service

Key informant interview and secondary information at Dugda district indicated that the awareness of farmers to vaccinate their livestock was very low. Besides, drug resistance of some livestock diseases and lack of vaccine for FMD were the major challenges to veterinary service delivery. . Uncontrolled animal movement in Lume district and prevalence of some important diseases in Yaya Gulele district were also identified as major animal health problems. An effective animal health service requires an efficient system that provides services to the farmer at an affordable price. Although animal health posts are available in the majority of rural *kebeles*, they were perceived to be inefficient in providing required services to the level that is required by the community. As indicated by farmers during matrix ranking (Table 20), disease challenge is ranked first in most of the study areas, compared with problems related to breed, feeds and market.

Rank and scores of major livestock diseases in the study districts is given in table 21. Although it happens once in a while (once in five years as stated by discussants), anthrax was identified to be the most severe disease in almost all kebeles followed by blackleg and lumpy skin disease (LSD) In Tede Dildimo kebele of Lume district, Mastitis was also mentioned as important health problem of improved dairy cows.

Table 21. Rank and scores of major livestock diseases in the three districts

Major diseases		Dugda district			Lume district			Yaya Gulele district		
Local name	Common name	KB	WK	TS	TD	DB	NA	KD	BK	DT
Abba Gorba	Blackleg	2nd (2)	-	3rd (2)	2nd (2)	2nd (3)	5th (0)	4th (1)	2nd (3)	2nd (4)
Abba Sanga	Anthrax	1st (3)	2nd (3)	1st (4)	1st (3)	1st (4)	3rd (2)	1st (4)	1st (4)	1st (5)
Dibe Gala/ Dibe Goga/Gunena	LSD	3rd (1)	1st (4)	2nd (3)	-	3rd (2)	1st (4)	3rd (2)	-	6th (0)
Mansa/Qabana	FMD	4th (0)	4th (1)	4th (1)	3rd (1)	4th (1)	2nd (3)	-	-	-
Busa	African Horse Sickness	-	3rd (2)	5th (0)	-	5th (0)	4th (1)	-	-	-
Dibe Mucha	Mastitis	-	-	-	4th (0)	-	-	-	-	-
Mariye/Desta	Rinderpest	-	-	-	-	-	-	2nd (3)	3rd (2)	-
Chitesa	Mange mite	-	-	-	-	-	-	-	4th (1)	3rd (3)
Dulandula	Leech	-	-	-	-	-	-	-	-	5th (1)
Gororsa	Pasteurellosis	-	5th (0)	-	-	-	-	5th (0)	5th (0)	4th (2)

KB = Koto Biliti; WK = Welda Kelina; TS = Tuchi Sumeya; TD = Tade Dildimo; DB = Dugugi Bekele; NA = Nanewa; KD = Kuchi Dengego; BK = Buyema Kuwat; DT = Dede Tigi.

In addition to the diseases affecting cattle, discussants also mention several diseases and parasites of small ruminants, chicken and honey bees and their traditional healing methods (Table 22). Most FGDs indicated that they vaccinate their animals according to the schedule of OLFRD. When their animals are sick, farmers bring their animals to the nearby animal health clinic or animal health post. However, the service they get is not always satisfactory due to lack of drugs and veterinarians. As a result, farmers have long been used ethinovet medicines given by traditional healers to treat their sick animals (Table 22). Traditional methods including fumigation, drenching, topical application and bath using leaves of different plants were among some methods of application the medicines. Fumigants were commonly used against ectoparasites such as mites, lice and fleas. Some farmers are also practicing tattooing of the animals to cure pasteurellosis. Discussants indicated that they apply ash under the hives to prevent ants from climbing into the hives.

Table 22. Important livestock diseases and parasites in the three districts and their traditional treatment.

Livestock types	Diseases	Ethnovet healers	Parasites	Ethnovet healers
Cattle	Blackleg	Drenching *Nicotiana tabacum*, cutting the vessel under the tongue	Tick infestation	Bath with goats' urine, applying cow dung, bath with leaf of *Calpurnia aurea*
	Anthrax		Lice infestation	Cleaning
	LSD	Bath with leaves	GIT parasites	
	FMD		Fascillosis	Badannoo, *Nicotiana tabacum*
	Mange mite		Mites	Cleaning, diesel
	Rinderpest	Cutting the vessel, haarngamaa		
	Pastuerellosis			
Chicken	NCD	Garlic, *Azadiracta indica*, Heexoo, loomii	Mites (itch mites)	Hygienic measures, diesel, fumigation using cow dung
	Fowl pox		Sticktight fleas	Diesel and petroleum jelly (Vaseline)
	Fowl cholera		Fleas	
Small ruminant	PPR		Tick	Diesel, bath with leaf of *Calpurnia aurea*
	Pneumonic pasteurellosis	Leaf of *Calpurnia aurea*, *Nicotiana tabacum*	Lice	
	Sheep and goat pox	Diesel	Fascillosis	
	Circling	*Nicotiana tabacum*		
	Leech	Letting the animal to stay thirsty and removing by hand		
	CCPP			
Honey bee			Ants	• Applying ash on the ground under the hives, • Covering the hive stand with anti-parasites, • Frequent cleaning, • Lifting of the hive above the ground, • Fumigation of the hives with bark and leaf of Soomboo
			Lizards	
			Fleas	
			Spider	
			Wax mouth	
			Chock broad	

Extension and financial services

Extension services of livestock production have entirely been provided by OLFRD office with a very limited support from external institutions including NGOs, agricultural research centers, private sectors and farmers' cooperatives. In addition to OLFRD, research centers (Adami Tulu and Debre Zeit Agricultural Research Centers) and poultry farms are providing extension services on dairy and poultry production, respectively to farmers in Tede Dildimo *kebele* of Lume district. However, the services were sufficient to meet the demand of the farmers. The services provided by these institutions vary from training to inputs and other services. FGDs at Kuchi Dengego indicated that institutions such as World Vission and Ethio chicken have been supporting them in providing pullet. Furthermore, discussants at Dede Tigi indicated that World Vision have provided them training on improved breeds and their managements.

Lack of access to credit and insufficient knowledge of farmers on this and on how to invest were other challenges mentioned by the discussants at several locations. At some locations, however, discussants indicated that the Oromia Saving and Credit Association (OSCA) have been providing them credit but they were discouraged by the high interest rate.

Table 23. Rank and scores of major livestock production constraints in the study districts

Problems	Dugda district			Lume district			Yaya Gulele district		
	KB	WK	TS	TD	DB	NA	KD	BK	DT
Breed	2nd (2)	1st (3)	2nd (2)	2nd (2)	3rd (1)	3rd (1)	3rd (1)	4th (0)	3rd (1)
Feeds	4th (0)	4th (0)	1st (3)	4th (0)	4th (0)	2nd (2)	1st (3)	2nd (2)	4th (0)
Diseases	1st (3)	2nd (2)	3rd (1)	3rd (1)	1st (3)	1st (3)	2nd (2)	1st (3)	1st (3)
Market	3rd (1)	3rd (1)	4th (0)	1st (3)	2nd (2)	4th (0)	4th (0)	3rd (1)	2nd (2)

KB = Koto Biliti; **WK** = Welda Kelina; **TS** = Tuchi Sumeya; **TD** = Tade Dildimo; **DB** = Dugugi Bekele; **NA** = Nanewa; **KD** = Kuchi Dengego; **BK** = Buyema Kuwat; **DT** = Dede Tigi. The number in parenthesis indicates summery of scores from matrix ranking.

Technological constraints

FGDs indicated that livestock production in the area, particularly dairy and poultry, are constrained with technological constraints such as processing, product transportation, and feed management technologies. Some research centers and NGOs have tried to demonstrate technologies in several areas of the study districts. For instance, at Tuchi Sumeya of Dugda district it is indicated that the catholic missionary located in Meki town has demonstrated small-scale technologies such as incubator, brooding, milking machine, and feeders for some experts and subject matter specialists from OLFRD. However, the experts and subject matter specialists did not demonstrate these technologies to users as intended due to lack of institutional arrangement to facilitate the process.

Discussants at Nanewa *kebele* of Lume district indicated that OLFRD has been encouraging them to practice improved forage production for their livestock. However, the technology could not be adopted by the majority of farmers due mainly to shortage of land that emanated from competition by crop farming. Because livestock feed is a big challenge to the existing livestock production, OLFRD has always been training farmers on methods of crop residue treatment, but farmers in several areas of the districts did not practice the technology. On the contrary, farmers at Buyema Kuwat kebele of Yaya Gulele district indicated that they have been practicing crop residue treatment from which they are benefited a lot. Although North Shoa zone of Oromia Regional State is known to be the major dairy producing area, lack of milk processing technologies was mentioned as a challenge to their dairy production. For example, cream separator has only been used by limited farmers of the Kuchi Dengego *kebele* of the district.

Market constraints

At smallholders level, like in the current study, informal market channel that does not fall within the formal business regulatory system including registered business and payment of taxes was the dominant marketing system. The main players in this sector are the traders who buy livestock products directly from farmers and sell directly to an end market and consumers. The farmers can also sell what they have produced directly to consumers living in urban areas. Discussants indicated that livestock products such as cottage type cheese, butter, honey and eggs are also sold at local markets as a source of income for the household.

Lack of market institutions, poor market information, absence of quality control, fluctuation of demands and poor transportation facilities were mentioned as a major challenges facing marketing of livestock products. For instance, farmers in Koto Biliti kebele were traveling about 30 km along a gravel road to reach a district market at Meki town. Farmers have experienced demand and price fluctuations for cheese, butter and eggs; both of them decreasing during fasting period for followers of Orthodox religion and increasing during holidays (traditional and religious festivals). On the other hand, farmers in all the study areas have experienced high prices and demands for livestock products during the dry season and non-fasting seasons.

Review of secondary information indicated that livestock marketing at Dugda district was discouraging for smallholder livestock producers as brokers are price makers while selling live animals. Lack of quarantine for animals which are brought from other distant areas for sale is also an important market constraint. In Lume district livestock marketing was not considered as constraint to the livestock sector. In Yaya Gulele district poor milk marketing system is becoming a concern as the area is known for its high milk production compared with Dugda and Lume districts. In North Shoa zone several milk processing plants are collecting whole milk from many smallholder dairy producers who are located in towns and villages nearer to the main asphalt road. Yaya Gulele district is disadvantaged in this regard as it is far from asphalt road. Hence farmers in different *kebeles* are selling milk at very low price (e.g., birr 7.50 at Kuchi Dengego *kebele*) as compared with other areas in the zone.

Farmers at Tede Dildimo of Lume district who submit milk to milk processing cooperatives operating in Modjo town indicated that they have milk quality problems due to lack of preservation technologies. Thus milk collectors have frequently rejected their milk and the price of milk was also dependent on the demand and decision of the milk collectors.

Fisheries and aquaculture

Secondary data from all districts under this study indicates that fishing has been practiced for long time from Lake Zuway for Dugda, Koka dam for Lume and Mugar River for Yaya Gullalle. The presence of suitable conditions such as market access, warm temperature and adaptive fish species in case of Lume and Dugda districts, cold temperature and adaptive fish species for Yaya Gullalle district (Table 24), makes the area suitable for large as well as small-scale fish production. The presence of many rivers and streams with irrigation structures, fish feed processing company, possibility of integration with other agricultural production practices such as horticulture and poultry and adaptive fish species selected for specific districts make the areas potential for aquaculture development even though it is not practiced yet in any of the districts mentioned.

Table 24. Fish resources of the study districts

District	Water body	Fish species (with their local names)	Potential of the district (kg/year)	Preference
Dugda	Lake Zeway	Nile tilapia (*koroso*)	3282	1st
		African catfish (*ambaza*)	2236	2nd
		Common carp (*jappe*)	876	3rd
		Labeobarbus	468	4th
Lume	Koka reservoir	Nile tilapia (*koroso*)	700000	1st
		African catfish (*ambaza*)	186000	3rd
		Crucian carp (*dube*)	More than tilapia	2nd
		Common carp (*jappe*)	Appearing recently	4th
		Tilapia zilli (*addise*)	Disappeared 3 years now	-
Yaya Gullele	Muger river	Four species are present, species are not identified	Potential is not studied	-

Review of secondary information also indicates that fishing has been practiced by farmers who reside in 11 rural *kebeles* closer to Lake Ziway in Dugda district and 6 rural *kebeles* closer to Koka reservoir in Lume district even though they take it as per time activity. It was seen that five fishery cooperatives at Dugda and three cooperatives at Lume districts were legally registered and performing fishing activities from the Lake Ziway and Koka dam respectively using different fishing equipments (Table 25). However, several unregistered fishermen who illegally harvest fish and use for home consumption and market have perceived to exist.

Unlike both districts, traditional riverine fishery is most important practice in lowland rural *kebeles* located closer to Muger River in Yaya Gullele district. Additionally, the fish species and potential of the river is not well identified. This calls for a thorough understanding of the potential of riverine fishery in similar areas of the region and its socio-economic importance for livelihoods of smallholder farmers. In all districts it was seen that fishing activity is year round, but high fishing pressure is during Orthodox lent months in March, April and July.

Table 25. Fishing gears, targeted fish species and season of fishing in Ziway and Koka

Type of fishing gear (mesh size in cm)	Fish species targeted	Time of setting	Pick season of exploitation
Gillnet (8-10 cm at Lake Zeway, 12-14 cm in Koka reservoir)	Nile tilapia, Common carp, (Crucian carp)	Stay in water for weeks, fish harvesting is every morning	Fishing activity is year round, but high fishing pressure is during Orthodox lent months in March, April and July
Long line (size 7 at Koka reservoir and to 11 at Lake Ziway)	African catfish	Stay in water for long time, but fish harvesting and bait hooking takes place simultaneously in the morning.	
Beach seine (6 cm at Lake Ziway, 10-12 cm at Koka reservoir)	All the fish species	Mainly overnight, but few fishermen still haul in day time	

Major constraints to fish production

Constraints identified during FGDs (Table 26) indicated that absence of fishery regulation which enables fishermen working in a legal manner ranked first in Lume district while lack of transportation facility and absence of appropriate fishing gears was ranked first at Dugda and Yaya Gulele districts. Lack of fish transportation facilities is also an important challenge faces both full and part time fishermen at Dugda and Lume districts. Furthermore, fish processing practices ranked third in all the districts as a challenge needs due attention. In Yaya Gulele district, farmers who have been practicing riverine fishery was mentioned lack of fishing gear as the second most important challenge for their traditional practices. These challenges were perceived as most important constraints for small-scale fish production, thus the sub-sector could not support the livelihood of the produces to its potential.

Siltation and pollution due to industrial effluent, agrochemical discharges and municipal wastes, particularly for Koka reservoir were severe challenges for fishery practices which need immediate solution. Reduction in volume of water bodies due to changing climate conditions and uneconomic or inefficient utilization of water for irrigation agriculture were also identified as important constraints. Moreover, constraints related to marketing, lower prices for fish and illegal fishing activity have been facing fish producers in the current study area. As already mentioned, aquaculture has not been practiced by neither farmers nor fishermen due to reasons related to water shortage in most areas of Dugda and Lume districts. Lack of knowledge and awareness, and lack of input for aquaculture (fish seed, feed, fishing equipment) are also most important constraints to undertake aquaculture.

Fish loss through spoilage was not identified as a major problem in both districts. During some parts of the year (March, April, and June), however, carps were harvested in surplus and thus spoilage becomes higher. Traders may reject carps at landing sites when spoilage occurs before storage. Fishermen were also complaining a rapid spoilage of fish (from one third to half of the catch) in lake overnight when there is a high water temperature especially during March and April. The spoilage during this pick time perhaps related to poor water quality associated with the incoming polluted flood up-stream.

Table 26. Summary of matrix ranking for major fish production constraints at study districts.

Constraints	**Dugda**	**Lume**	**Yaya Gullele**
Absence of fishery regulation	2nd (4)	1st (5)	1st (2)
Lack of fish transportation facility	1st (5)	2nd (4)	-
Poor fish processing practices	3rd (3)	3rd (3)	3rd (0)
Over exploitation of fish from lake	4th (2)	4th (2)	-
Low price of fish	5th (1)	5th (1)	-
Lack of stable fish marketing place	6th (0)	6th (0)	-
Lack of fishing gear (input)	-	-	2nd (1)

NB: Number in parentheses represents scores

Natural Resource and Management

Water resource and management

Surface water from Lake Ziway and Meki River are the major water sources of Dugda and Lume districts respectively where ground water is also widely used for irrigation and other purposes. In Dugda district, during 2015 G.C., out of 16,076 ha irrigated land 1,313 ha was under modern and the rest 14, 763ha under traditional irrigation scheme eventhough it is not indicated in the selected kebeles. Koka dam, Awash River, Modjo River and shallow wells are the major water sources of Lume district and used for traditional irrigation which covers 8175ha. Yaya Gullalle of north shoa Zone is gifted with a number of rivers which is taken as the major water sources for irrigation in the district. During 2015 G.C., about 84 ha of land was under irrigation by those rivers in the study area (Table 27). Water harvesting techniques being functioning in the districts are majorly rain water harvesting eventhough financial problem for Geo-membrane and to make Pond, seepage, technology constraints / Knowledge gap and lack of awareness on irrigation water management and crop water requirement are the most important constraints in all study districts.

Land resource and management

Major Soil Types

Soils of the study areas were classified by farmers during Focus Group Discussion (FGD) on the bases of color, workability, texture, productivity and response to fertilizer application, as: black (43.33%), redish (45%) and sandy (11.67%) for Dugda and black (55%), redish (38.33%) and sandy (6.67%) for Lume districts of east shoa zone. According to the local community, Black "*Koticha*' soil has high water holding capacity, compacted when wet and cracked on dry period, form aggregate during plowing and not pulverized easily, sticky and not easily removed from "*Maresha*" plow implement, low infiltration and water logged when comparing to the Red (Dimile)"*Gombore*" and Sandy soil. On the other hand, Reddish/*Gombore* and sandy soil requires more fertilizer. These soils are naturally less in chemical fertility according to the farmers' opinion. In *Walda Kelina Kebele of Dugda district*, there were a sign of salinity which is white crust and white foam "*Omecha Adi*" left on the farm land while irrigating. According to farmers' expression, low production per area is due to low chemical infertility of the soils.

Table 27. Water sources, Major irrigation schemes and major water harvesting techniques of the study districts

Zone	District	Kebele	**Water sources**				**Irrigation schemes**		**Water harvesting Techniques**		
			River	Lake	Ground water (Bore hole)	Pond	Traditional	Modern	Cistern	Rain water harvesting	Cut off Drain
East Shoa	Dugda	Walda Kalina	xx	Ziway	Bore hole	xx	45% lake Ziway, 55% shallow well	Not available	No	No	No
		Kotto Biliti	xx	xx	xx	Pond	Not available	Not available	No	pond	No
		Tuchi Sumeya	xx	xx	Bore hole		Shallow well	Not available	No	No	No
	Lume	Dungugi Bekele	Awash and Modjo	Koka Dam	Shallow well	No	35% Modjo river, 65% shallow well	Not Available	No	No	No
		Tede Dildima	No	No	Shallow well	No	Not Available	Not Available	No	Small pond	No
		Nanawa	xx	xx	xx	100%	Not Available	Not Available	No	Communal & individual pond	No
North Shoa	Yaya Gullalle	Buyama and Kuat	Mogor, Kawa, Babali & Horoda	xx	xx	xx	100% Alaltu river	Not available	No	No	No
		Dede Tigi	Warke & Chakka	xx	xx	xx	100% Chekka River	Not available	No	No construction (communal)	No
		Kuchu and Tengego	Alaltu	xx	xx	xx	100%Mogour river	Not available	No	No	No

NB: xx = not applicable for the Kebele, Not available is to represent specific Kebele not the district (e.g, Dugda has modern irrigation scheme in some kebeles).

Table 28: Percentage of major soil Types in Dugda, Lume, and Yaya Gullalle districts

Zone	District	Kebele	Major soil types		
			Guracha/Koticha (Black)	Gombore/Dimile(Reddish)	Cirracha (sandy)
East shoa	Dugda	Walda Kelina	70	25	5
		Kotto Biliti	55	45	0
		Tuchi Sumeya	5	65	30
		Average	43.33%	45%	11.67%
	Lume	Dungugi Bekele	40	50	10
		Tede Dildima	45	50	5
		Nanawa	80	15	5
		Average	55%	38.33%	6.67%

Soil physico-chemical management

Tillage practice is one of the soil physical management practices under taken in the low and mid land area of the districts. Four to five times tillage for Black/*Koticha* soil and three to four times for Reddish/*Gombore* and Sandy soil is a known practice. Manure/*compost* application, crop rotation and planting salt tolerant crop like barley are alternative soil chemical management practices exercised in *Welda Kelina* as explained by the farmers. Farmers use “Dike" /compost/ manures as organic fertilizer while DAP/NPS and UREA are inorganic fertilizer sources in all low land and mid land *Kebeles* of all districts. Biofertilozer application is also known in Yaya Gullale of North Shoa while not in both districts of East Shoa Zones (Table 29).

Table 29. Major use of Fertilizer in the *Kebeles*'

Zone	Woreda	Kebele (PA's)	Fertilizer use		
			Organic	Inorganic	Bio-fertilizer
East shoa	Dugda	*Walda Kelina*	Dike/Manure	NPS/Urea	No
		Kotto Biliti	Dike/Manure	NPS/Urea	No
		Tuchi Sumeya	Dike/Manure	NPS/Urea	No
	Lume	*Dhungugi Beqele*	Dike/Manure	NPS/urea	Eco _green
		Tede Dildima	Dike/Manure	NPS/urea	no
		Nanawa	Dike/Manure	NPS/urea	
North Shoa	Yaya Gullale	Kuchu and Tengago	Dike/Manure	NPS/Urea	Biofertilizer
		Dede Tigi	Dike/Manure	NPS/Urea	Biofertilizer
		Buyama and Kuat	Dike/Manure	NPS/Urea	Biofertilizer

Natural resource management constraints

Sheet and gully erosions coused by over flow of Meki River and Ziway Lake during rainy season and degradation of river and lake embankments are the most important constraints in east shoa zone (table 30). Deforestation, diversion of small water ways to river from upper stream, repeated tillage on *reddish and sandy soil* and drainage ditch is another most important constraint in Dugda district. On the other hand, physical and biological soil conservation are errosion mitigation practices carried out in all study districts. Lack of uniform awareness on fertilizer application time and rate, increased cost of chemical fertilizer and absence of sufficient credit, lack of granular fertilizer type and low quality of the powdery one and low moisture which hinder farmers from using recommended fertilizer rates are the most important constrants in all kebeles of the sudy districts. Variation in critical natural resource management constraints across the study is seen in that salinity and soil fertility decline are the main constaints in Dugda while water supply is for Lume district. In all study distrcts, deforestion is important while it is the most important constraint is Yaya Gullalle District of North Shoa Zone.

Table 30. Major soil Erosion types and soil conservation measures *in the Kebeles'*

Zone	District	Kebele	Erosion Type			Soil Conservation Techniques	
			Gully	Sheet	Overflow of river and Lake	Physical	Biological
East shoa	Dugda	*Walda Kelina*	No	Yes	yes	Soil bund	Grass & Tree planting
		Kotto Biliti	yes	Yes	No	Soil bund	Tree planting at farm boundary
		Tuchi Sumeya	No	yes	No	Soil bund, Contour plow	No
	Lume	*Dhungugi Beqele*	high	medium	No	Soil bund &live check dam	Tree planting
		Tede Dildima	Small	Sevier	No	Soil bund & drainage ditch	Tree planting
		Nanawa	Sevier	High	No	Soil bund, stone bund, gully trt, check dam, Drainage ditch	Tree & grass spp

Technology gaps on soil, water and forest

- Unavailability of soil fertility improvement technologies
- Unavailability of soil fertility status identification and rate of fertilizer application on specific soil types.
- Unavailability of moisture conservation methods and techniques mainly on moisture stress area on “Dimile” and sandy soil types.
- Lack of awareness on salt reclamation methods.

Knowledge gap on soil management techniques

- Proper water use efficiency
- Lack of Irrigation water quality assessment and test
- Lack of knowledge on rain water harvesting techniques.
- Lack of forest management (silvicultural practices of indigenous tree species)
- Lack of management on newly regenerated seedling
- Lack of positive attitude on tree growing.
- Lack of identification and control mechanism of tree seedling disease at nursery

Institutional gaps

- Lack of Government support on water supply
- Lack of credit access for fertilizer
- Lack of support from Gov't and NGO's on provision of water harvesting materials.
- Lack of support from research institutions and NGO's
- Lack of follow up on the pollution of river and lakes (Due to effluent of flower farms and Tannery around Modjo and koka).

Table 31. Natural resource management constraints matrix ranking and score in the study districts

Constraints	Dugda			Lume			Yaya Gullalle		
	Walda Kalina	**Tuchi Sumeya**	**Koto Biliti**	**Tade Dildimo**	**Dungugi Bekele**	**Nanawa**	**Kuchu and Dengego**	**Dede Tigi**	**Buyama and Kuat**
Deforestation	3 [2]	3 [4]	4 [1]	3 [2]	3 [1]	3 [2]	3 [1]	3 [1]	3 [1]
Climate change	1 [4]	**	**	**	**	**	**	**	**
Soil fertility reduction	2 [3]	2 [3]	1 [4]	2 [3]	0 [4]	0 [5]	0 [4]	0 [4]	1 [3]
Rainfall pattern	1 [4]	**	**	**	**	**	**	**	**
Irrigation water quality	2 [3]	4 [1]	**	**	**	**	**	**	**
Soil salinity	5 [1]	**	**	**	**	**	**	**	**
Soil erosion	**	3 [2]	0 [5]	0 [5]	1 [3]	1 [4]	2 [2]	2 [2]	0 [4]
Temperature increased	**	0 [5]	2 [3]	1 [4]	2 [2]	2 [3]	1 [3]	2 [2]	2 [2]
Water supply	**	**	3 [2]	4 [1]	**	4 [1]	**	**	**

Livelihood system and household economy

Socio-cultural setting and resource endowments

Among many, *ider* and *debo*/*jigi*/*wenfel* were the most important social institutions through which the community helps each other during different incidences and transfer their traditions from generation to generation. *Ider* is mainly used as a means of supporting the one who lost his/her families and relatives through death. The support includes financial contribution, sharing ones grief and different contributions that vary from place to place and among communities. Besides, *debo*/*jigi*/*wenfel* is a mechanism of supporting each other during the pick work load period such as sowing and harvesting of crops. As far as religious concerned, both church and mosque were also identified to be found at different locations based on the interest but as the majority of farmers in the study areas were the Oromo ethnic groups, Gada and other traditional festivities are being practiced.

Survival strategies of farm households

Community of the study districts have an experiences of saving food crops for future consumption and the better-off farmers were helping the destitute through donation of money and sharing food grain in case of challenges including food shortage, drought, disease and pest outbreaks and water shortage. Selling of animals and their products to buy food crops and migration to urban areas in search of labor job to support the family were the most important survival strategies during the occurrence of such shocks. Farmers who are living in Mid Rift valley areas where recurrent drought is frequent have been practicing growing early maturing varieties and drought tolerant crops and conserving crop residues for latter day feeding.

Involving in irrigation agriculture in all districts under study and migrating to Muger riverbank during drought periods as a survival strategy in Yaya Gullalle district is a known practice.

Gender roles and decision making

Gender division of labor

Agricultural activities including crop production, livestock husbandry and management and natural resources management are carried out by all family members of the farming community in the study area. As indicated in table 32, women (wife and girls combined) have participated in crop cultivations in almost equal proportion (42 percent) to men in addition to entirely engaged in household activities. The overall participation in crop cultivation accounts for about 33, 24, 25 and 18 percent for husband, wife, boys and girls, respectively, at Lume district. Similarly, the overall participation of husband, wife, boys and girls at Yaya Gulele was 29, 27, 24 and 20 percent, respectively.

Table 32. Gender participation in crop cultivation at Lume and Yaya Gulele districts

Activities	**Households participation at Lume (mean)**				**HH participation at Yaya Gulele (mean)**			
	Husband	**Wife**	**Boy(s)**	**Girl(s)**	**Husband**	**Wife**	**Boy(s)**	**Girl(s)**
Land preparation	4.00	1.00	3.33	0.67	4.00	2.00	2.67	1.67
Preparation of seed	4.00	2.67	1.00	1.33	3.67	3.67	2.00	1.67
Plantation(sowing)	4.00	2.33	3.00	1.00	4.00	3.00	2.33	2.00
Cultivation	2.33	4.00	2.67	3.67	2.67	3.67	3.33	3.67
Weeding	2.67	4.00	3.33	3.67	2.67	3.67	3.33	3.33
Harvesting and collection	4.00	3.33	3.67	2.33	4.00	3.00	3.33	2.33
Threshing	4.00	2.67	3.67	2.33	3.33	2.33	3.67	2.33
Storage	4.00	2.33	3.67	1.67	3.33	3.00	2.33	2.00
Selling and marketing	4.00	2.00	1.00	1.00	3.00	4.00	2.33	2.33
Overall participation	***3.67***	***2.70***	***2.82***	***1.96***	***3.41***	***3.15***	***2.81***	***2.37***

Mean score on a four-point Likert scale: 1 = to very low extent, 2 = to some extent, 3 = to an average extent, and 4 = to a great extent.

As indicated in the results table 33, activities related with livestock husbandry and management has been conducted mainly by husbands and wives. The major activities performed to a great extent by boys and girls were herding and watering of livestock. It is also clear that milking of cows, selling of butter and cheese and selling of chicken and eggs were entirely performed by wives and to some extent by girls. The overall percentage participation of husband (34 vs. 31), wife (30 vs. 27), boys (22 vs. 23), and girls (14 vs. 19) at both districts were in line with each other.

Table 33. Gender participation in livestock production at Lume and Yaya Gulele districts

Activities	Households participation at Lume (mean)				Households participation at Yaya Gulele (mean)			
	Husband	**Wife**	**Boy(s)**	**Girl(s)**	**Husband**	**Wife**	**Boy(s)**	**Girl(s)**
Herding of livestock	1.33	2.00	4.00	1.00	2.33	2.33	4.00	3.00
Watering of livestock	1.33	2.00	4.00	1.00	2.33	2.33	4.00	3.00
Feeding of oxen	2.67	2.00	3.00	1.00	3.33	2.33	3.33	2.33
Feeding dairy cows	2.00	3.33	3.00	2.00	1.00	4.00	2.67	2.33
Feeding calves	2.00	3.67	2.33	2.00	1.00	4.00	2.67	2.33
Caring of sick animals	3.00	3.67	2.00	1.00	4.00	3.67	2.33	2.00
Milking of cows	1.67	4.00	1.33	2.00	1.33	4.00	1.33	2.67
Selling of butter & cheese	0.67	4.00	0.67	2.00	1.00	4.00	1.00	3.00
Selling of oxen/bulls	4.00	1.33	1.33	0.67	4.00	2.00	1.33	1.00
Selling of cows/heifers	4.00	1.33	1.00	0.67	4.00	2.00	1.33	1.00
Selling of calves	4.00	1.33	1.00	0.67	4.00	2.00	1.33	1.00
Selling of donkey	4.00	1.33	1.00	0.67	4.00	1.67	1.33	1.00
Selling of goats and sheep	4.00	1.67	1.00	0.67	4.00	1.67	2.33	1.00
Selling of chicken and eggs	0.67	4.00	2.00	2.33	1.00	4.00	2.67	2.67
Making and hanging hives	4.00	1.67	1.67	1.00	4.00	1.33	2.00	1.00
Harvesting of honey	4.00	1.67	1.00	1.00	4.00	1.33	2.00	1.00
Transferring of colony	4.00	1.67	1.00	1.00	4.00	1.33	2.00	1.00
Selling of honey	3.67	3.33	0.67	0.67	4.00	2.33	1.33	1.00
Overall participation	***2.83***	***2.44***	***1.78***	***1.19***	***2.96***	***2.57***	***2.17***	***1.80***

Mean score on a four-point Likert scale: 1 = to very low extent, 2 = to some extent, 3 = to an average extent, and 4 = to a great extent.

Majority of activities related with natural resources management have been performed by husbands (Table 34). However, soil conservation encompasses activities such as construction of beds, plantation of grass strips and trees, and contour tillage and terrace were performed by wives to an average extent in both districts. Besides, soil fertility management crop rotation, compost making, manure and inorganic fertilizer application were performed both by husbands and wives. Protection of common resources such as grazing lands, water, forest and protected areas as well as water harvesting activities were not common at Yaya Gulele district. About 36, 24, 20 and 20 percent of activities related to natural resources management at Lume district was, respectively, performed by husband, wife, boys, and girls. At Yaya Gulele district too, husband, wife, boys, and girls have been participated in these activities with 37, 22, 24, and 15 percentage participations respectively.

Table 34. Gender participation in natural resources management at Lume and Yaya Gulele districts

Activities	Households participation at Lume (mean)				Households participation at Yaya Gulele (mean)			
	Husband	**Wife**	**Boy(s)**	**Girl(s)**	**Husband**	**Wife**	**Boy(s)**	**Girl(s)**
Seedlings/seeds preparation	4.00	3.00	2.67	3.00	4.00	1.33	2.33	1.00
Bed preparation, plantation	3.67	2.67	3.00	3.00	4.00	1.33	2.33	1.00
Cultivation	3.67	2.33	3.00	2.67	3.33	1.33	2.33	1.00
Watering	3.00	2.67	2.00	2.67	3.33	2.00	2.33	1.67
Soil conservation	4.00	3.00	1.00	1.00	4.00	3.33	2.67	2.00
Soil fertility management	4.00	3.00	2.67	1.33	3.67	4.00	2.33	2.00
Water harvesting	2.67	1.33	1.00	1.00	-	-	-	-
Protect common resources	4.00	1.33	1.00	1.00	-	-	-	-
Overall participation	3.63	2.42	2.04	1.96	3.72	2.22	2.39	1.45

Mean score on a four-point Likert scale: 1 = to very low extent, 2 = to some extent, 3 = to an average extent and 4 = to a great extent.

Resource access and decision making

Resources has been nearly equally shared between husband and wife (40 vs. 31 percent at Lume and 31 vs. 31 percent at Yaya Gulele), thus access to resources by the children varies from very low to some extent (Table 35 and 36). Still, the findings indicated that access to resources was largely deviated to husbands. The overall access to resources by husband, wife, boys, and girls were, respectively, accounts about 40, 31, 16, and 13 percent at Lume (Table 35) and 31, 31, 19, and 18 at Yaya Gulele (Table 36).

Table 35. Gender access to and control over resources at Lume district of Oromia Regional State

Activities	**Access to resources (mean)**				**Control over resources (mean)**			
	Husband	**Wife**	**Boy(s)**	**Girl(s)**	**Husband**	**Wife**	**Boy(s)**	**Girl(s)**
Land	4.00	4.00	1.67	1.33	4.00	2.00	0.67	0.67
Farm tools	4.00	2.00	2.33	1.67	4.00	1.33	0.67	0.67
Income from sale of food crops	4.00	2.67	1.67	0.67	4.00	1.67	0.67	0.67
Income from sale of cash crops	4.00	3.67	1.33	1.33	4.00	3.67	0.67	0.67
Income from sale of livestock	4.00	3.67	1.33	1.33	3.67	4.00	0.67	0.67
Income from sale of dairy products	4.00	3.67	1.33	1.33	1.33	4.00	0.67	0.67
Income from sale of skin and hides	4.00	2.33	1.33	1.33	4.00	2.67	0.67	0.67
Income from off-farm/non-farm works	2.67	2.00	1.00	1.00	2.67	1.33	0.67	0.67
Overall mean	***3.83***	***3.00***	***1.50***	***1.25***	***3.46***	***2.58***	***0.67***	***0.67***

Mean score on a four-point Likert scale: 1 = to very low extent, 2 = to some extent, 3 = to an average extent and 4 = to a great extent.

On the other hands, differences were observed between husband and wife in terms of the overall control over resources. Husbands had a right to control over resources to a great extent (3.46 at Lume *versus* 3.54 at Yaya Gulele) while that of wives was to an average level (2.58 at Lume *versus* 3.09 at Yaya Gulele). About 47, 35, 9, and 9 percent resources at Lume (Table 35) and 42, 37, 7 and 7 percent resources at Yaya Gulele (Table 36) was, respectively, controlled by husband, wife, boys, and girls.

Table 36. Gender access to and control over resources at Yaya Gulele district of Oromia Regional State

Activities	**Access to resources (mean)**				**Control over resources (mean)**			
	Husband	**Wife**	**Boy(s)**	**Girl(s)**	**Husband**	**Wife**	**Boy(s)**	**Girl(s)**
Land	4.00	4.00	1.33	1.33	4.00	3.33	1.00	1.00
Farm tools	4.00	3.00	2.67	1.67	4.00	1.33	1.00	1.00
Income from sale of food crops	3.33	4.00	2.67	2.67	3.67	3.67	1.00	1.00
Income from sale of cash crops	3.33	4.00	2.67	2.67	3.67	3.67	1.00	1.00
Income from sale of livestock	4.00	3.67	2.67	2.67	4.00	3.67	1.00	1.00
Income from sale of dairy products	1.00	2.67	0.67	0.67	1.00	2.67	0.67	0.67
Income from sale of skin and hides	4.00	2.67	2.33	2.33	4.00	2.67	1.00	1.00
Income from off-farm/non-farm works	4.00	4.00	2.33	2.33	4.00	3.67	0.33	0.33
Overall mean	***3.46***	***3.50***	***2.17***	***2.04***	***3.54***	***3.09***	***0.88***	***0.88***

Mean score on a four-point Likert scale: 1 = to very low extent, 2 = to some extent, 3 = to an average extent and 4 = to a great extent.

Nutrition

From the table, it is seen that diet combination of the community of the study districts from cereal (as main source for energy requirements), pulse (cheep protein source), vegetables (vitamins and mineral sources) and animal products such as milk and cheese to supplement the fat and oil requirements (Table .37).

Table F. Main diet combination of the farm community at Dugda, Lume and Yaya Gulele districts

District	***Kebele***	**Main food crops used**	**Main livestock source foods**	**Main diet combinations**
Dugda	Koto Biliti	Maize and wheat	Milk and cheese	• Maize enjera with shiro wet prepared from faba bean, pea or grass pea • Maize/wheat bread with shiro wet prepared from faba bean, pea or grass pea • Maize enjera or Maize/wheat bread with cabbage • Milk and cheese can be consumed with enjera and bread
	Welda Kelina	Maize, wheat and teff	Cheese and milk	• Teff enjera with shiro wet prepared from pea or grass pea • Teff enjera with cabbage and tomato in the form of wet • Bread from a mixture of maize and wheat with wet prepared from pea or grass pea
	Tuchi Sumeya	Maize, teff and wheat	Milk and cheese	• Teff/maize enjera with shiro wet prepared from faba bean, pea or grass pea flour. Cabbage can also be used in accompany with teff or maize enjera • Bread prepared from a mixture of wheat and maize can be eaten with cabbage or shiro wet or cheese • Milk is mainly consumed by children & it can be used along with coffee
Lume	Tede Dildimo	Teff and wheat	Milk and butter	• Enjera prepared from teff alone, or a mixture of teff, wheat, maize, millet, rice and barely can be consumed with shiro prepared from pea, faba bean, chick pea or grass pea, or wet prepared from grits of lentil or pea • Bread prepared from wheat alone or a mixture of wheat and maize with milk or wet
	Nanewa	Wheat, teff and barely	Butter, milk and cheese	• Enjera prepared from teff alone, or wheat alone, or a mixture of both with shiro of grass pea, chick pea, pea, or faba bean. Butter can also be added to shiro wet in order to increase taste and flavor • Bread of wheat is rarely consumed with milk or cheese
Yaya Gulele	Kuchu Dengego	Teff, wheat and sorghum	Milk and cheese	• Enjera prepared from a mixture of teff and wheat or teff and sorghum with shiro wet prepared from faba bean, pea or chick pea. Enjera can also be consumed with cabbage and other vegetables in the form of wet or cheese • Wheat bread with milk or cheese
	Buyema Kuwat	Sorghum, teff, wheat and maize	Arera	• Enjera prepared from sorghum alone, a mixture of sorghum and teff or sorghum and maize can be consumed with shiro of faba bean, cabbage and arera • Bread of wheat, maize or a mixture of both can also be consumed with wet or arera
	Dede Tigi	Barely, wheat and teff	Cheese and milk	• Enjera prepared from teff alone, mixture of barely, wheat and teff, or teff and wheat, or barley and wheat can be consumed with wet prepared from shiro of faba bean or pea, or potato, or cabbage, or other vegetables • Wheat bread with milk or cheese or other livestock and crop source foods

Climate smart agriculture

In all the study areas deforestation, soil erosion and decline in soil fertility due to frequent tillage, recurrent rain which results in dry up of streams and other direct and indirect impact on climate smart agriculture is pertinent in all the study districts. Fluctuation of rainfall and recurrent droughts, shifts in cropping seasons, crop and livestock diseases prevalence, shortage in animal feeds and temperature rises which leads to drought of river and spring water sources due to long dry season are the most important effects of climate change summarized from the FGDs at different locations. In all the study districts, even though farmers are aware of their environment is changing; mitigation practices such as water resource management, rain water harvesting, forest management and protection, soil conservation and use of organic fertilizers like compost are not satisfactory to cope with an existing situation.

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Fall Armyworm *Spodoptera frugiperda* Smith (Lepidoptera, Noctuidae): The New Catastrophic Insect Pest in Ethiopia

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Abstract

In the whole of Africa, food security is under threat from Fall Armyworm (*Spodoptera frugiperda)* (FAW) which is native to and largely confined to the Americas. The first detection of FAW in Africa was notified in January 2016 when it was reported from Nigeria. From there it spread to several other West African countries and to Central Africa by April 2016 and less than one year later it had also invaded Southern Africa by December 2016. By early 2017, the pest had been reported in all mainland countries in Southern Africa except Lesotho and in multiple countries in Eastern Africa. Currently out of 54 countries in Africa 28 countries have confirmed the presence of FAW, while a further nine countries suspect its presence, or are awaiting official confirmation of the pest in the country. Two countries (Somalia and Djibouti) have conducted surveys and not found any FAW. It has now considered as quarantine pest in Europe and is occasionally intercepted on imported plant material from the Americas. Pathways of the introduction of fall armyworm into West and Central Africa are subject to speculations; but the presence of at least two distinct haplotypes within samples collected on maize in Nigeria and São Tomé suggests that the present incursion originated from at least two independent introductions into the African continent. How far FAW has already expanded onto the African continent remains to be determined; but considering its high spreading performance, large reproductive capacity, absence of diapause, and wide host plant range it is likely that the pest will soon be able to colonize most of tropical Africa. The pest has a wide host range and has been reported in over 100 plant species belonging to 27 families. This polyphagous characteristic is an additional challenge to the intercropping system which is common among smallholder farmers in Sub-Sahara Africa. Initially, misdiagnosis of FAW was reported in several African countries and as a result, control measures were in several cases targeting the wrong pest. Farmers need to first understand what FAW is – how to identify it and understand its biology and ecology. Currently in Ethiopia FAW infestations were reported from all regions except Somali. The speed with which it conquers the country highlights its adaptability, invasiveness and probably superior competitive ability over indigenous species. Out of 2.1M ha of land currently under maize cultivation in Ethiopia 22.23% (650,000 ha) of the total maize planted has been infested with FAW. Estimated yield losses range from15-30% in SNNPR and 5-20% in Oromia region. In response to the arrival of FAW to Ethiopia several efforts have been made such as: training of researchers, experts, DAs and farmers; nationwide coordinated survey and exchange of FAW current distribution and damage; formulation of research strategy and agendas; involvement of graduate students to research on the biology, ecology and management; fast track testing of management options including insecticides, bio-pesticides, sex pheromone traps, botanicals and cultural methods. This paper provides: (I) A comprehensive literature review of FAW origin, distribution, biology, identification, host range and strains; and (II) Its status, impact and efforts made so far in Ethiopia.

Key words: *Spodoptera frugiperda*, Biology, Identification, Maize, Africa, Ethiopia

Introduction

Importance of Maize

Although it is an introduced crop, maize is now the highest productive and widely grown staple crop in Ethiopia. The crop has gained strategic importance in the agricultural sector owing to its meaningful contribution to income generation, employment, nutrition, and food security in the country. Besides, it has a huge potential as an export commodity for value-added food or non-food products. It is grown in almost all agro-ecological zones. It grows under a wide range of environmental conditions between 500 to 2400 meters above sea level. Maize is Ethiopia's leading cereal in terms of production, with 7.15 million tons grain produced by 9.55 million farmers on 2.11 million hectares of land (CSA, 2015/16 *meher* season). Maize is mainly grown in the four big regions of the country: Oromia, Amhara, SNNP, and Tigray and Oromia and Amhara, which contributed to almost 80% of the maize produced in 2012 (CSA, 2011/2012). Over half of all Ethiopian farmers grow maize, mostly for subsistence, with 75 % of all maize produced being consumed by the farming household. Although maize is the major stable food crops of the country, their production is being constrained by invasive and catastrophic insect pests like FAW among other factors. Its lack of a resting period and polyphagous behaviour poses numerous management challenges.

History and Origin of FAW

Fall Armyworm *(Spodoptera frugiperda),* FAW, is native pest to the tropical regions of the Western Hemisphere from the United States to Central America and in the Caribbean to Brazil (Knipling 1980, Pashley et al. 1985, Pashley 1986, 1988). The scientific name is derived from the feeding habits of the larval life stage, *frugiperda* meaning "lost fruit" in Latin, as the pest can cause damage to crops resulting in severe yield loss. Although it is tropical in origin, FAW has become a permanent resident of the Southern Gulf coasts of the United States where it can survive mild winter climatic conditions. FAW has a migratory behavior with high dispersal capacity that allows the pest to quickly spread along the rage of its host plants. In early spring, FAW moths emerge from the overwintering pupae and migrate long distances to areas where the climate permits their survival; this can occur for successive generation from spring to fall (Vickery 1929). However, they are unable to survive the winter in the northern states and the species is destroyed each winter throughout its range in the United States except in the southern Florida and southern Texas where the winter is mild (Barfield et al. 1980). The recognition of FAW as a serious economic pest in America dates back more than 250 years. The fall armyworm has a remarkable dispersal capacity and is observed to migrate every year from its endemic area in the warmer parts of the new world over more than 3000 km crossing the entire US up to Canada in the North and reaching the northern parts of Argentina and Chile in the South (Barfield et al. 1980; Difabachew, 2011). This capacity for a long distance movement, up to 480 km/generation (Sparks 1986), has contributed to widespread distribution of the FAW in the Western Hemisphere (Nagoshi et al. 2007). This seasonal migration of FAW could occur in response to seasonal changes in rainfall, temperature, and planting of host plants. Moreover, prevailing winds and frontal systems with their converging air masses during the spring are thought to largely determine the extent and direction of FAW adult migration (Rainey 1979, Pair et al. 1986). Until 2016, it was largely restricted to the Americas i.e. native to America. High infestations can lead to significant yield loss. Farmers in the Americas have been managing the pest for many years, but at significant cost.

Distribution in Africa and Global Spread

Africa has been experiencing a steady accidental introduction of insect pests for the past two decades. These newcomers have negatively impacted the livelihoods of millions of people. The continent is considered to be particularly vulnerable to invasive species due to its high dependence on agriculture and foreign aid. An increase in international trade and easy air travel has greatly facilitated biological invasions in recent decades.

The first detection of Fall Army Worm in Africa was notified in January 2016 when it was reported from Nigeria, Sao Tomé, Benin and Togo (IITA, 2016; IPPC, 2016). From there it spread to several other West African countries and to Central Africa by April 2016. In late 2016 and early 2017 it was detected in Angola, Botswana, Burundi, Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Malawi, Mozambique, Namibia, Niger, Rwanda, Sierra Leone, South Africa, Tanzania, Uganda, Zambia, and Zimbabwe, and it is expected to move further north and beyond (See Fig. 1 below) (CABI, 2017a; FAO, 2017; BBC, 2017). Currently the pest has reached 28 African countries which covers approximately greater than 15 million km^2 (Figure 2). In Ethiopia, FAW was first observed on off-season irrigated maize in the rainforest zone of Southwestern Ethiopia by Mizan-Tepi plant health clinic on 30th February 2017 (Mizan-Tepi plant health clinic report, 2017). How far the fall armyworm has already expanded into Africa is presently not known but with regard to its high spreading performance, large reproductive capacity and wide host plant range it is likely that the pest will soon be able to colonize most of tropical Africa. But the speed with which it spreads from the initial areas of introduction on the African continent highlights its adaptability, invasiveness and probably superior competitive ability over indigenous species which share the same habitats. It can spread fast, and can fly over 480kms per generation and 100 kilometers in one night assisted by the wind and reproduce every 1-2 months, which helped the pest spread rapidly across Africa.

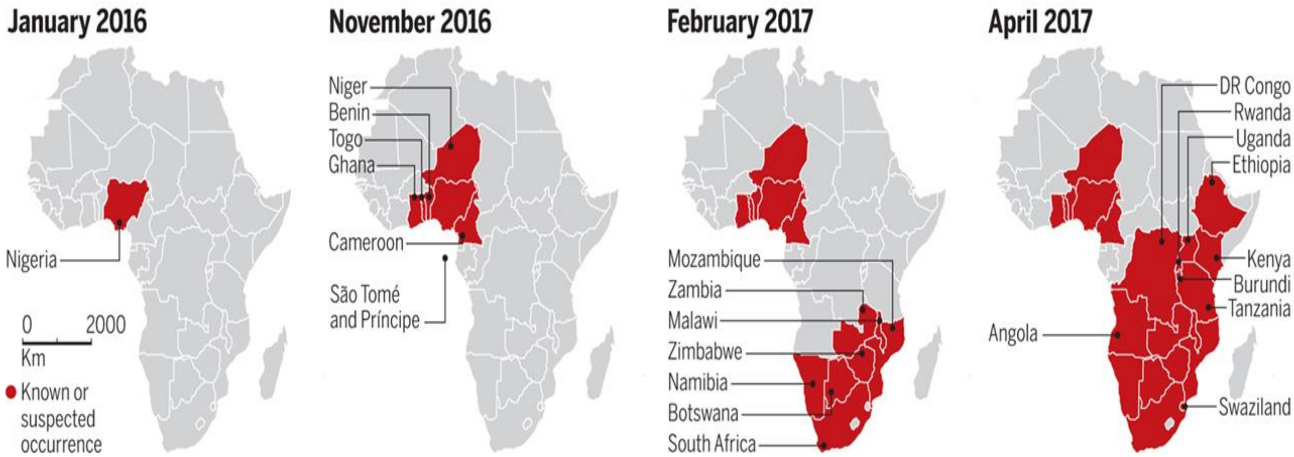

Fig. 1. FAW distribution and spread since its introduction until early 2017

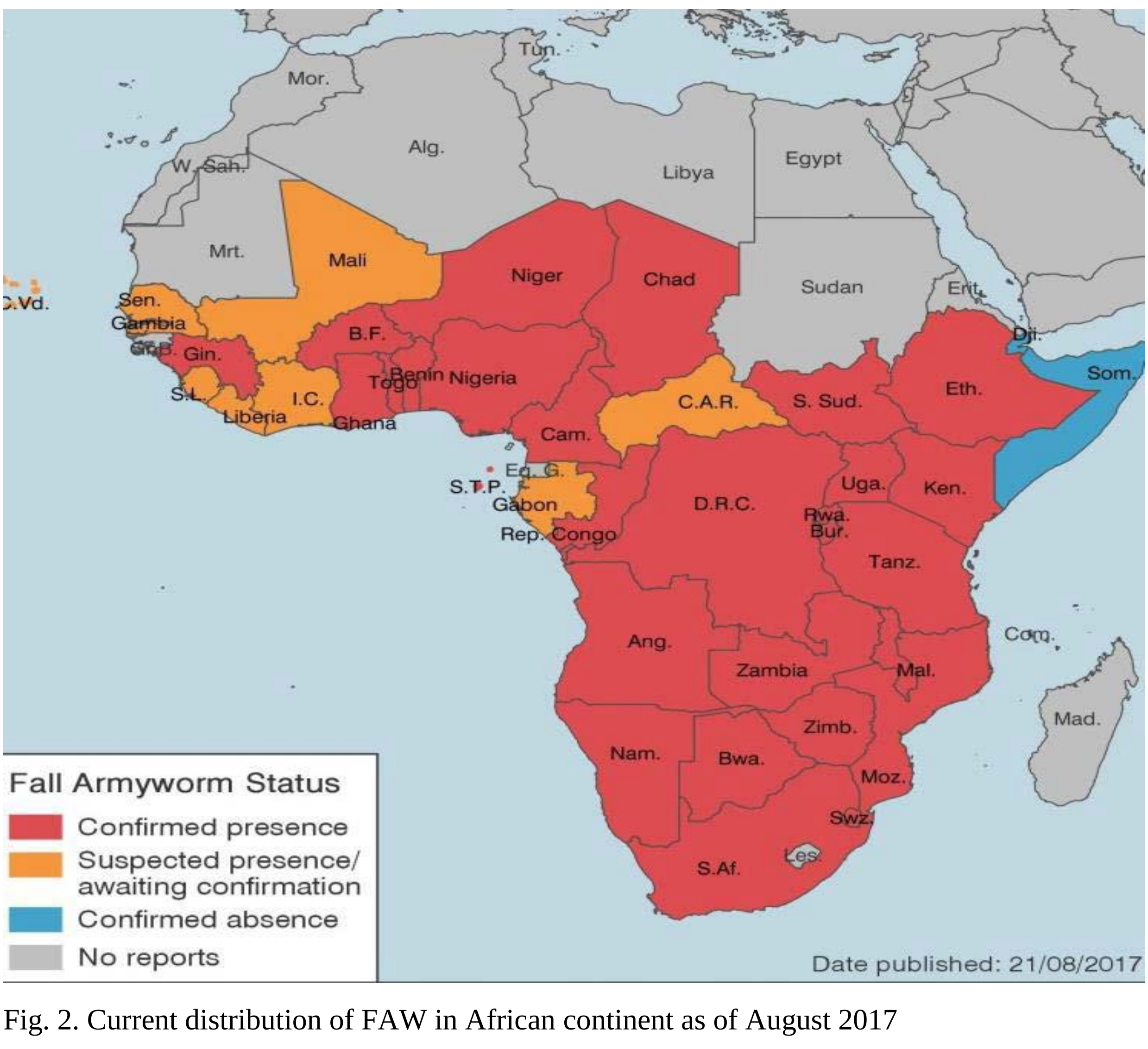

Fig. 2. Current distribution of FAW in African continent as of August 2017

Pathways of the recent accidental introduction of the fall armyworm into West, Central, South and Eastern Africa are yet unknown but increase in international trade volume and easy air travel of people from one continent to another has amplified the phytosanitary risks of even multiple introductions. For the time being, its modality of introduction and its spread to Africa and adjustments of its bio-ecology are still speculative (FAO, June 2017). The presence of at least two distinct haplotypes within samples collected on maize in Nigeria and São Tomé suggested multiple introductions into the African continent (Goergen et al, 2016). Having established a foothold in Africa, further spread into Europe via the Mediterranean Basin and Asia through the Middle East is almost certain. It has been detected in Europe several occasions but has not established there owing to effective actions taken against it. It has now considered as quarantine pest in Europe and is occasionally intercepted on imported plant material from the Americas. Figure 3 below showed current status of FAW spread globally

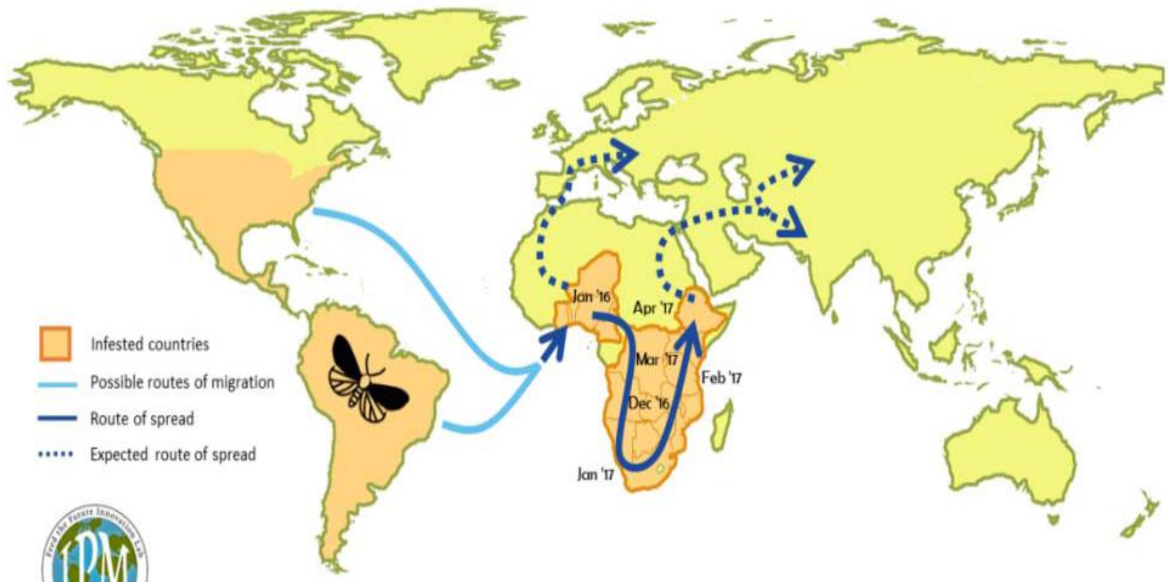

Fig. 3. Fall armyworm current global spread

Life Cycle and Damage to Maize

The FAW completes its life cycle in about 30 days during the summer. But, the duration can be extended to 60 days in the spring and autumn, and 80 to 90 days during the winter. There are no reports on the ability of FAW to diapause. The lifecycle includes egg, 6 growth stages of caterpillar development (instars), pupa and moth. Figure 4 illustrates the lifecycle, showing developmental period of the Fall armyworm found on maize plants at any given stage. Adult FAW moths deposit a layer of egg masses on the leaves of host plants that will hatch within 2-3 days. FAW has 6 larval instars per generation and can have multiple generations per year (Capinera 2001).

DAY 1-3: 100-200 eggs mass up to 2000 are generally laid on the underside of the leaves typically near the base of the plant, close to the junction of the leaf and the stem that will hatch within 2-3 days. These are covered in protective scales rubbed off from the moths abdomen after laying. When populations are high then the eggs may be laid higher up the plants or on nearby vegetation.

DAY 3-6 (Growth Stage 1-3): Newly hatched larvae of FAW are greenish with a black head, the head turning orangish in the second instar. At the end of the second larval stage, the dorsal surface of the body becomes brownish, and lateral white lines begin to form. After hatching the young caterpillars feed superficially, usually on the undersides of leaves. Feeding results in semitransparent patches on the leaves called windows. Young caterpillars can spin silken threads which catch the wind and transport the caterpillars to a new plant. The leaf whorl is preferred in young plants, whereas the leaves around the cob silks are attractive in older plants. Up to the third instar, the caterpillars can hide between host leaves and there is not much cannibalism. Feeding is more active during the night.

DAY 6-14 (Growth Stage 4-6): Once attaining fourth and later instars the head becomes reddish brown spotted with white, and the brownish body bears white subdorsal and lateral lines. Matured FAW larva has a white inverted "Y" mark on its head and a four square black dots at the last 8^{th} abdominal segment. By stage 4-6 it will have reached the protective region of the whorl, where it does the most damage, resulting in ragged holes in the leaves. Feeding on young plants can kill the growing point resulting in no new leaves or cobs developing. Often only 1 or 2 caterpillars found in each whorl, as they become cannibalistic when larger and will eat each other to reduce competition for food. Large quantities of frass present. When this dries it resembles sawdust. If the plant is older and has already developed cobs then the caterpillar will eat its way through the protective leaf bracts into the side of the cob where it begins to feed on the developing kernels (seeds) predisposing them to infection by cob-rotting fungi.

After approximately 14 days the fully grown caterpillar will drop to the ground. The caterpillar will then burrow 2-8 cm into the soil before pupating. The loose silk oval shape cocoon is 20-30 mm in length. If the soil is too hard then the caterpillar will cover itself in leaf debris before pupating.

After approximately 8-9 days the adult moth emerges to restart the cycle. The adult lives for an average of 10 days (range 7-21 days).

Larvae cause serious leaf feeding damage as well as direct injury to the tassel and cobs. Larvae can cause damage to nearly all maize stages of development, but will concentrate on maize plants that have not yet silked. The most common damage is to late pre-tassel maize. Maize plants often recover from whorl damage without reduction in yield. With tasseling larvae may partly or totally destroy young ears, which is more important than leave damage. Usually damage is found in patches in the field. Larval feeding and adult activity most frequently occurs at night, but can occur in late evening and early morning. Although larvae tend to conceal themselves during the brightest time of the day, they are not cryptic feeders like stem-borers. Though *S. frugiperda* larvae can burrow deep into the whorls of maize plants, they do not tunnel into stems.

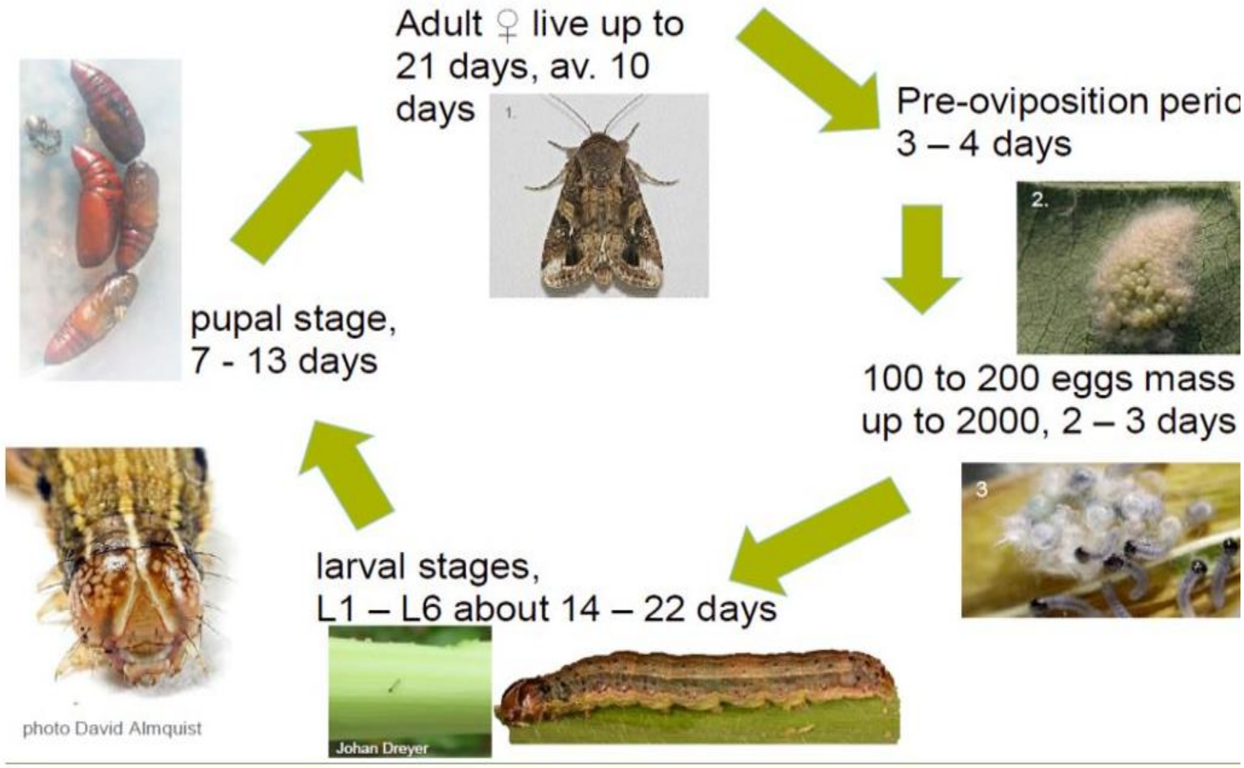

Fig. 4. Life cycle of Fall Armyworm

Identification of fall armyworm

Incorrect identification of the fall armyworm (*Spodoptera frugiperda*), as well as incorrect reporting of feeding on uncommon hosts, are usually due to the lack of good visual reference material. Fall armyworm larvae may be mistaken for other lepidopteran species which are a problem in agro-ecosystems. It is therefore important that the pest be correctly identified as misdiagnosis can impact management decisions. In Africa, other Lepidoptera (moths and butterfly group) whose larvae (caterpillars) may be confused with fall armyworm include the African armyworm (*Spodoptera exempta*), maize earworm (*Helicoverpa armigera*) and False armyworm [*Leucania* (= *Mythimna*) *loreyi*]. FAW identification can be done in one of two ways: Direct identification using morphological characters and indirect identification through characteristic injury symptoms but often requiring confirmation using direct identification.

Direct identification using morphological characters

The main direct distinguishing morphological features of FAW from other similar and common caterpillars encountered in Africa are as follows:

Identification based on egg morphology

FAW eggs are laid in egg masses covered with hairs from female moth's body, imparting a furry or moldy appearance (Plate 1A). In contrast, eggs of stem-borers are laid in egg batches not covered with hairs (Plate 1B).

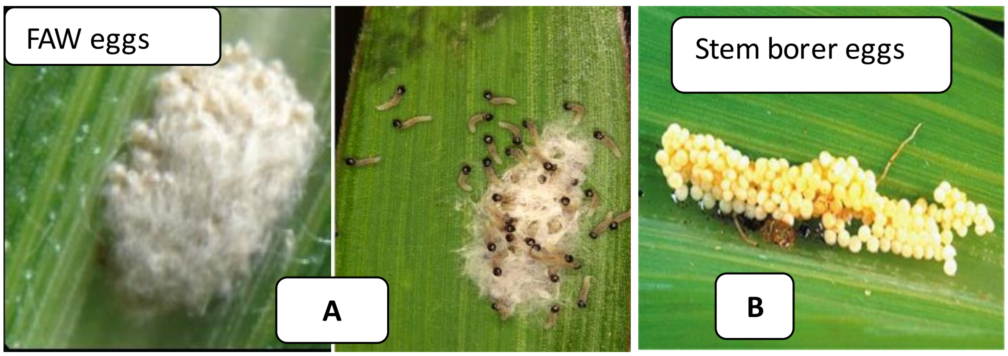

Plate 1. A - Fall armyworm eggs coved by hair, B – Stem borer eggs (not covered)

Identification based on larval morphology

FAW larvae is morphologically distinguished from other similar caterpillars by white inverted Y-shaped suture on the front of the head of a mature larva; distinctive pale or yellowish dorsal lines running lengthwise along the body (Plate 2A) and four distinctive dark spots (tubercles or "bumps"); which are arranged in a square-like pattern on dorsal surface of the 8^{th} abdominal segment of a full-grown caterpillar (Plate 2B).

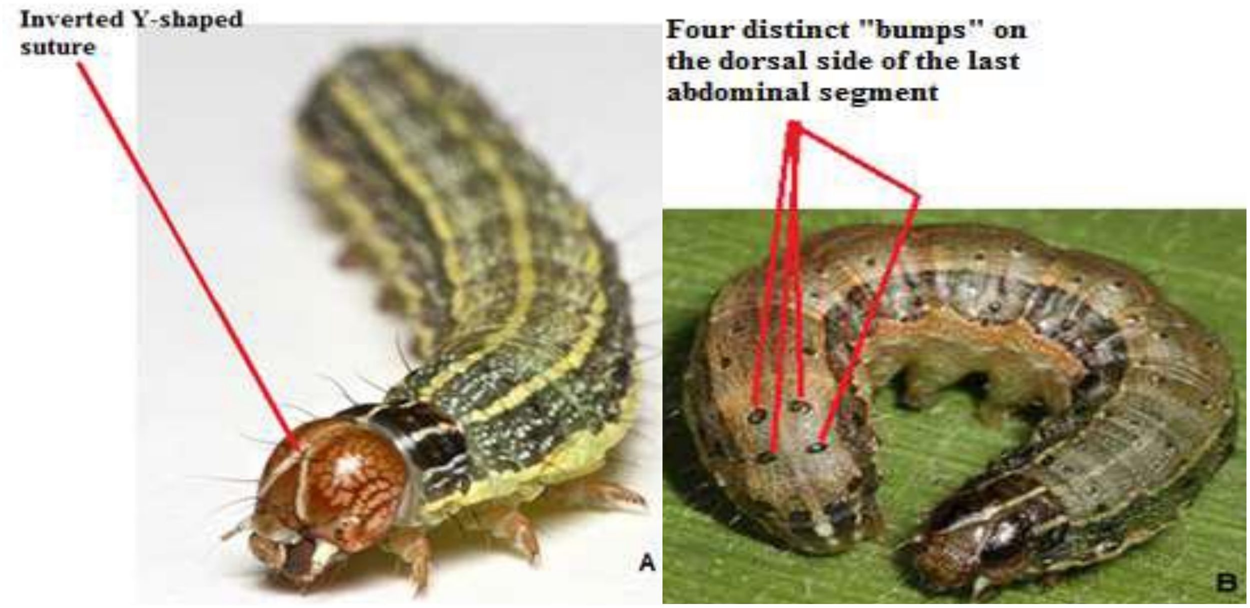

Plate 2. A - Mature fall armyworm larva showing the characteristic white inverted Y-shaped suture on the front of the head, B – Four characteristic bumps on the last abdominal segment of a fall armyworm larva

Each of the other body segments also has four spots, but they do not form a square pattern (yellow circles) rather it forms “trapezoid” pattern. Although other caterpillars can also show an inverted Y-shaped suture on the front of the head this is usually a similar colour to the rest of the head.

Identification based on adult moth morphology

Main distinguishing morphological features of adult *S. frugiperda* moth from other common caterpillars encountered in Africa is forewing of the male moth generally has shades of grey and brown, with triangular white spots at the tip and near its centre (Plate 3A, B).

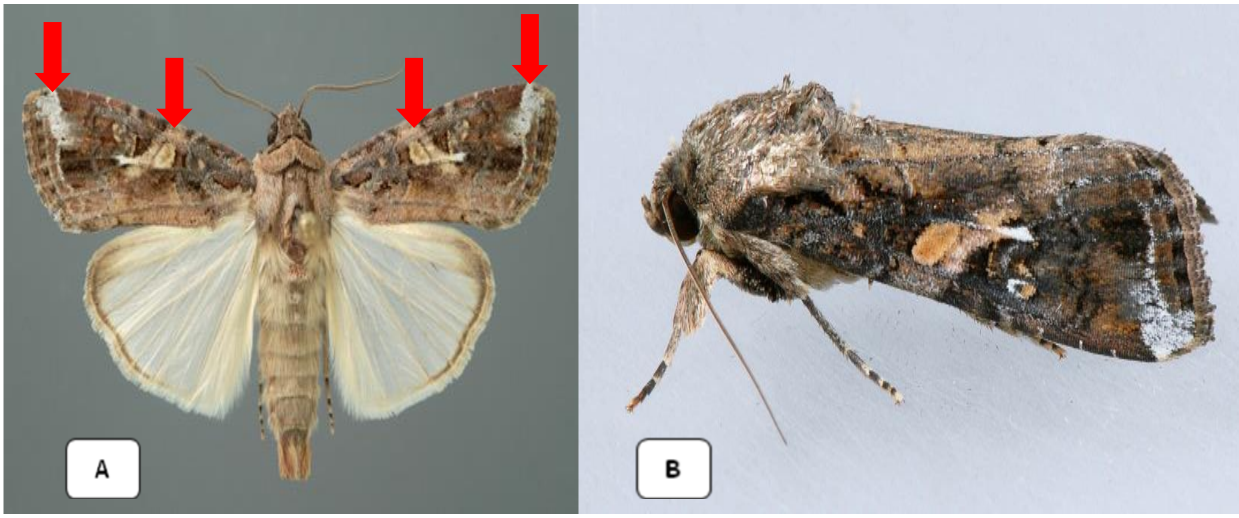

Plate 3. *S. frugiperda* male moth with wing deployed (A) and at rest (B)

Indirect identification through characteristic injury symptoms

While crop injury symptoms can also be used to provide preliminary indications of the presence of the fall armyworm, an inexperienced scout can easily misidentify the cause of "windowpanes", whorl and tassel damage, and cob-boring on maize to be fall armyworm when in fact the pest will be a stem-borer. Thus, only examination of live larval specimens can confirm pest species identity during surveys or field scouting activities. However, there are some characteristic differences in damage and feeding behaviour in maize which an experienced scout can use to provide rapid pest diagnosis. For the Fall Armyworm, its cannibalistic behaviour, generally only one larva is found feeding on a single plant. This is in contrast to stem-borers such as *Busseola fusca* (African maize stem-borer) or *Chilo partellus* (spotted stem-borer) where several medium to large-sized larvae can be found feeding together on unfurled whorl leaves and developing tassels. Early feeding by FAW can appear to be similar to other stem borers but leaf damage by FAW is usually characterized by ragged feeding, torn and moist sawdust-like frass (Plate 4A) near the whorl and upper leaves of the plant unlike stem borer feeding which often produces a characteristic rows of holes on the leaves (Plate 4B).Though *S. frugiperda* larvae can burrow deep into the whorls of maize plants, they do not tunnel into stems. *Spodoptera frugiperda* produces copious amounts of yellowish-brown frass during feeding. This frass is aggregated in the form of "balls" (Plate 5A). In contrast, the frass produced by the stem-borers tends to be loosely aggregated, often sticking to the plant at the larval entry hole into the stem or cob (Plate 5B).

Plate 4. Characteristic leaves feeding due to FAW larva (A) and stem borer larvae (B)

Plate 5. Characteristic frass produced by FAW larva (A) and by stem-borer larvae (B)

Farmers can easily recognize the pest (caterpillar) presence by checking damage (windows caused by young worms, and plant shredding by large worms), mass of frass on the plant (saw dust like substance when worms are small; large brown pellets at 5^{th} and 6^{th} instar); and presence of the worm (baby bluish and green when small; dark green 3rd and 4th; brownish at 5^{th} and 6^{th} instar). Farmers can easily differentiate this pest with stalk borers because the FAW does not bore into the stem and stay there; they bore, get in and continue to come out while at the same time shredding the plant haphazardly. In contrast, stalk borers have less frass on the maize and once they bore on the stem, they remain in. In comparisons to cutworms; the cutworms are serious on young crop and would cut it on the ground level. They will be found during the day on the ground underneath the cut seedling. The FAW targets above ground parts mainly the foliage and reproductive structures.

Host range and Strains of FAW

Host range of FAW

FAW is migratory, polyphagous and noctuid moth which attacks a wide variety of crops. Although FAW is highly polyphagous with a host range of about 100 plant species, it prefers to feed on gramineous plants in particular on economically important crops such as maize, millet, sorghum, rice, wheat, and sugar cane (Plate 6). Other crops of major agricultural importance attacked by the pest include cowpea, peanuts, potato, soybean and cotton (Plate 6). It also feeds on Bermuda grass and grass weeds such as crabgrass and *Digitaria* spp. Other field crops that are frequently injured by FAW include alfalfa, barley, clover, oat, ryegrass, sugar beet, Sudan grass and tobacco (Knipling 1980, Pashley 1986). In maize FAW feeds on leaves, leaf whorl, tassel and silk, they also burrow into the ear and feed on kernels like that of corn earworm, *Helicoverpa zea* (Boddie). But, unlike corn earworm, fall armyworm will feed by burrowing through the husk on the side of the ear. Larvae of FAW seem to be much more damaging to maize than most other African *Spodoptera* species having developed comparatively strong serrated cutting edges of mandibles as a way of overcoming high silica.

Plate 6. Major preferred host of FAW

Host-adapted Strains of FAW

Spodoptera frugiperda host strains was first named and identified by Pashley (1986). There is some evidence that two strains of the *S. frugiperda* exist, based primarily on their host plant preference. The two strains are morphologically indistinguishable. Can only be identified by a small number of genetic markers. The two genetic markers used for population studies are

Mitochondria marker *CO1*and Nuclear marker *Tpi* (Pashley, 1986). Based on genetic studies and field observations in a number of countries in the Americas, *S. frugiperda* is reported to have differentiated into a maize and rice strain. While the maize-adapted strain seems to be more abundant in maize, cotton, sorghum, sugarcane and sweet sorghum, the rice-adapted strain feeds principally on rice, Bermuda grass/Couch grass (*Cynodon dactylon*) and Johnson grass. The only reported strain differences include pheromones, mating behaviors, reproductive incompatibilities and resistance traits. Despite these differences, the strains are really hard to tell apart. Females of the rice strain readily mate with maize strain males giving rise to mixed populations. On the other hand, maize strain females and rice strain males appear to be reproductively incompatible.

The existence of *S. frugiperda* as distinct strains has implications on pest management strategies in the pest's now-expanded geographical range. Studies conducted in the Americas have shown that resultant populations arising from the two strains differ significantly not only in their biology and behaviour but also in their tolerance to insecticides and *Bacillus thuringiensis* transgenic crop varieties. Thus, in newly-invaded regions (Africa and elsewhere), more cost-effective and sustainable strategies to manage fall armyworm could be developed if the strain being targeted and its insecticide susceptibility status from the Americas is already known.

Current Status and Distribution of FAW in Ethiopia

Regarding the fall armyworm situation in Ethiopia, it was a team of experts from Mizan Plant Health Clinic who first intercepted the insect from South Western Ethiopia in March 2017 in Yeki woreda, Sheka zone in SNNPR. Since its first report, the insect has been spreading to new areas in SNNPR, Gambella, Oromiya, Amahara, Benishangul Gumz and Tigray regions (Figure 5). The most recent report showed that the insect has reached Afar region. Severer infestations were reported from all regions mentioned above. In Somali region the presence of FAW has not yet officially reported. Currently it has been reported in 411 woredas from across the country. FAW's presence in Ethiopia is irreversible. Large-scale eradication efforts are neither appropriate nor feasible. Gathering and analyzing experiences and best practices from the Americas will help design and test a sustainable FAW management program for smallholders in Ethiopia.

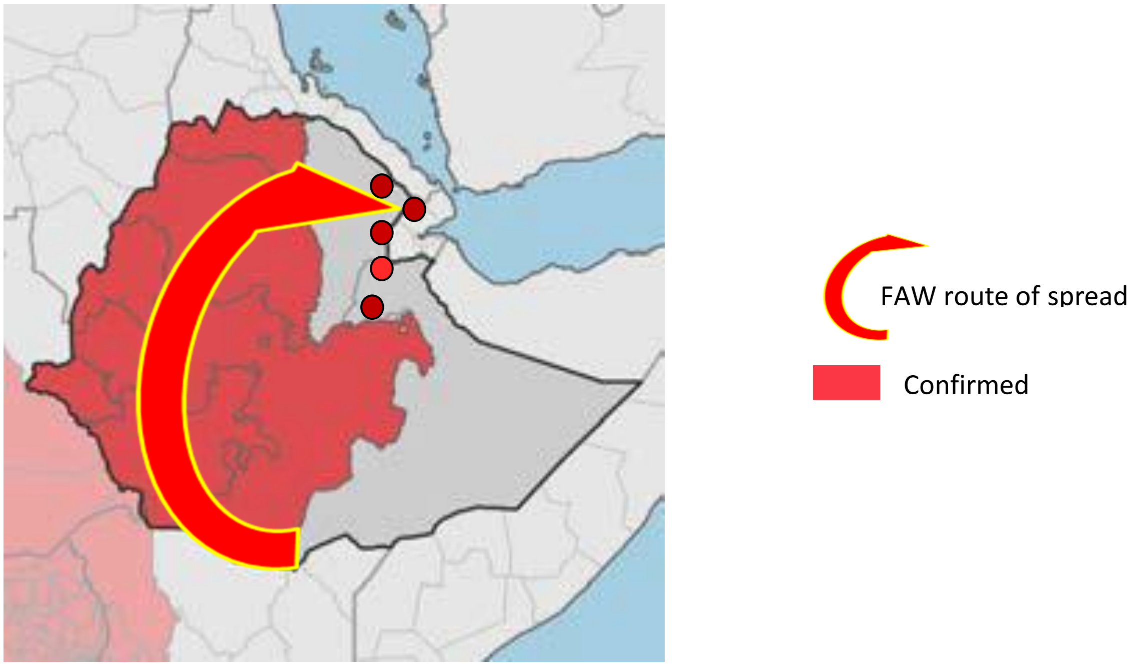

Fig. 5. Current Distribution of FAW in Ethiopia

The Present and Possible Impact of FAW

Although it is too early to know the long-term impact of FAW on agricultural production and food security in Ethiopia, it has the potential to cause serious damage and yield losses.

Prevalence: Currently out of 2.1M ha of land under maize cultivation 22.23% (650,000 ha) of the total maize planted to date (irrigation, belg and meher) has been infested with FAW and infestation levels fluctuate as crop is planted (and reinfested). Need continuously updated data on infestation levels. Using the available resources and human capacity out of this area, it was possible to spray only on 38.75% with insecticides. The cultural control of FAW by handpicking and killing accounted for 53.50% of the total FAW infested area to date. The area where it was not possible to take control measure on about 8% (46522.94) of the total infested area, which is about eightfold of the total area planted in Rwanda every year. Such a country wide intervention within a short period took place because of the significant engagement and participation of farmers in using cultural control measures, mainly handpicking and killing. Farmers' engagement was the due to efforts made to increase awareness on the invasiveness of the FAW and its possible impact on maize and other cereals production. Despite the increased efforts to contain the spread and damage of FAW, reinvasion has occurred in most of the places it was observed earlier. . As a result, there is a fear that the population of the insect may be high enough to cause serious damage during the following off season.

Impact: Data on impact of the infestation (e.g. yield loss) not available, yield loss assessment is underway for harvest that occurred over the last main season. Estimates range 15-30% yield loss (in SNNPR) and 5-20% (in Oromia region), with variability from plot to plot. The damage in some farms visited in Bench-Maji reached 100% but through intervention using insecticides (Malathion, Diazinon and Chlorpyriphos) the crops have recovered. Other possible impacts include; Losses to maize seed production fields, Regional and international trade (So far FAW has not caused measurable problems with trade but this is another potential loss, as FAW is a quarantine pest in Europe) and Environmental and human health impacts of synthetic/chemical pesticides.

Impacts of FAW were estimated for 12 major maize-producing countries in Africa by extrapolating estimates of proportion of yield loss and combining this with published data on national maize production and other information. The 12 countries included are major producers of maize in Africa (in terms of metric tonnes/year): Ghana, Zambia, Benin, Cameroon, Democratic Republic of Congo, Ethiopia, Malawi, Mozambique, Nigeria, Uganda, Tanzania, and Zimbabwe. The total estimated national yield and revenue losses for each of the 12 countries, are summarized in Table 1. Losses are related to total expected maize production and value in each country. Among other countries the estimates for Ethiopia indicate that without use of control options, the potential impact of FAW on country wide maize yield lies between 1.23 and 3.1 million tonnes per year of total expected production of 7 million tonnes per year and with losses lying between US$ 292.6 and US$728.3 million per year of total expected value of US$ 1,580.2 million per year (CABI, 2017b).

Table 1. Expected maize production and estimated lower and upper yield and economic losses in the top maize-producing countries included in the study

Country	Maize production (three-year mean) (thousand tonnes)	Value of maize (three-year average FAO stats) US$ million	Yield loss (lower) (thousand tonnes)	Yield loss (upper) (thousand tonnes)	Mean yield loss (thousand tonnes)	Economic loss (lower) (US$ million)	Economic loss (upper) (US$ million)
Benin	1,285.3	376.5	295.6	735.8	530.4	86.6	215.6
Cameroon	1,665.7	697.8	319.2	794.4	687.4	133.7	332.8
Democratic Republic of Congo	1,173.4	343.7	254.5	633.4	484.2	74.5	185.5
Ethiopia	6,628.3	1,580.2	1,227.2	3,054.7	2,735.2	292.6	728.3
Ghana	1,825.5	629.8	401.6	1,213.9	824.3	138.5	418.8
Malawi	3,344.9	979.7	769.3	1,915.0	1,380.3	225.3	561.0
Mozambique	1,247.2	365.3	99.7	239.2	514.7	35.0	84.1
Nigeria	9,302.7	3,271.8	2,129.1	5,299.7	3,838.9	748.7	1,863.6
Uganda	2,748.3	805.0	558.9	1,391.1	1,134.1	163.7	407.5
Tanzania	5,732.6	1,679.1	1,301.3	3,239.0	2,365.6	381.2	948.8
Zambia	2,913.0	500.9	728.1	1,456.1	1,154.0	125.2	250.4
Zimbabwe	1,104.1	360.7	234.8	584.4	455.6	76.7	190.9
Total	**38,971**	**11,590.5**	**8,319.3**	**20,556.7**	**16,104.7**	**2,481.7**	**6,187.3**

Source: CABI September 2017

Efforts made so far to address the FAW

Following its arrival in Ethiopia, the MoANR, EIAR, regional BoANR and other partner institutions have been making multifaceted efforts to curtail the damage by FAW where a number of preparatory activities and control measures were taken. Some of the accomplished tasks were review of global information sources on the FAW, establishing technical committee, developing different awareness creation materials, organized training of trainers program for federal and regional stakeholders that was extended to within regions, woredas and kebeles; producing emergency action plan, which included training provision, wider awareness creation using different communication media, distribution of technical leaflets and posters in different local languages, mobilization of resources (finance, vehicles and insecticides); human and material resources were galvanized from different national and non-governmental institutions including regional BoANR, EIAR, Hawassa University, DLCOEA, FAO, CIMMYT, SG2000, ICIPE, USAID, and CABI. Additional undertaken tasks are nationwide coordinated survey and exchange of FAW current distribution, damage and management; formulation of research agendas by EIAR and FAW policy areas; involvement of graduate students to research on the biology and ecology and management of the FAW; fast track testing of management options including insecticides, sex pheromone traps, biorationals, botanicals and cultural methods are being underway. Result of data collected so far from evaluation of different pheromones indicated that FAW lure II and IV from India and Xlure-FAW pheromone from UK had *Spodoptera frugiperda* specific with a very few non-target capture rate which makes them useful for development of monitoring and IPM programs in Ethiopia. Result of data collected from screening of different insecticides indicated that Coragen 200 SC (Chlorantraniliprole) and BELT 480 SC (Flubendiamide) have been the most effective against FAW. The results obtained from evaluation of different Russel IPM biorational products revealed the potency of the technology; Biotrine *(Abamectin 5%),* Antario *(Bacillus thuringiensis kurstaki and abamectin 0.1%),* Recharge *(Metarhizium anisopliae) and* Fhytomax PM (0.1% Azadirachtin) against fall armyworm. This scientific outcome therefore recommends the use of the technology but emphasis on timely and appropriate spraying techniques, proper inspection, scouting and field identification of early larva instars and plant damage symptoms are put forward for sustainable management of the pest. Even as we respond to FAW, it should be noted that the other pest challenges exist, and a holistic management system shall be needed for sustainable growing of maize.

Key Messages

The recent detection of FAW in Ethiopia presents a very serious threat which requires country wide collaboration in the search for a sustainable management strategy. The pest is unfortunately likely to stay for a long time in Ethiopia due to highly conducive conditions and has the potential to cause significant maize yield losses in the absence of any control methods. FAW attacks maize plant from seedling to seed. With the current fragility of the country's crop production and food security systems, the fall armyworm could have a multiplier effect on the already precarious situation.

The country's largely tropical climate and year-round cultivation of maize plants offers ample opportunities for its further spread into Eastern parts of the country. The high levels of infestation so far noticed on maize poses a major control challenge particularly in those parts of the country where maize is the staple crop. So much needs to be studied about the pest now that it has become endemic in Ethiopia where the need to migrate long distances may not be necessary given the ready availability of a mosaic of crops of varying phenologies and economic values. The invasiveness and damaging potential of the fall armyworm as well as transboundary migrations therefore highlight the need for a coordinated national approach in building capacities to deal with the pest menace.

Way Forward

Control of FAW requires an integrated pest management (IPM) approach.

Immediate recommendations include (i) awareness raising campaigns and capacity building on FAW symptoms, identification, early detection and control, including beneficial agronomic and other cultural practices; (ii) national preparation and communication of a list of recommended, regulated pesticides and biopesticides and their appropriate application methods (when/when not, and how to apply chemical control). Work should also start immediately to (i) breed crop varieties for resistance or tolerance to FAW; (ii) introduce classical biological control agents from the Americas. A conducive policy environment should promote lower risk control options through short term subsidies and rapid assessment and registration of biopesticides and biological control products.

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Agricultural Production Constraint Analysis in the Selected Districts of West Shoa, East and Horro Guduru Wollega Zones

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Abstract

There is an increasing call for identification of agricultural production and productivity constraints and analysis that provide insight into the complex and interrelated nature of agricultural production constraints and that leads to points of interventions to solve these constrains by different agents; so that, production and productivity can be enhanced. Having the above felt needs this study purposively identified two districts from East Wollega Zone and one district each from Horro Guduru Wollega and West Shewa depending on the concept of representativeness for each Zone agricultural production system complex in line with Agricultural Growth Program II (AGP-II) project objectives and districts. PRA tools which were aimed to improve active participation of farmers in problem identification and prioritization, close interaction between researchers and farmers, the potential usefulness of farmers' to contribute more directly and creatively to the design and evaluation of new technologies was employed for the study. Accordingly, first high price of inputs, low price of crop produce, crop diseases, termite attack were among the prioritized constraint regarding crop production. Second, shortage of grazing land, livestock diseases, low supply of improved breeds, high price of improved breeds, low supply of improved forage in number and kind were major constraints that decreases livestock and livestock products production and productivity. Third, soil erosion, deforestation, termite attack, land slide were among identified constraints that decreases benefits obtained from natural resources. Therefore; any interventions in terms of development works aimed to decrease or alleviate these problems in all sectors and more explanatory researches are recommended for respective study areas as well as for areas with similar farming system characteristics.

***Key words**: Community level participatory planning (CLPP), Participatory Research Approach (PRA)*

Introduction

Understanding farmers' socio-economic situation, their environments and agricultural production constraints and opportunities are prerequisites to implement any kind of research and development intervention. As elsewhere in developing countries, many forms of agricultural production co-exist in all regions of Ethiopia (Notenbaert *et al*., 2009). Some geographical areas are endowed with agro-ecological conditions suitable for rain-fed cropping, while in others agricultural activities are limited to irrigation or grazing. Some districts have a well-developed road infrastructure, whilst others have limited access to road services and markets. Understanding of such conditions offers a basis for designing and implementing pro-active, more focused and sustainable development that could bring impact on food security and poverty reduction through enhanced agricultural productivity (Notenbaert *et al*., 2009).

A total of 10 AGP-II supported districts are found in East Wollega and Horro Guduru Wollega and in 1 district of West Shewa zones Bako Agricultural Research Center (BARC) are mandated. They are highly potential for increasing production and productivity of crops, natural resource and livestock. There are three Oromia Agricultural Research Institute (IQQO) research centers in these zones (Bako Agricultural Research Center, Bako Agricultural Engineering Research Center and Nekemt Soil Research Center), mandated to address the respective disciplines. Bako agricultural research center is the nuclear center for major AGP crops such as maize, teff, wheat, sorghum, sesame and potato in the region.

Therefore, the aim of the present study was to assess agricultural production systems and its constraints in selected AGP-II districts of West Shewa, Horro Guduru Wollega and East Wollega zones using participatory rural appraisal (PRA) tools in combination with the data collected through community level participatory planning (CLPP). The study will provide sufficient information on priority constraints and opportunities for agricultural development, socio-economic and livelihood related issues in order for designing efficient research and development interventions by various research institutions, development entities and other stakeholders

Methodology

Description of the study area

Agricultural production constraint assessment was conducted in four purposively selected representative districts namely; Bako Tibe, Horro, Guto Gida and Gida Ayana. Selection criteria was mainly targeting agro-ecological diversity, representativeness in terms of agricultural production particularly to address the major AGP commodities of crops and livestock production potential.

Guto Gida and Gida Ayana are located in East Wollega Zone. This zone is found in the coordinate ranging from $8^0$31’20" N - $10^0$22'30"N and $36^0$06'00" E - $37^0$12'00" E and the total area of the zone is about 14,102.50 km^2.

Gidda Ayana is the largest district in the zone accounting for 10.61% of the total area. The district has around 22 rural Kebeles; where 12 located in the midland agro-ecology, 8 in the lowland and 2 in highland areas. It has variable climatic condition situated at an elevation between 800-2195m.a.s.l. and receives an annual rainfall of 900-1400mm.

Horro is one among the districts of Horro Guduru Wollega zone. The total area of the zone is around 7867.6 km^2. About 68% of the total area in the district (15 kebeles) is categorized under midland agroecology and 32% is highland covering about 7 kebeles. The altitude ranges from 2350-2998masl and annual rainfall of about 787-1794mm.

Bako Tibe district was selected from West Shewa zone. The zone is found between 8^0 17" - 9^0 60"N and 37^0 17"- 38^0 45'E. The altitude range of the district is from 1500-2650masl. It received annual rain fall of 1000-2000mm and annually an average temperature was 23^0c in the year 2015. Only two kebeles fall in the high altitude area, 10 mid and 14 is in lowland area.

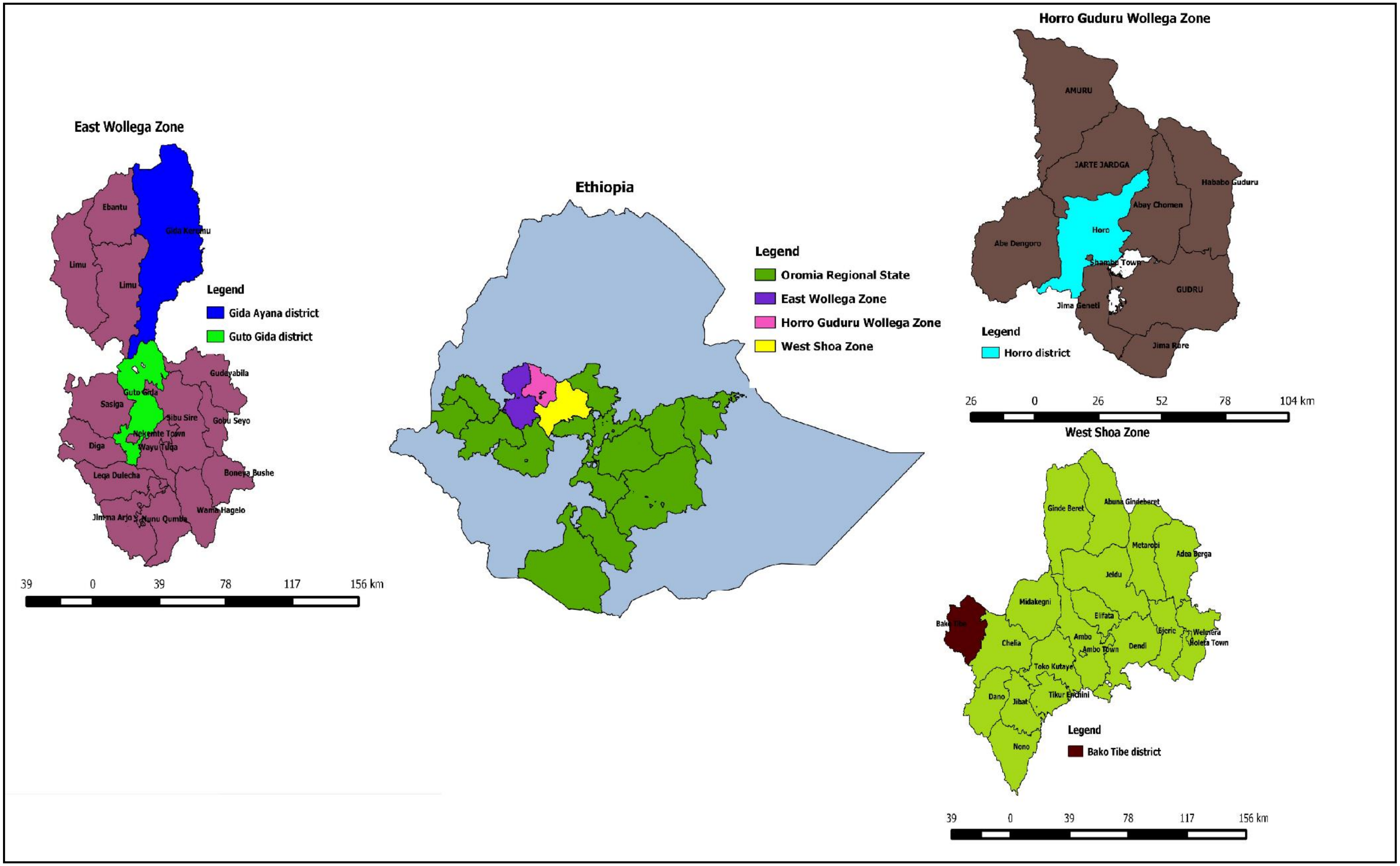

Figure 1. Map of the study areas

Data collection and analysis

This study largely used secondary data collected from different respective government organizations residing in the target AGP-II zones and districts, while the primary data were collected from a group of key informants. Primary data were collected from 10-15 representative key informants selected from the smallest administrative structure (Kebele) including administrators, DAs, elders, Women and Youths from each agro-ecologies (lowland, mid and highland). The selections of these groups of residents were purposively made to consider appropriate representatives, who can express the real situation in their agro-ecology on crop and livestock production, natural resources related issues, and identify production constraints.

Secondary data were also collected from the selected AGP-II zones and districts office of Agricultural and natural resource management, livestock and fishery development offices and farmers training center (FTC) of the existing agro-ecologies. Data collected using this PRA techniques were analyzed by qualitative assessment tools namely tabulation, conceptualization and narration. On the other hand, percentages and tabulations were used to describe quantitative data collected from secondary sources.

Result and discussion

Secondary data analysis result

The demography and natural resources available in the districts

According to the data collected in 2014, the total population of Gida Ayana district was 162,985. Among those, 85042 was male and 77943 was female (table 1). The district is endowed with numerous perennial rivers such as Warabessa, Mito and Jawaro and streams like Wasarbe, Laga Kabade and Burka Ketta. Among those, Warabessa river is used for fishing in addition to irrigation practices. One natural lake known as Haro with length of about 100m and depth of one meter is also used for fishing. Sandy loam is the major soil type found in all agro-ecologies of the district.

The total population of Guto Gida district was 117,581 as per the data collected in 2014. Among those, 59,855 was male and 57,726 was female. Guto Gida is characterized by different landforms including flat land (69.6%), undulated (4.47%), mountain (3.09%), hilly (7.24%) and the remaining landforms accounts for 15.6%. Currently; 67,283.93 ha of land is used for crop cultivation, where 63,489.93 ha is under annual crop production, 3,794 ha is used for perennial crop cultivation while the remaining is covered by pastures/grazing land, degraded/barren and forest areas. The Forest of the district is categorized as natural forest (61% or 3007.75ha), man-made forest (28% or 1391.5ha) and Shrub land (11% or 524 ha). The major soil type found in the district is loam soil (42.80 % of the total land) followed by Sandy soil (23.09%), Clay loam (16.32%), Silt (9.7%) and Clay (8.08%). The major perennial rivers include Laga Harre, Ukke and Loko. Two artificial lakes known as Sorga and Ukke also found in the district. Urban and rural population of the district uses tap water, spring, river, well and pond water for drinking.

In Horro District, the assessment result indicated that majority of the population is residing in midland altitude areas. The landscape is characterized by undulated land features to east, south east and north of Chabir where the altitude is peak in the district. The land is relatively plain to west of Chabir especially around Sekela. The common soil types include sandy soil, clay, clay-loam and silt. The district is bordering to manmade Lake Choman, which is the base for Fincha hydroelectric power and Fincha sugar factory and lake Nashe which is the source of hydroelectric power of Amart-Nashe. Beside those lakes, there are several year round rivers in the district used for irrigation, fishing and source of drinking water for human and livestock. Because of deforestation and climate change, the rainy season gradually declined from 6 month that lasts from May to December to the present erratic 3 months rainy season which lasts from June to September. The land use classified as potential arable land, cultivable land, pasture land, forest and swampy land and others like for construction purposes (Table 2).

In Bako Tibe district, majority of populations and kebeles are found in the lowland areas (relative term), 10 in midland, while only two kebeles are categorized under high land agro-ecologies. The northern high and midland part of the district is characterized by undulated features mainly dominated by mountainous and gorges; whereas the southern part of the districts characterized by flat landscape mainly in the Gibe Valley. Like other districts, rainy season is decreasing from 6 months to three months, mainly attributed to climate change and natural resource degradation. In this district, the land is divided among the following land use categories: potential arable land, cultivable land, pasture land, forest land, area closures and swampy land and others like for construction proposes (table 2).

The common soil types include sandy soil, loam and clay but sandy soil covers the lion share (about 60%). Gibe River is the major river flowing in the west part of the district bordering the district as well as West Shewa Zone with East Wollega Zone. Similarly, numerous streams like Abuko, Lega Kela, Lega Robi and some other year round Gibe river tributaries are also found in the district.

Table 3. Population of respective study areas for the year 2014

Districts	**Rural**			**Urban**			**Total**		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**
G/Ayana	55,561	50,608	106,169	29,481	27,335	56,816	85,042	77,943	162,985
G/Gida	56,535	54,419	110,954	3320	3307	6627	59,855	57,726	117,581
Horro	44,243	43,774	88,017	2,560	2,553	5,112	46,803	46,327	93,130

Table 4. Different Land Use Patterns of Bako Tibe and Horro District for the Year 2016

Land Use type	Bako Tibe		Horro	
	Size(ha)	%	Size(ha)	%
Potential arable land	3377	6.52	21000	28.73
Cultivable land	32079	61.94	32984	45.12
Pasture land/grazing land	2798	5.40	14498	19.83
Forest land	2355	4.55	2968	4.06
Area closer	3584	6.92	-	-
swampy land	4387.7	8.47	500	0.69
Others(construction)	3213.3	6.20	1150	1.57
Total	51794	100	73100	100

Source: Bako Tibe and Horro district office of Agriculture and natural resource, 2016

Agricultural Land holding of the study areas

Land is the major resource for agricultural production. Land holding size per household is shrinking from year to year. Cultivable land per capita was reduced globally; 0.45ha in 1966, 0.25 ha in 1998 and projected to be 0.15ha in 2050 (reduced by 40%) (FAO, 2013). The majority of land holding size of the household in the study districts ranges from 1-2ha (Table 3).

Table 5. Agricultural Land holding distribution of study districts

Land holding amount	Number of farmers owning specified amount of land per districts		
	Gida Ayana	Guto Gida	Bako Tibe
<0.5 hectares	433	704	0
0.5-1 hectares	1811	1641	2174
1 - 2 hectares	5773	6438	11860
2 - 5 hectares	4985	5925	3963
> 5 hectares	1444	0	5

Source: Respective Agriculture and natural resource Office, 2016, NA=data not available

Crop production

Major crop types grown

Crop cultivation has been the main livelihood of the communities in the study districts adopted from their ancestors, and mainly characterized by unimodal growing season or rainfall type. The major crops grown from mid to highlands of the study areas includes teff, maize, sorghum, wheat, barley, finger millet, faba bean, noug, potato, cabbage, onion and garlic. However, popular crops in the low -to-mid altitudes includes maize, sorghum, finger millet, teff, groundnut, haricot bean, soy bean, sesame, noug, potato, pepper, tomato, mango, coffee, banana and sugarcane.

The area allocated, production and productivity of each crop varies from district to district and from season to season (Table 4). Variability between crops are dependent on ecological suitability, but the variation in productivity of a given crop in the same location but different season mainly indicated the inconsistence in environmental and other climatic factors. For instance, the two years (2013 & 2014) data indicated that area coverage and productivity of all crops showed an increment in Gida Ayana district, but tremendously decreasing in Guto Gida district except for wheat and maize (Table 4).

Table 6. Area coverage, production and productivity of major crops grown in the study districts

District	Prod year	Area coverage	Sorghum	Maize	Teff	Wheat	Barley	F. Millet	F. bean	F. pea	Sesame	G. nut
Gida Ayana	2013 G.C	Area (ha.)	3,652	11,301	8,352	774	376	5,123	722	208	1,612	1,342
		Prod. (qt.)	85,822	712,159	70,992	12,376	6,768	87,291	8,303	1,456	8,060	7,8182
	2014 G.C	Area (ha.)	3,864	-	9,855	1,167	582	5,402	768	172	1,768	1,436
		Pron. (qt.)	91,140	-	100,720	19,972	10,368	97,773	9,990.8	1,440	10,254	30,742
Guto Gida	2013 G.C	Area (ha.)	6,172	7,376	4,502	187	177	2,175	165	118	3,052	1,735
		Prod. (qt.)	164,246	379,454	31,709	3,140	2,786	30,489	2,038	1,133	15,358	20,725
	2014 G.C	Area (ha.)	4,171	13,470.5	4,075	195	165	1,732	118	35	1,558	1,735
		Prod. (qt.)	113,917	795,711	28,648	3,455	2,545	20,760	1,172	352.5	5,128	20,956
Horro	2013 G.C	Area (ha.)	-	6,398	6,156	6,999	5,888	-	2,697	1,729	385	-
		Prod. (qt.)	-	320,144	86,953	174,962	159,979	-	28,638	12,604	3,830	-
	2014 G.C	Area (ha.)	-	4,500	6,150	8,329	9,592	-	3,143	1,980	-	-
		Prod. (qt.)	-	273,330	125,891	421,198	263,205	-	29,638	28,472	-	-
Average area (ha)			4,464.8	8,609.1	6,515.0	2,941.8	2,796.7	3,608.0	1,268.8	707.0	1,675.0	1,562.0
Average production (Qt)			113,781.3	496,159.6	74,152.2	105,850.5	74,275.2	59,078.3	13,296.6	7,576.3	8,526.0	25,100.8
Average productivity (Qt/ha)			25.5	57.6	11.4	36.0	26.6	16.4	10.5	10.7	5.1	16.1

Source: Respective Agriculture and natural resource development districts offices, 2016

Although there is very high potential for irrigation water and larger irrigable land in the study area, modern and traditional irrigation is almost negligible. Accordingly, rain fed cultivation took the widest area coverage and highest production when compared with traditional and improved irrigation system during the last five years (Table 5). Tomato, potato, hot pepper, sugarcane, banana, maize and other vegetables are some of the major crops grown under the limited irrigation practices. Residual moisture (bone) was also used to grow maize on very limited areas in few districts.

Table 7. Cultivated land (ha) of study districts during the last five years

Districts	Cultivation season	2011	2012	2013	2014	2015
Guto Gida	rain fed	28,922.5	29,979	30,037	29,990	30,047.5
	modern irrigation	259	440	1,785	1,475	1,945
	traditional irrigation	2,043.5	1,778	4,372	5,027	5,470
Gida Ayana	rain fed	40,629	41,252	44,271	42,768	44,254
	modern irrigation	536	917	1,046	2,139	3,011
	traditional irrigation	610	1,385	3,616	5,738	1,157
Bako Tibe	rain fed	27,885	27,885	27,710	27,710	28,138

Source: Respective district Agriculture and natural resource development offices, 2016

Natural resource management

Vegetation and Soils

According to the data collected from bureau of agricultural and natural resource management of the respective districts, about 47,842 hectares of land is covered by dense forest in Gida Ayana district in addition to the considerable coverage of shrub and bush land and manmade forest. Guto Gida district has a delineated natural and manmade forest on estimated area coverage of 4923.25 hectares of land. However, the natural forest owned by the district is currently under the risk condition of deforestations and environmental degradation thus needs due attention in order to save for future ecological balance of the surrounding. Horro and Bako Tibe districts are gifted with natural forests covering 30,837.24 and 2,355 hectares of land, respectively.

The soils of Guto Gida is characterized by clay loam soil (16.33%), sandy soil ((23.09%) and dominated by the agriculturally potential soil type or loam soil (42.80%). Types of soils commonly found in Gida Ayana district include diystric nitosoils, humic cambisoles and orthic cambisoils. In the district dystric nitosoils cover highest proportion land coverage and have good agricultural potential and high water retention capacity, but the humic camisoles and orthic cambisoils types of soils found on steep slopes, as a result they have limited agricultural potentiality. Bako Tibe district is characterized by having 24%, 16% and 60% coverage of the total district by clay, loam and sandy soils, respectively. Horro district is characterized by having sandy, clay, clay-loam, silt, and sandy-clay and silt-clay soil types.

Livestock production

Livestock Population and their Species

The present study revealed that all districts are dominated by indigenous livestock breeds while very few crossbred cattles are found in all districts. Improved poultry breed and modern honey bee hive technologies are behind the demand in the areas. Horro district had the highest population of all livestock species followed by Gida Ayana and Bako Tibe districts. Guto Gida district has been producing more numbers and species of local chicken probably due to access to market being in the vicinity of the zonal town, Nekemte. Beekeeping has been practiced using three types of bee hives in all districts of the study sites (Table 6).

Table 8. Livestock Type and Population of the study districts

Livestock types	Gida Ayana	Guto Gida	Horro	Bako Tibe
Cattle	169,746(366*)	93,863(239*)	206,960(354*)	140,837(543*)
Sheep	45,132	16,590 (44*)	57,490	13,006
Goat	28,212	12870	33,249	14,785
Donkey	14,421	8499	14,421	8,753
Horse	NA	620	20,480	3,795
Mule	519	401	1,687	1,054
Chicken	82,212	124,335(11882*)	76,476	10,2594
Honey bee colony (total)	67,592	65,682	29,338	25,437
Traditional hives	64,172	57,507	25,072	24,000
Transitional hives	2,059	6,160	3,472	1318
Modern hives	1,359	2,015	794	118

*Source: Office of livestock and fisher of each district 2016, *Crossbred or improved breed*

Primary data analysis

Crop production

Cropping system

Maize mono cropping is predominantly practiced in the maize belt areas of Guto Gida, Bako Tibe and Gida Ayana districts. Only few farmers practice crop rotation of maize with other crops biennially. In the high land areas of those districts, rotation of maize and other cereals to pulses and horticultural crops are practiced. Farmers also replied that growing of teff, wheat or maize on the same land for two years in the highland areas are rarely practiced. By its nature, under rain fed condition, potato is produced around homestead year after year.

Cereal-pulse crop rotation is commonly practiced in Horro district. Few farmers practiced double cropping of two row barley (“samareta”) type after harvesting of potato. Besides, intercropping of maize with bean and pea is rarely practiced. Other cropping patterns such as fallowing, intercropping, shifting cultivation, alley cropping and others practices are not common in these districts. Generally, cropping pattern is largely dependent on agro-climatic zones; land availability; economic and dietary importance of the crop and farmers knowledge.

Crop management

Fertilizer application and source of fertilizer

Although there is knowledge gap in using appropriate rate, type and time of application, key informants across all district are well aware of the importance of inorganic fertilizer such as Diamonium phosphate (DAP) and Urea. The study indicated that the main supplier of fertilizer for farmers is the district Agriculture and natural resource development office, farmer's cooperatives and unions. Application of Organic fertilizer particularly compost is practiced by few farmers in the study areas.

Since recent years, application of DAP fertilizer is reduced and gradually to be replaced by a blended fertilizers. DAP is applied at sowing and UREA is applied by splitting. However, split application time of urea is not uniform among farmers and also doesn't follow research recommendations across all study districts. The amount of Inorganic fertilizer distributed in Bako Tibe and Gida Ayana districts for the last five years were relatively higher than Horro and Guto Gida districts (Fig 2). This might be due to the difference knowledge among farmers in adopting inorganic fertilizer, or variation in level of soil fertility or else other reason.

Applications of fertilizer to crops are variable from place to place. Farmers commonly used fertilizer for maize, teff and wheat in both mid and highland, but only for maize and sesame in lowland areas and irregularly for other crop types (Table 7). According to the key informants, higher quantity of fertilizer is applied for hot pepper (160/240 Kgha^{-1} DAP/Urea), onion and garlic (200/200 Kg ha^{-1} DAP/Urea) and for potato (160 Kg ha^{-1} DAP). The rate of application in Horro district is relatively lower than other districts and this might be due to the better soil fertility condition of the district. Use of bio-fertilizer for faba bean was also started on few farmers' fields.

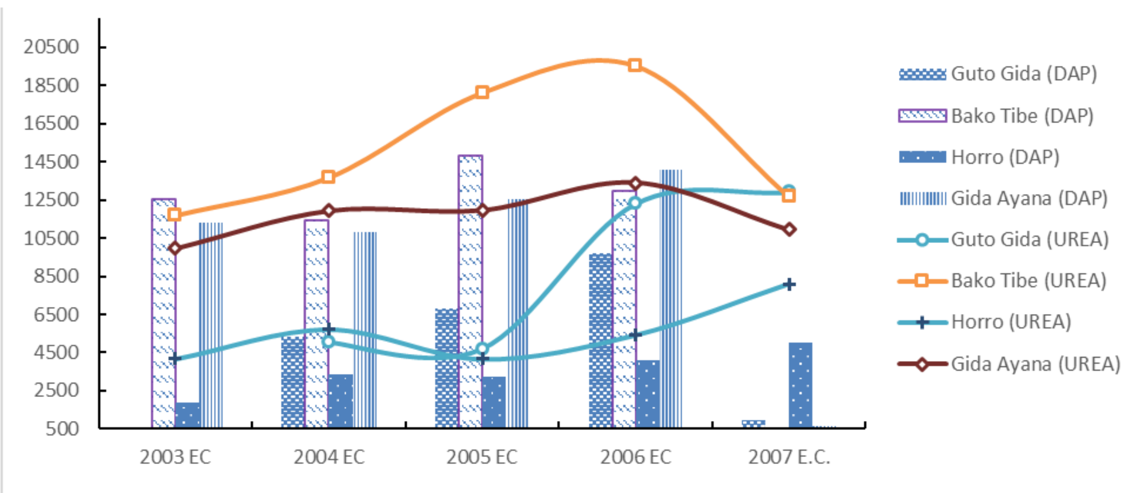

Fig 2. Trends of UREA and DAP fertilizer application (kg ha^{-1}) in the study districts

Table 9. Fertilizer rate and time of application based on key informants in study districts

District	Tef		Maize kg/ha		Wheat		Faba bean		Sesame	
	DAP/NPS	UREA	DAP/NPS	UREA	DAP/NPS	UREA	DAP/NPS	UREA	DAP/NPS	UREA
Bako	40-80	25-50	100-150	100-250	50-80	50-80	-	-	-	-
Horro	100	50-100	50-75	50-75	160	240	50	-	-	-
Gida A	50	50	50-100	50-200	50	50	-	-		20-35
Guto G	50	50	100	100	150	150	50	-	-	-
RRR	**100**	**50**	**100**	**100**	**100**	**150**	**100**	**50**	**100**	**-**

RRR=Research Recommended Rate

Improved seeds

The present assessment revealed that majority of farmers in the study area has limited access to improved seeds of many crops apart from maize and wheat. Those crops and the other limited crop seeds are supplied through cooperatives, research centers and private seed suppliers. Local crop varieties are obtained from markets, relatives and neighboring. Farmers also select their own seeds and save to use for next cropping season. At least one or more number of improved crop varieties were released or recommended by the regional or national agricultural research centers for almost all crops grown in the study area. However, most of farmers in the study area are not using improved varieties except for maize and few other crops implying the gaps in research-extension-farmers linkage. Maize has relatively several optional varieties adaptable to various agro-climatic zones. The popular improved maize varieties include Limu, BH-540, Shone, BH-140, BH-660 and BH-661(Table 8). Sorghum varieties such as Chemeda, Gemedi and Lalo have been produced in Guto Gida and Bako Tibe district, but only local variety has been produced in Gida Ayana and Horro district (Table 8). Kena, Kuncho and Guduru teff varieties; wheat variety such as Digalu and Danda'a and potato variety such as Jalane, Gudane and Belete are some of the improved crop varieties used by farmers in different districts (Table 8).

Table 10. Types of improved and local crop varieties grown by farmers in the study districts

Name of districts	Teff	Maize	Sorghum	Wheat	Barley	Potato
Gida Ayana	Kena, , Kuncho, Guduru	BH-660,BH-661, BH-540, Limu, Shone, BH-140, Agar	Local	Digalu, Danda'a	Local (Samareta type)	Gudane, Jalanee
Guto Gida	Local	BH-660,BH-661, BH-540, Limu, Shone, BH-140, Agar,	Chemeda, Gemedi, Lalo	Local	Local Samareta	Local
Bako Tibe	Kuncho, kena, Guduru, local	BH-660,BH-661, BH-540, Limu, Shone, BH-543	Chemeda, Gemedi, Lalo	Digalu, Danda'a	Local Samareta	Belete, Gudanee, Jalanee
Horro	Kuncho, Kena	BH-661, BH-660	Local	Danda'a, Digalu, Alidoro, Hidase, Kubsa	HB-1307	Gudane, Jalane, Belete

Source: PRA report, 2016

Farm implements and practices

Traditional farm implement called oxen drawn "maresha" plowing method is commonly used across all districts. Most private investors in the lowland areas of Guto Gida and Gida Ayana used their own or rented tractor, while few small scale farmers are rented from private investors for land preparation particularly for maize production. All other farm activities such as sowing, harvesting, weeding, threshing and etc for majority of the crop have been conducted by traditional method or manually. Maize is the only crop cultivated by tractor, sown using recommended seed rate and threshed by Combiner and mechanical Sheller in few lowland areas.

Seed rate and sowing method

The seed rate indicated for listed crops is an estimation of members of PRA group discussion and it's not majorly based on the research recommendation (Table 9). Method of sowing practiced for majority of the crops grown across all districts is broadcasting. Row planting is practiced for maize and few horticultural crops.

Cropping calendar

Although cropping calendars slightly vary among the study districts, planting under rain fed farming starts in late March with sorghum in Guto Gida; whereas, for all crops grown under irrigation, it starts in October. Harvesting and Thrashing of these crops last until January for both growing calendars (Table 9). Under rain fed condition, crops planting in Gida Ayana and Bako Tibe district starts with sorghum and potato in April and harvesting of lowland pulse begins in October, but cereal crops are harvested starting from December. Potato and other horticultural crops mostly harvested starting from July. Threshing of major pulse crops starts in November, while it is in January for cereal crops (Table 9). Under irrigated farming, planting starts in October in Guto Gida, Horro and Gida Ayana districts, but tomato is planted commonly around December to January across study districts (Table 9). Similarly, Horro district started with potato planting in March and harvesting of this crop in August.

Post-harvest loss and management

Post-harvest loss in all districts are related with farm management activities and technologies used. Loss of grain yield after harvest is the major bottleneck farmers' face attributed due to the lack of improved post-harvest management technologies In study districts, post-harvest loss is more in the horticultural crops than the field crops as the storage duration is longer for the field crops than the perishable horticultural crops. However; due to traditional threshing practice, storage system, transportation and pest attack post-harvest grain losses of field crops are also the major constraint for crop production. The storage systems for all crops in all study districts are similar. For cereal and pulse crops, locally produced storage materials known as "*Gumbi, Gotera"* and Fertilizer bag and sisal sack are used. Horticulture crops are either consumed or sold immediately after harvest due to perishability and lack of improved storage facilities. Never the less, underground storage system is practiced for potato storage in most areas. Majority of field crops lose viability and severely affected by weevil if stored for more than six months without chemical treatment. Due to such storage problem farmers are forced to sell their product immediately after harvest or threshing. But, teff, finger millet, sesame and noug can be stored for years except that weight loss can be observed for nesame and noug. In all study districts especially in Bako Tibe area, farmers use chemical insecticide to reduce weevil problem. Recently, Hermetic plastic silos are also being adopted and used by few farmers in the maize production areas.

Table 11**.** Cropping calendar and Seed rate of major crops grown in all study districts

Districts	Cropping calendar	Teff	Wheat	Maize	Sorghum	Barley	Finger Millet	Faba Bean	Field pea	Sesame	Hot pepper	Potato	Mango
Bako Tibe	Sowing date	July 1st - end	July 19-30	May1st- June 1st	-	June, July	May-June	June	End June	-	Mid-June	April	June
	Harvesting date	November	December	November	-	January	Nov-Dec.	October	November	-	December r	August	March
	FSR	30-40kg/h	200Kg/ha	25kg/ha	-	2.5Qt/ha	20Kg	72Kg/ha	64Kg/ha	-	16kg/ha	9-16Qt/h	4000seedling/ha
Horro	Sowing date	July-Aug1st	July	April-May	-	July 1st	-	End of June	Mid-June	-	-	March	-
	Harvesting date	November	December	December	-	December	-	November	November	-	-	August	-
	FSR	60-100kg	1.5-2Qt/ha	25kg/ha	-	2Qt/ha	-	120Kg/ha	64-80 Kg/ha	-	-		-
Guto Gida	Sowing date	July 1st	Mid July	May 1st	March-May	-	May-June	June	-	June	-	October	-
	Harvesting date	December	December	November	Dec-Jan	-	-	-	-		-		-
	FSR	20kg/ha	150Kg/ha	25kg/ha	10-12 kg/ha	-	9-12Kg	72Kg/ha	-	6Kg/ha	-	600kg/ha	-
Gida Ayana	Sowing date	July 1st	July 19-30	May 1st	April-May	-	May-June	June	-	May	-	April	-
	Harvesting date	December	December	November	Dec-Jan.	-	Nov-Dec.	October	-	September	-	July	-
	FSR	20kg/ha	150Kg/ha	25kg/ha	5 kg/ha	-	20Kg	72Kg/ha	-	6-7Kg/ha	-	900kg/ha	-
	RSR	10Kg	120-150	25kg		120-150	15kg	120kg	80-100	5kg	2kg	1.8-2.2tonnes/ha	

FSR: Farmers' seed rate, RSR: Research Recommended seed rate (Source from BARC Research teams)

Pest management practices

The major pests affecting crop production in the study areas include weeds, disease, birds and insects. Although not regular, abiotic factors such as shortage or excess rainfall amount, frost, high wind and flooding damage crop either directly or indirectly. Pest management practices of farmers in the study districts are mainly field sanitation and chemical control. The types of pests listed below were based on respondents' feedback relating the symptom mentioned by farmers to the actual scientific symptom. Therefore, it should be noted that identifying the actual target pests listed by farmers needs further research investigation by professionals.

Major weeds and management practices

All crop types grown in study districts are affected by one or more types of weeds throughout the cropping season (Table 10). The dominant weeds flora frequently observed in crop fields includes, *Guizotia scabra spps* , *Grass spp, Snowdenia polystarcya* , *Plantago lanceolata, Eleusine indica, Trifolium arvensis, Striga spp., parthenium, Avena tatura, Biden brown, Cynodon dactylon Sorghum halepense, Galinsoga partlora, Datura stramonium, Solanum nigrum, Commelina benghalensis, Lolium benghlensis Seteriapallid fusca, Raphanus raphanistrum, Argemon mexicana, Parthenium, Cuscuta compestris, Argenia mexica, parthenium, Seteria pumila*, *"Sogidda ra'ee, Siqaa, Qore, Alladu, Bosoqqee, Dargu, Caffee, Doobbii,* Atari warabesa, *Marga goggorii"*

Weed management options exercised by farmers in all study districts is typically hand weeding which comprise of cultivation (loosing/hoeing), "shilshalo" (oxen plow) and slashing. It is mostly conducted throughout crop growing season until the crop is enough to compete for nutrient. Therefore, weeding time and its frequency majorly depend on crop type, the weed population and stage of the crop.

Since recent years, due to shortage of labor, application of herbicides such as, 2,4-D, Integrity, Pallas 45-OD, Primagram and Steller-star are becoming the common practice for major cereal crops such as wheat, teff and maize. In few areas of Bako Tibe and Guto Gida, pre planting herbicide such as roundup is used followed by minimum tillage for planting of teff and other crops.

Insect pests and management practices

Most of insect pests listed by members of key informants across all study districts are non-migratory insects (Table 10). Migratory insect such as army worm and desert locust outbreak was not observed in the previous few years. But those migratory insect outbreak may appear with the interval of 7-10 years. It was reported that termite is currently a series problem devastating almost all crops, animal feeds and natural resources, and thus needs urgent intervention across all study districts. The problem is very sever in mid and low land areas of Guto Gida, Gida Ayana and Bako Tibe districts. Farmers use traditional control methods such as flooding, destroying the mound and application of insecticide chemicals.

Weevil problem in the field and during storage is common on major crops such as maize, wheat, sorghum, beans and peas. Few farmers use storage insecticides for weevil control but these insecticides are becoming less effective and also poses health hazard. Proper drying of grain prior to storage is the traditional control methods exercised by few farmers. Stalk borer in sorghum and maize, and pod worm (pod borer) on Faba bean, Field pea, Soybean and haricot bean impose significant yield reduction. The common insects reported by the key informants in all study districts for potato was red ants. Leaf minor (*Tuta absoluta*) and Tomato fruit worms are the major insect pests reported by PRA's on tomato crops. Farmers in Gida Ayana and Bako Tibe districts reported that mites locally called "*qinqan"* that feed on the stem and bark of coffee trees are the major constraint in coffee production. In addition, many species of Aphid, thrips and other insect pests damage the crops even though most of them are not clearly identified by PRA members.

Disease and management options

All the study areas are clustered under sub-humid agro-ecological classification where the relative humidity, temperature and other weather conditions are favorable for disease development. Therefore, almost all crops are affected by one or more diseases although the severity varies from season to season. The major disease observed on maize includes Turcicum Leaf Blight (*Exserohilum turcicum*), Grey Leaf Spot, Common Smut (*Ustilago maydis*) and currently MLND (Maize Lethal Necrosis Disease) is observed in lowland areas of Guto Gida and Gida Ayana districts where maize grain is dominantly produced. Sorghum Anthracnose (*Colletotricum subleniolum*), grain mold and birds are serious problem in major sorghum growing areas.

Leaf rust of soybean, common bacterial blight and anthracnose of haricot bean and chocolate spot of faba bean are among the major disease identified for pulse crops. In few districts such as highlands of Bako Tibe and Horro, symptoms of Faba bean gall was reported by PRA members. Fusarium rot of hot pepper, tomato fruit rot, bacterial wilt and late blight of tomato and potato was also the major disease observed on horticultural crops. From oil crops sesame is affected by sesame bacterial blight.

Pesticides of different types (Mancozeb, Matico, Ridomil, Tilt etc) are massively used to control different diseases observed on horticultural crops. However, farmers are not using the recommended type and rate of pesticides and thus pest controlling efficiency is much lower. For many other diseases of cereal and pulse crops, no effective management options are practiced by farmers in the study districts.

Table 12. Important crop pests identified in study districts

Important Diseases				**Important Insects**				**Important Weeds**			
Types of diseases	Target crop	control method	**Districts**	Type of insects	Target crops	control method	**Districts**	Specific type of weeds	Target crop	control method	**Districts**
GLS ,TLB, and grain rot	Maize	no	All	Termite	All	malathion	All districts	*Snowdenia polystarcya, bidens spp.*	Maize	*2x HW in combination with herbicides*	All
Yellow and Stem rust	Wheat	Rarely Rexduo	All	Aphids, Shoot fly	Sorghum and Teff	-	BT, GG, GA	*Avena tatura, Lolium benghlensis*	wheat	1x HW *in combination with herbicides*	All
Septoria	Wheat	-	BT	Weevil	Maize, Sorghum,	-	All districts	*Sorghum halepens*	Sorghum	2X HW	GG, BT
Lose smut and scald	Barley	-	BT,HR	stalk borer	Maize Sorghum	Field Sanitation	All	*Striga spp*	Sorghum	3-4x HW	GA
Chocolate spot	Faba bean	-	All	Caterpillar	Wheat and Faba bean	Malathion	BT, HR, GA	*Cascuta campestris*	Noug	1x HW	All
Fusarium wilt	Hot Pepper	Ridomil	BT,GG	Mango white scale	Mango	-	BT				
Late blight and tuber rot of potato	Potato	Mancozeb Ridomil & Matico	All	Red ants	Potato	-	All				
Faba bean gall	Faba bean	-	HR	Thrips	Horticultural crops	-	BT, GG				
MLND	Maize	-	GG,GA	"Sotallo" pod borer	Faba bean/sesame	-	HR, GA				
Common Smut	Maize	-	GG	Tuta absoluta	Tomato	Diaznon	BT, GG				
Smut, ergot and Grain mold	Sorghum	-	BT,GG ,GA								
Anthracnose	Sorghum	-	BT,GG								
Sesame leaf blight	Sesame	-	GA,GG								
Fruit, stem and bulb rot	Horticultural crops	-	GG,BT								

NB: HW: Hand weeding, HR: Horro, BT: Bako Tibe, GG: Guto Gida, GA: Gida Ayana

Major Constraints of crop production

Production and productivity of crops are constrained by several biotic and abiotic factors as described by farmers. Although the severity of those problems varies, all of them impose negative impact on crop produce. Unpredictably and erratic nature of rainfall, change in temperature, unexpected over flooding, unseasonal rain and frost are some of the environmental factors uncontrollable by farmers. Agro-climatic and district based matrix ranking of constraints were conducted by farmers (Table 11). In matrix ranking, the constraint with highest number assumes the least important and vice versa. Generally, crop growing farmers across all the study areas mentioned problems like high input price, high incidence of crop diseases, poor yield, high cost of farm inputs and problem of termite infestations to be the topmost five constraints.

Marketing constraints

Market access and market related issues of grain are almost similar for all study districts. In most of study districts there is an access of a near village or near town market place where the farmers can sell their farm products. The farmers acknowledge that the current price of their grain products was better than some years ago. However, the rate at which the price of industrial output has been increasing is much faster than the rate of increase of prices received for their farm output. As a result, majority of the respondents emphasized the need to get better market access for their products to be able to meet their expenses, particularly from December to February. The institution/government has not prepared convenient place to sell their crop products.

The fluctuation of grain price depends on the variation in demand and supply from time to time. Some of the major actors participated in agricultural market system are farmers, cooperatives, unions, rural assemblers, brokers, urban and rural grain traders and consumers and these make the system more complex than selling to a single dealer. Due to traditional harvesting, threshing, winnowing and storage system farmer’s crop product has lower quality. The grain is going for marketing with impurities such as weed seeds, dusts, sand and crop straws that significantly reduced the selling price.

Knowledge for management of constraints

All districts share the same issues regarding knowledge for management of constraints by farmers. The government has a lot of agricultural expertise residing at district level and also larger number of development agents within the community. Nevertheless, the service they have been providing were very limited, and do not cover the whole kebele. The staffs are often overloaded with different assignments, which limit the level of service that they should be providing. The service they provide is inadequate and needs to be improved technically. This means that the capacity of DA’s and others needs to be built. Even though not frequent, the farmers have got training by agricultural experts and development agents as well as non-governmental organizations. The training and capacity building delivered for farmers mostly focus on agronomic practices of major crops. However, very limited information is delivered or awareness is created on market and other related issues for farmers.

Irrigation constraints

The crop production was undulating under rain-fed agriculture and as a result the performance of rain-fed productivity remained low and stagnant for most crops. The dependence on rain has significantly affected the life of the people in particular and economic development of the country in general. Irrigation is one means for a good farm husbandry, better land utilization, stable and higher crop production. Both modern and traditional irrigation method is practiced on limited areas in the study districts. The actual implemented irrigable land is considerably less than the potential. Rain water harvesting for irrigation purpose is almost negligible across all study districts.

Farmers of the study districts use irrigation only for horticultural crops (potato, tomato, onion and cabbage) and in some areas for maize. The farmers use irrigation by schedule and irrigate their field mostly in the afternoon. In traditional irrigation method, farmers manually produce a canal and divert the water from main rivers. The problem with this type of irrigation is, loss of water, labor intensive and cause soil erosion. The other constraints related to irrigation water that was raised by PRA members across all districts includes absence of modern irrigation schemes, conflicts in water use (lack of rules in using water among users), limited capacity of water to cover large areas, crop disease and knowledge gaps.

Constraints of crop production in terms of inputs quality and supply

Fertilizer availability and supply

Maintaining a high yielding potential in crops requires soil health and fertility management. Besides, knowing the overall properties of soil is fundamental in making soil management and utilization decisions. Fertilizer application based on soil testing usually leads to an increase in crop yields by providing the correct amounts of nutrients keeping ecological and economic feasibility. To this end, the effort made thus far was negligible.

Adoption of alternative fertilizers other than inorganic fertilizer is very limited in all study districts. In the study districts, farm yard manure (FYM) application is practiced based on traditional experience inherited from forefathers. Although the respondents are well aware of compost preparation and application, usage of this fertilizer for crop production is still low. In some districts like Bako Tibe and Horro, bio-fertilizer of rhizobium is rarely adopted on legume crops such as Faba bean, Soybean and Haricot bean.

Even though farmers are entirely aware of the use of inorganic fertilizers, the cost is becoming unaffordable particularly by subsistent farmers. Farmers, therefore, hesitate in using these expensive inputs. As a result, majority of farmers use fertilizer below the recommended rates and every farmer applied different rate of fertilizers. Such practice greatly reduced the expected yield and its side effect goes from individual farmer to the nation at large.

Improved seed availability and supply

Reliable supply of good quality seed is crucial to the development of the crop subsector of the nations. Availability of improved seed remains one of the main constraints to the small scale farmers. Among the other inputs good quality improved seed is essential to increase productivity but it is generally costly input for crop cultivation. Unavailability and high price of improved seed for some crops, for instance maize variety Limu and Shone, are among the major bottle neck in the study areas. As a result, farmers were forced to use their own saved local varieties which are low yielder, poor quality, susceptible to pests and diseases.

Improved seeds delivered for farmers has no wider adaptability and doesn't meet the requirement of different agro-ecologies. The good example is Kuncho varieties of teff formerly adopted in most teff growing areas but currently less preferable by farmers due to its adaptability problem in all study districts. The major constraint of improved varieties of maize crop which is available in all districts is related with high price, untimely delivering of seed and the packed weight is below its standard for few varieties such as Limu and Shone (< 12.5kg).

Chemical pesticides

Pesticides mostly herbicides and insecticide are readily available at wholesale stores and retailers. Effective disease management pesticides mainly fungicides are rarely available to control horticultural crop diseases. The major problem in this regard is, farmers purchase pesticides from local retailers without any restrictions, no information is given for them about its proper application, hazardous effect and safety precautions. Besides, there is knowledge gap with farmers which types of chemicals can be used for which types of pests and they depend only on the experience of neighbor farmers to decide pesticide use. This problem was/is unseen, but potential to cause deleterious effect on human health.

The farmers in all study districts did not receive any training or technical support on how to use and handle pesticides. Extension workers in the study areas also have not got adequate training on pesticide management, hence unable to provide adequate services to farmers with regard to safe use and handling of pesticides. Integrated pest management (IPM) and biological control are not practiced nor fully understood by the farmers.

Credit constraints

The participants replied that there is limited access to credit services to purchase inputs. There is also no linkage with cooperatives, unions, saving and credit associations and agro-industries. Moreover, the limited credit services provided by the micro-finance institutions are group based and unlikely to treat individual farmers.

Crop production and productivity constraints ranking

All key informants across the study districts were informed to select and prioritize the first five major crop production and productivity constraints in their agro-climatic zones. Among the major problems prioritized by the key informants, shortage of improved crop technologies, high price of inputs and termites are the common problems across all agro ecologies. In addition, low price of outputs and crop pests are the major problems in the high altitude (2140 m.a.s.l) areas of Gida Ayana district (Table 11). Shortage of farm land and decline in soil fertility due to erosion are the major constraint in the mid altitude (1500-2140m.a.s.l) areas of the district. Likewise, lack of postharvest technology and problem of crop pests are the other priority constraint in lowlands (below 1500 m.a.s.l) of Gida Ayana district (Table 11).

In Guto Gida district, the agro-climatic zones were grouped in two; mid altitude and lowland. In the mid altitude agro-climatic zones, termite, soil acidity, shortage of crop land and shortage of improved crop technologies were prioritized by the key informants. The same problem was reported in the lowland areas of the district in addition to the low price of outputs and high prices of inputs (Table 11).

Horro districts were only categorized in to two, the highland and mid land. The priority problems in the highland and midland areas of the district includes soil fertility depletion, shortage of crop land, shortage of improved crop technologies, high price of inputs, crop pests and soil acidity (Table 11).

Across all agro-ecologies of Bako Tibe district, the priority problems include crop pests (diseases, insects and weeds), low price of farm output, high price of inputs, untimely supply and limited in quality and quantity of improved crop varieties. Besides, lack of infrastructure to market (no roads and transportation) and lack of effective pesticides are the major problems in the highland areas. In the mid altitudes areas, termite, shortage of land for crop production and inconsistency in price of farm outputs are the major problems (Table 11). Similarly, deterioration in quality of improved seeds of maize and poor soil fertility are among the major problems in lowland areas of the district (Table 11).

Generally, the present study revealed that high price of inputs, low price of crop output, problem of pest and disease, shortage and untimely supply of improved crop technologies, soil fertility depletion due to erosion, termite, shortage of crop land and soil acidity were among the priority problems raised by key informants in the different districts and agro-climatic zones (Table 11). Those major production constraints, although not the only, urges for immediate research and development interventions. Problems related to the inconsistence and relatively lower price of crop output and higher price of inputs (such as fertilizer and seeds), lack of infrastructure and the limited access to micro finance to solve the problem of input-output price mismatch are pertinently refers to policy makers. Research centers are mandated to solve the problem related to shortage of improved variety resistant to pests and diseases, soil fertility and crop management activities. Bureau of Agricultural and natural resource development should give due emphasis for the shortage and delay in supply of crop technologies, acid soil reclamation, soil and water conservation, etc. Development partners such as seed enterprises and others are the prime to solve the problem related to improved seed quality, quantity and untimely supply.

Table 13. Summary of major production constraints across study districts and agro-climatic zones

Major problems crop production constraints	Major problems in the high land areas						Major problems in the mid land areas								Major problems in the low land areas					
	Gida Ayana		Horro		Bako Tibe		Gida Ayana		Guto Gida		Horro		Bako Tibe		Gida Ayana		Guto Gida		Bako Tibe	
	Score	Rank	Score	rank	Score	rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
High price of inputs	4	2	3	2	4	2	NI	NI	NI	NI	NI	NI	3	3	3	2	3	2	1	3
Low price of outputs	5	1	NA	NA	5	1	NI	NI	NI	NI	NI	NI	4	2	NI	NI	4	1	4	1
Shortage of improved crop technologies	1	5	2	3	1	5	0	5	0	5	4	1	NI	NI	2	3	NI	NI	NI	NI
crop pest	2	4	4	1	0	6	1	4	3	2	3	2	2	4	1	4	1	4	3	2
termite attack of crops	3	3	NA	NA	NI	NI	3	2	4	1	0	5	5	1	4	1	0	5	NI	NI
soil fertility decline due to erosion	NI	NI	1	4	NI	NI	2	3	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
shortage of crop land	NI	NI	0	5	NI	NI	4	1	1	4	2	3	0	6	NI	NI	2	3	NI	NI
Transportation problem to market produces	NI	NI	NI	NI	3	3	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Lack of unit-insect chemicals supply	NI	NI	NI	NI	2	4	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Acidity of crop land	NI	NI	NI	NI	NI	NI	NI	NI	2	3	1	4	NI	NI	NI	NI	NI	NI	NI	NI
delay supply of improved seeds	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1	5	NI	NI	NI	NI	1+1	5
seed quality and quantity decreases (maize)	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1+1+1	4

Source: PRA report, 2016, NI=Not identified (i.e not mentioned as a top 5 priority constraint in the district), + used to break Tie

Natural Resources and Management

In Ethiopia in general and the study area in particular, many rural populations are directly or indirectly depends on the exploitation of natural resources for crop and livestock production, fishing, basic needs and fuel, both to meet their own subsistence requirements as well as to sell in markets for cash income. Rapid land use change meant that natural environments and habitats are disappearing quickly, with the result that critical ecological resources and functions are being disrupted or lost. The ever growing population size further increased the demand for natural resource use and conversion. Finally, for many low and middle-income economies natural resource-based development and primary commodity exports are the main engines for growth and long-term development (Edward, 2005).

Natural resources are clearly central to sustainable economic development process: many low and middle-income economies are highly dependent on the exploitation of their natural capital to secure the needs of the present generation as well as to develop and meet the needs of future generations. However, the evidences going to be presented throughout this research work indicated that increasing economic dependence on natural resources in the study areas associated with poor economic performance due to miss use and management of natural resources in the areas. Such situations have been the problem of many low and middle-income countries.

Natural resource management aims for the efficient and sustainable utilization of natural resources. The best methods for managing a given natural resource system depend upon factors such as relative resource prices, available substitutes, environmental impacts, societal values, and physical characteristics of the resource. In all the study areas, the natural resource management did not based on the sustainable and efficient use but only for the current production purposes. This days the government attention in sustainable uses of natural resource is on the way of changing because different organizations have been giving awareness on sustainable use of natural resources. In subsequent topics we will see different methods of natural resource management practiced by different organization and the farm household in the study areas.

Common Property Resources and their Management

A common property system is a particular social arrangement regulating the preservation, maintenance and consumption of a common-pool resource. Examples of common-pool resources include irrigation Rivers, fishing grounds, pasture lands, forests, water or the atmosphere. A pasture, for instance, allows for a certain amount of grazing occurring each year without the core resource being harmed. In the case of excessive grazing, however, the pasture may become more prone to erosion and eventually gives less benefit to its users. Because the core resources are vulnerable, common-pool resources are generally subject to problems of overcrowding, overuse, pollution, and potential destruction unless harvesting or use limits are devised and enforced (Wikipedia, the free encyclopedia, https://en.wikipedia.org/wiki/Common-pool_resource, 2016). In the study areas such type of resources includes grazing land, natural forest, natural rivers and lakes which are communally managed.

In Gida Ayana, Guto Gida and Bako Tibe districts, the common property resource identified were; communal grazing land, perennial rivers and natural forests. The communally owned resources especially grazing lands in these districts have been distributed to landless youngsters. But their efficiency in proper utilization and management thus far is unsatisfactory, partly fenced and fallowed for no use. The common property resources identified in Horro district were the same with other districts except Horro own two manmade lakes which provide hydro-electric power.

According to the present study, the management system of these resources is almost similar across the study districts. Village residents are equally responsible for the management of grazing land. The management aspect of this resource is only to decide on who have the right to use or not to use. The decision on the extent of this resource use is open in all of the study areas. The common-pool forest resource in all districts of the study areas is currently managed by Kebele administrators of the respective districts. Natural rivers which flow throughout the year in all districts are meant open access resource except for irrigation use. The use of natural river for irrigation is possible only for farmers who has farm land around that river provided that the river is accessible for irrigation and that farmer has the right to manage and use the river in his/her territory. There are similar local management regulations for the manmade lakes concerning the right to fish or not just like the decisions made on natural rivers for irrigation. Never the less, if the lake is bounded by public natural forests such part becomes an open access especially for fishing.

It is understood from this study that common-pool resources may be owned by national, regional or local governments as public goods, by communal groups as common property resources, or by private individuals or corporations as private goods. When they are owned by no one, they are used as open access resources. In all the study areas, communal grazing land at each village level are owned by those villagers but owned and managed by the kebele if that grazing land is very large. The natural forest found at each kebele belongs to it except when that forest is registered and owned by Oromia Forest and Wildlife Enterprise the ownership.

Soil conservation problem and Managements measures

Due to shortage of farmland and an increase in population size regularly, intensive crop cultivation across all study areas were reported by the key informants. This resulted in over depletion of soil nutrients and thus poor fertility. Fallowing is less practiced, crop rotation is usually practiced in the highland areas, but mono cropping is common for maize in maize belt areas. Deforestation, soil degradation and severe soil erosion are frequent problems. Land use planning is uncommon and hence farmers currently plough very sloppy land aggravating severe erosion and land degradation. Therefore, application of inorganic fertilizer and rarely organic manure (farm yard manure) is practiced to keep the soil productive.

The participants across all districts pointed out that the major causes of soil fertility decline includes deforestation, removal of crop residues from the fields, land fragmentation, overgrazing, soil erosion, low fertilizer inputs, inadequate soil conservation, plowing of marginal lands, mono-cropping and poor soil conservation practices. Therefore, strengthening of soil conservation measures in the degraded highlands and stabilizing with multipurpose tree species is very important to conserve the soil and increase production of crops yields.

Soil erosion types mostly observed in all districts are gully erosion and sheet erosion mainly caused by flood (run off) and land slide. Soil acidity is also the major concern in all study districts mainly attributed to the effect of soil erosion. No amendments are practiced for acidity management across all the study districts except that few farmers practiced lime application in Guto Gida district to reclaim the acidity problem. According to the information from District Finance and Economic Development Office (DFEPO) of respective districts, assessment of soil acidity analysis is on the way for future lime application. Although the input is available, it is understood that there is reluctance with experts and farmers to apply lime.

Soil and water conservation practiced in the study districts are marked by the combination of physical, chemical and biological conservation measures. The physical conservation measures practiced include minimum tillage, constructing soil bund, cut of drain and terrace. Inorganic fertilizer application is the common chemical soil conservation measures. The biological soil conservation measures being applied are composting, planting grass and tree species on the constructed physical structures and use of bio-fertilizers in few districts.

In Horro districts, the major soil conservation techniques practiced are cut-off drain, bench terrace, hill side terrace, plantation and crop rotation while Gida Ayana district mainly focused on following good crop cultivation systems such as shifting cultivation, intercropping and relay cropping as the major soil conservation measures. Plantation, constructing different soil physical and biological structures are the main measures practiced by the farmers of Bako Tibe district.

The major tree species identified in each district is listed according to the information obtained from the respondents; Gida Ayana district (*Podocarpus falcatus , Syzgium guineense, Millettia ferruginea Albizia gummifera*), Guto Gida district (*Ficus vasta* **,** *Ficus sur, Eucalyptus camadulensis, melia azandirach, -Jatropha Curcas, Cordia africana, croton microstachyus, Aningeria adolf-freidericii, Vernonia amagdilinia and etc*), Horro district (*Podocarpus falcatus , Syzgium guineense, Prunus africana , Ficus vasta , Acaica abyssinica, Croton macrostachyus, Ficus sur, Ekebergia capensis,etc*) and Bako Tibe district (*Podocarpus falcatus , Prunus africana* **,** *Acaica abyssinica, Ekebergia capensis, Olea Africana, Erythrina abyssinica,-Eucalyptus globules, Varnonia amagdilinia, Albizia gumiferia and etc*).

Natural Resource Utilization Constraints

The participant farmers in the process of PRA survey were identified the priority constraints contributing for the destruction and productivity decreases of natural resource in the high, mid and lowlands of Gida Ayana district. The major problems reported across the three agro-climates of the district include soil erosion, land slide, deforestation and termite attack (Table 12). In addition to the above mentioned problems, insect pests are another bottleneck in the mid altitude of the district.

The major natural resource constraints reported in Guto Gida district include less utilization of water resource for irrigation purpose due to less development of irrigation schemes, soil erosion, termite attack and deforestation. Similarly, those problems are also common in lowland areas in addition to the shortage of land to utilize the accessible irrigation water (Table 12).

Group discussions made in Horro district identified and prioritized the major constraints such as soil erosion, land slide, deforestation and drying up of different streams in the highlands and mid altitude areas of the district. Termite is also reported as a bottleneck in the mid altitude of the district (Table 12).

The problems contributing for productivity decreases of natural resource utilization in the highland areas of Bako Tibe district are soil erosion, land slide, deforestation and plowing mountainous ears of land for long period of time. Problem of termite, soil erosion, landslide and deforestation are also common in mid and lowland areas of the district.

Table 14. Summary of major constraints of utilization of natural resources across study districts and agro-climatic zones

Major problems crop production constraints	Major problems in the high land areas						Major problems in the mid land areas								Major problems in the low land areas					
	Gida Ayana		Horro		Bako Tibe		Gida Ayana		Guto Gida		Horro		Bako Tibe		Gida Ayana		Guto Gida		Bako Tibe	
	Score	Rank	Score	rank	Score	rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Soil erosion	1	3	1+1	2	1	4	3	2	0	4	2	2	2	2	1	3	1	3	2	2
Land slide	0	4	1	3	0	5	0	5	NI	NI	0	4	0	4	0	4	NI	NI	1	3
Deforestation	3	1	3	1	4	1	4	1	3	1	3	1	3	1	3	1	3	1	3	1
Termite attack	2	2	NI	NI	NI	NI	2+1	3	2	2	1	3	1	3	2	2	0	4	0	4
Pest attack of trees	NI	NI	NI	NI	NI	NI	2	4	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Less developed irrigation	NI	NI	NI	NI	NI	NI	NI	NI	1	3	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Shortage of land	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	2	2	NI	NI
Dry up of streams	NI	NI	1	2	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Ploughing mountainous land	NI	NI	NI	NI	3	2	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Ploughing the same land for long time	NI	NI	NI	NI	2	3	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI

Source: PRA report 2016, NI=Not identified (i.e. not mentioned as a top 5 priority constraint in the district), + used to break Tie

Livestock Production

Livestock Production Systems and Productivity

Livestock production systems are classified into different categories according to the several criteria which includes integration with crop production, the animal-land relationship, agro-ecological zones, intensity of production, type of product, size and value of livestock holdings, distance and duration of animal movement, types and breeds of animals kept, market integration of the livestock enterprise, economic specialization and household dependence on livestock.

Crop-Livestock mixed production systems can be divided into extensive and intensive. Mixed extensive systems include rain-fed crop production and livestock with limited or no use of purchased inputs, and have been practiced supporting the livelihood of farming communities in all the study districts. On the other hand, mixed intensive systems are characterized by irrigated agriculture and intensive use of purchased inputs; but such type of production system has not been practiced by small scale farmers in all districts under study. Farmers are not familiar in supplementing purchased concentrate feeds such as linseed, noug-seed cakes and wheat bran. Never the less, few farmers used to fed their milk cow and draft power animals with homemade supplemental feed, like milled barley, impure maize and teff grain (“girdi”) and green fodder.

The present PRA study indicated that mixed farming system is predominantly common practice in all agro-ecologies of each study districts as the climatic conditions are conducive for farming of crops and raising livestock. In this production system, livestock and crops are maintained as complementary enterprises. Farmers keep livestock on private and/or communal grazing land during the wet season while undertaking free extensive grazing/uncontrolled of their all livestock species during the summer and spring seasons of the year. We noted that livestock production is usually characterized by low productivity due to lack of inputs like improved breeds, no improved forage and limited veterinary services (supply of drugs and marketing information). Group discussion in all districts from all agro-ecologies pointed out that mean daily milk yield and annual egg production from both indigenous and improved breeds of cattle and chickens as well as annual honey production from traditional, transitional and modern hives is too low (Table 13). The average milk yield of indigenous cattle breed across different agro-ecologies of the study districts varies from 0.75 to 1.5 liters per day, with low yield at Gida Ayana and relatively better production at Horro and Bako Tibe districts, respectively. The key informant reported that the average daily milk yield of indigenous cattle at Gida Ayana, Guto Gida, Horro and Bako Tibe were 1.9, 1.65, 4 and 1.5, respectively. This result was similar to the secondary data collected except for Horro district which seems higher in this case. The report collected from each district livestock and fishery development office showed that the average milk production from improved breeds were 7, 10.35, 12 and 8 liters per day per cow from Gida Ayana, Guto Gida, Horro and Bako Tibe, respectively. But these figures were not verified with primary data except in Horro district where 3 liter per day was reported only in one kebele.
Across all the study districts, livestock productivity showed decreasing trend through time mainly due to shortage of feeds attributed to the population increase and an expansion of crops land that caused shortage of grazing land. Similarly, the productivity of honey harvested

per hive per year from all bee hive types were reported decreasing from time to time may be due to problems likes shortage of skilled man power, limited supply of bee equipment at district level, lack of beekeeping extension service, pests and predators, the deleterious effects of pesticide application, etc. The PRA group pointed out that honey yield in these districts varies depending on seasonal variation. When rain fall season is good, the amount of honey produced is high compared to the prolonged dry season mainly due to limited of availability bee forage. In almost all of the districts honey is collected at the end of rainy season between October and December and most of the farmers harvest honeys once per year while few farmers harvest twice a year.

Table 15. Mean Productivity of Milk, Eggs and Honey in Different Agro-Ecology of study districts

Livestock types	Breed	Gida Ayana			**Guto Gida**		Horro		Bako Tibe		
		GJ*	**KJ⁺**	**W@**	**NG⁺**	**UK@**	**GD***	**GB⁺**	**WB***	**KC⁺**	**TS@**
Cattle (lit, MY/per lactation)	Indigenous	270	240	160	360	360	540	360	540	360	360
Cattle (lit, MY/per lactation)	Crossbred						1080				
Chicken, (No. of eggs/ year)	Indigenous	72	72	70	72	72	75	90	72	70	72
Chicken, (No. of eggs/year)	Improved	-	-	-	-	-	360	-	-	-	-

Source: from PRA report 2016. GJ =Gaba Jimata; KJ= Konaji; W = Warabo; NG = Nagasa; UK =Uke; GD = Gitili Dale; GA = Gidina Abuna; WB = walikituma Bakarere; KC = Kortu Canco; TS=Tulu Sangota; @=lowland, +=midland, *=highland and NA=Data not avialable MY= Milk Yield

Reproductive Performances of Different Livestock Species

The secondary data collected from each district of the study areas indicates that lactation length for indigenous cattle breed is less in all districts except for Gida Ayana district. The weaning ages for indigenous cattle breeds in Gida Ayana and Horro districts are similar while Bako Tibe and Guto Gida districts have the same weaning age. On the other hand, age of bull at first draft power and draft service varies from district to district (Table 14). The crossbred bulls are rarely used for draft power in the study districts.

Table 16. Productive and reproductive performance of cattle in the study districts

Productive & reproductive performances	Breed	Gida Ayana	Guto Gida	Horro	Bako Tibe
Lactation length (months)	Indigenous	10	6	8	6
	Crossed	9	9	10	8
Weaning age (months)	Indigenous	10	7	10	7
	Crossed	9	6	10	5
Age at first calving (years)	Indigenous	4	4	4	3.5
	Crossed	3	3.5	3	2.5
Age of bull at first draft power (years)	Indigenous	5	4	4	3.5
Draft service of bull (years)	Indigenous	5	6	9	8

Source: Respective District Offices of Livestock and Fishery, 2016

The result obtained from each agro-ecology through PRA and the secondary data collected at district level indicated that the average weaning ages for indigenous and crossbred cattle has little difference based on several factors among which feed shortage, breed and diseases have the lion's share for the decreases in lactation period but increases in weaning age (Table 14 and 15).

Table 17. Weaning age (months) for indigenous Livestock species in different kebeles of the study districts

Livestock species	Gida Ayana			Guto Gida		Horro		Bako Tibe		
	GJ	KJ	W	NG	UK	GD	GA	WB	KC	TS
Cattle	12	10	8	9	12	12	12	8	7	8
Sheep	6	4	4	6	4	6	6	4	4	4
Goat	5	4	4	4	3	4	5	4	3	3
Poultry	4	3	2	3	2	3	3	3	2	2
Donkey	12	12	12	12	12	2	12	10	6	6
Horse	12	-	-	-	12	8	12	8	-	-

Source: from PRA report 2016. GJ =Gaba Jimata; KJ= Konaji; W = Warabo; NG = Nagasa; UK =Uke; GD = Gitili Dale; GA = Gudina Abuna; WB = walikituma Bakarere; KC = Kortu Canco; TS=Tulu Sangota

Age of Puberty

Puberty is related to age and body weight. The key informant indicated that the age at first heat of different livestock species has variability within the district from one agro-ecology to another (Table 16). This might be due to several factors such as feed shortage, husbandry management, breed and diseases. It was also observed that age at first on heat decreases from high land to lowland with some exceptions in few districts.

Table 18. Age at first on heat (months) for indigenous livestock species under different kebeles in the study districts

Livestock species	Gida Ayana			Guto Gida		Horro		Bako Tibe		
	GJ	KJ	W	NG	UK	GD	GA	WB	KC	TS
Cattle	54	60	48	48	36	36	48	36	48	36
Sheep	8	12	6	9	12	12	7	6	6	12
Goat	7.5	9	5	6	12	5	5	5	4	7
Poultry	6	7	3	6.5	4	5	6	5	6	5
Donkey	24	24	-	30	-	18	24	36	18	18
Horse	-	-	-	-	-	24	24	36	-	-

Source: from PRA report 2016. GJ =Gaba Jimata; KJ= Konaji; W = Warabo; NG = Nagasa; UK =Ukke ; GD = Gitili Dale; GA = Gudina Abuna; WB = walikituma Bakarere; KC = Kortu Canco; TS=Tulu Sangota

Parturition interval of different livestock species

This is an economically important trait of any livestock species for humans because it determines the rate of genetic progress and population turnover rate of those livestock species. However, many factors affecting parturition interval like feed shortage, breed type and diseases would also affect parturition interval. Information collected from farmers using PRA tools revealed that the average calving intervals (months) of local cattle shows similar trends in Horro and Bako Tibe districts. Similarly, average clutch intervals for poultry in all districts has similar trend except little difference in Gida Ayana district (Table 17).

Table 19. Parturition interval (months) for indigenous livestock in the study districts

Livestock species	Gida Ayana			Guto Gida		Horro		Bako Tibe		
	GJ	KJ	WB	NG	UK	GD	GA	WB	KC	TS
Cattle	24	36	18	20	18	24	24	24	24	24
Sheep	6	8	6	7	7	12	6	6	6	6
Goat	6	7	5	6	6	6	5	5	5	5
Poultry	1	0.7	0.5	0.5	0.5	0.5	0.75	0.5	0.5	0.5
Donkey	12	24	-	12	-	12	12	12	12	12
Horse	-	-	-	-	-	12	12	24	-	-

Source: from PRA report 2016. GJ =Gaba Jimata; KJ= Konaji; WB = Warabo; NG = Nagasa; UK =Ukke; GD = Gitili Dale; GA = Gudina Abuna; WB = walikituma Bakarere; KC = Kortu Canco; TS=Tulu Sangota

Livestock management

Livestock management practices in the study areas are mainly based on the traditional knowledge of the farmers and it was noted that the farmers lack adequate knowledge and skills in improved livestock management practices.

Livestock feeds and feeding system

This study showed that grazing of natural pasture constitutes the main source of animal feed throughout the year with maximum availability during crop growing season (June to December) but there is shortage from January to May in all the study districts. Free grazing is the commonly practiced system in the villages.

Fodder conservation for the dry season is not a common practice. Thus, the excess forage available during the rainy season is often wasted by being trampled upon by animals and burning during the dry season for the aim of cleaning land for crop production. Different crop residues are available during the dry season from October to March at household level and used as a feed for livestock particularly for large ruminants. But most of crop residues are wasted due to lack of proper conservation, storage and feeding systems. Naturally occurring and planted green forages are important next to grazing of natural pasture and crop residues in terms of its contribution to the livestock feed supply in the study areas with some variations among districts.
Only few farmers supplement their animals with concentrate particularly in peri- urban of Bako Tibe and Guto Gida districts. Milled barley, impure maize and teff grains (“girdi”) are takes the largest share of concentrate feed for lactating cows, draft power animals, and poor body condition animals. The study identified that forage development at farm household level was not adopted well by majority of the farmers in the study areas primarily due to poor extension system. But during wet seasons especially from June to August farmers practice closuring some of their own grazing lands and grow grass for the next September to October for grazing of their livestock species.

Animal feeding system by production purpose

Free grazing of grazing land, crop aftermath and crop residues utilization is the major feed sources and feeding system for livestock species. Supplementing with some locally available feeds for selected livestock species according to their purpose of raising is commonly practiced by all farmers under all districts of the study areas. Accordingly, providing a byproduct of local breweries such as “atela” for the milking cows under farmers’ management is aimed at collecting more milk per day. For fattening purpose, agro-processing byproducts like noug-cake and crop residues treated with salt is additionally provided for cattle and small ruminants. Different leaves and pods of trees and shrubs like *vernonia amagidlia* species locally known as “Ebicha” is also fed to the milking cows and other livestock species (cattle, sheep and goat) during fattening. Some shrubs such as *vernonia* is also used to treat livestock against some diseases in all the study areas. On the other hand, some farmers in Guto Gida and Bako Tibe districts practice supplementation of agro-industry by-products for the lactating and fattening animals.

Water Sources for Livestock

All year round flowing rivers, streams, springs, manmade lakes, ponds and other sources of water are merely important sources of water for all livestock species in all of the districts both during dry and wet seasons. There is no water harvesting practice from flood/ home roofs for watering their livestock species or even for agriculture in all the study areas.

Livestock Housing

In all the study areas, it was observed that matured cattle are kept in open enclosures or kraals during the night to prevent them from wandering around and damaging crops or other properties and to protect them from predators. However, animals under fattening program kept in separated houses made from grass or corrugated sheet roofs for three to four months for single livestock species. This management practices are almost similar in all the study districts. Farmers periodically shift kraal for two major objectives; to maintain cleanliness of the kraal and to attain uniform soil fertility with manure as organic fertilizer. This is a very useful indigenous traditional practice that has helped to maintain the resilience and sustainability of the smallholder agricultural system especially for soil fertility management. Small ruminants, young calves and chickens are housed in one corner of the family dwelling and their excreta (manure and urine) are cleaned from the house daily.

Livestock Species Health Management

Major animal diseases, particularly on cattle including Trypanosomosis, anthrax, blackleg and foot and mouth disease (FMD) and parasites were identified through PRA group discussions in all districts. All of them are common in almost all of the study areas but their prevalence on the livestock species differs from one agro ecology to another. Chicken are severely affected by fowl cholera, Newcastle disease and predators while sheep and goat pox, contagious caprine pleuropneumonia (CCPP), FMD and Footrot are major challenge in sheep and goats. Ticks, mites and flies are reported as major external parasites whereas gastrointestinal nematodes and liver fluke are major internal parasites causing considerable loss of animals in these areas. Several farmers use indigenous knowledge as an alternative measure of ethno-

veterinary treatments such as extracts of leaves and roots from local vegetation/shrubs and other ingredients are applied against various diseases and parasites.
Diseases challenge is very critical constraint to livestock production and productivity in the study areas. In addition, leech (blood sucking parasites) infestation is reported as the most important constraint and all farmers have many worries in all study areas particularly in the highland areas during the dry season. Regular vaccination, access to adequate veterinary care and services, drug that reduce leech and increased water quantity during dry season to create unfavorable condition for leech multiplication are potential solutions suggested to control livestock diseases and parasites in all the study areas. It was identified that, cattle and small ruminants are subjected to heavy internal and external parasitic burdens in water logged grazing areas as these areas are favorable environment for the parasites and their vectors mainly during the rainy season. Absence of veterinary clinics and service, limited drug supply according to the farmers demand in veterinary clinics, high price of veterinary medicine, shortage of skilled human power and capital to purchase medicines were mentioned as factors contributing to severity of animal diseases. Farmers mostly rely on locally prepared herbal medicines to treat different livestock species' diseases due to the increased cost of medicines. It was observed from the study that, limited extension services were given to livestock sub sector compared to crop sub sector. Adoption and popularization of new forage technologies and separation of breeds according to their purpose of raising (milk or meat) were not practiced in the study areas despite some efforts on forage development activities on very few farmers' field and Farmers training center (FTC).

Most of the respondents were aware of the local names of the diseases, symptoms of those diseases, type of animal they affect, their seasonal occurrence, local curative measures and post mortem indication, which can readily be translated into standard veterinary terms. Some of the diseases that were identified by PRA group discussions in all districts of the study areas are listed in the following (Table 18).

Parasitic Diseases

The present study indicated that parasitic diseases remain as the major causes of mortality, loss of production, hide and skin quality deterioration and predisposing animals to many infectious diseases. A high prevalence of *fasciolosis* was reported in all the study sites mainly due to the fact that the intermediate host (snail) may be found in the wide marshy areas. It is well understood that ectoparasites such as tick and mange mites are important economical vectors that affect hide and skin quality in large and small ruminants in the study areas. Leech is also the other parasite which respondents indicated during the PRA discussions as an imperative health problem to the livestock.

Miscellaneous Diseases

During the discussions made with various groups in all districts of the study areas, it is indicated that diseases of undifferentiated causative agents and traumatic cases such as complex respiratory problems, are the other health issues of livestock species. The high occurrence might be due to climatic stress, malnutrition, and maltreatment (traditional) i.e. drenching. Bloat and circling disease are also identified as major health problems which are common gastrointestinal disorder that causes sudden death of ruminant occurring in the study areas when animals graze lush grass in and around the marshy areas. It may also occur due to anatomical disorders like esophagus obstruction. Circling disease is a major problem of small ruminants in the study areas most probably caused by coenerus cerebrals as respondents confirmed that they frequently found the cyst when the head of animals opened after slaughtering.

Mastitis was reported as the most severe disease with high prevalence in the study areas resulting in decreased milk yield and quality and premature culling of cows. High incidence of lumpy skin disease was also reported in calves and dairy cows. The poor hygiene of cows' shelter, overcrowding, failure to control mastitis as well as low level of management were reported by the respondents as the major reasons for the high prevalence of mastitis in the study areas. It was also indicated that the incidence of heart water associated with high tick infestation and lack of vaccination for the infestation contagious diseases.

Table 20. Major livestock diseases identified with their different management options in all the study districts

Livestock species	name in Afaan Oromo	Common name	Parasite	Traditional Management		Modern Management	
				Disease	Parasite	Disease	Parasite
Cattle	Gandi	Trypanosomosis	Ticks	None	Treating by crashed hot pepper	Medicine from clinics	-
	Albaasaa	Diarrhea	GIT	-		Drug	-
	Garaa qooqsaa	CBPP		-		Drug	-
	Dhukkuba gogaa	LSD		-		None	-
	Bokoksaa	Bloat		-		None	-
	Dhukkuba muchaa	Mastitis	None	None	None	None	-
	Dhulaandhula (parasite)	Leeches infestation	-	-	Hand removal, use of tobacco leaf	None	-
	Afaan madeessa,qeensa baqaqsa	FMD	-	Washing with ash	-	-	-
	Abbaa sangaa	Anthrax	-	-	-	drug	-
	jiitoo	Fasciolosis		-	-	Drug	
Poultry	Fungel/boquu micciira	NCD		Garlic & lemon	-	Drug	-
	Bilii/siisawoo		Ecto parasite	-	-	None	-
Sheep and Goat	Arraba qoraattii	Tongue blood vessels engorgement		-	Bleeding using sharp material	None	-
	Albaasaa	Diarrhea		-	-	Drug	-
	Maraammartoo	Circling disease				None	-
	Mandarraa	Orf			Giving hot pepper	None	-
	Muujalee/oo'ichoo	Foot rot		-	Removing by using materials	None	-
	Ni qufaasisa	CCPP		-	-	None	-
	Raammoo mataa	Ceonorosis		-	-	None	-
	Mataa itti dhiitessa	Fasciolosis		-	-	None	-
Apiculture	Bird attack			-	-	None	-
	ants			-	Ash application	None	-
	Chemicals			-	-	None	-

Source: PRA report from each district

Breed and Breeding Practices

Indigenous breed of livestock species is the only breed reared except few crossbred dairy cattle and improved chicken rarely reared in the study district. Natural uncontrolled mating was the predominant breeding method for all livestock species in almost all study areas while the majority of farmers practice controlled mating for their cows during the wet season. During the dry season, breeding bulls are freely used to serve own and neighbors' herds that indicates controlled and planned mating is not commonly practice. Therefore, it needs awareness creation for planned and controlled mating to synchronize delivery of calves in seasons of better feed availability. An artificial insemination service has been recently practiced in these areas supported by hormonal synchronization though its efficiency and effectiveness is very poor. This is most likely attributed to poor accessibility and distance to AI station and inadequate knowledge of AI technicians; even farmers miss perceived this service as if it makes the cattle infertile in almost all the study sites.

Credit Services

It is understood that credit sources for livestock and crop production are less pleasing almost in all districts of the study areas. Although credit facilities are available from microfinance institutions such as Oromia Saving and Credit association, most farmers do not use the services because of fear of risks associated with uncertainty of livestock performance and high interest rate that could lead to failure of repayment of the loan. Moreover, the credit services provided by the micro-finance institutions are group based which makes individual member accountable for the group members who may fail to repay the loan.

Animal Health Service

An effective animal health service requires efficient system that provides services to the farmer at affordable prices. It was perceived that animal health posts available in the majority of rural kebele of the study areas are mostly inefficient in providing vaccination and treatment services to the level that is required by the community. In almost all the study areas, one animal health post is expected to serve three neighboring kebeles. Nevertheless, the newly established livestock and fishery resource office is not effective due to lack of supports from different organization in the study areas.

Livestock Product Processing

The PRA result showed that farmers of the study areas have been practicing traditional ways of milk handling and processing due to inadequate knowledge, information and improved technologies on milk and milk product processing techniques. Furthermore, there is no egg handling and transporting facilities available at community level to take to the market and thus traditionally straw of crop is used to protect from breakage. Processing, preservation and transportation facilities of livestock product (milk and milk products, meat and honeybee) are lacking across all the study districts.

Fish production

The present study indicated that fishing has been practiced from main rivers in all districts by young boys and adult men as a sideline activity to get cash income. Besides, Horro district use two artificial lakes. Due to lack of knowledge, the majority of farmers in the study areas are not aware of using fishes as food or income generation. The study identified that the majority of fish species existing in the study districts are Nile tilapia. In addition, African catfish is found in Gida Ayana and Barbus in Bako Tibe district. The currently available population of fish across districts does not commensurate with the production potential and the available water resources (Table 19). The major constraints of fishery production in most of the districts of the study areas includes poor management practices, lack of knowledge in identifying appropriate species for warm and cold water and feeding system. Horro district is relatively potential area for fishery development and there are more producers of fish. None the less, lack of access to market, poor road infrastructure and scarcity of fishing materials are among the major constraints.

Table 21. Major fish species and potential production of each district of the study areas

District	Water body	Fish species	Potential of the district (kg/year)
Gida Ayana	Hangar and Warabessa	Nile tilapia	5,000
		African catfish	2, 000
Guto Gida	Alaltu, Ebicha, Loko, Hangar and Jiregna rivers	Nile tilapia	600
Horro	Choman and Nashe lake	Nile tilapia	1,825,000
Bako Tibe	Gibe and Robi rivers	Nile tilapia	600
		Barbus	1,000

Source: Office of Livestock and Fisher Development of Each Districts, 2016

Livestock Production constraints

The major constraints supposed to contribute to the decreases in productivity and production of livestock and livestock product in the high, mid and low land areas having different altitudes in the four districts (Gida ayana, Guto Gida, Horro and Bako Tibe) of the study areas are summarized in the following table

Table 22. Summary of constraints to livestock production

Major problems crop production constraints	Major problems in the high land areas						Major problems in the mid land areas								Major problems in the low land areas					
	Gida Ayana		Horro		Bako Tibe		Gida Ayana		Guto Gida		Horro		Bako Tibe		Gida Ayana		Guto Gida		Bako Tibe	
	Score	Rank	Score	rank	Score	rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Shortage of grazing land	4	1	4	1	5	1	3	3	4	1	2	3	3+1	2	2	4	2	2	0	4
Livestock diseases	3	3	2+1	5	1	5	4	2	3	2	4	1	4	1	3+1	2	0	4	3	1
Low price of livestock market	NI	NI	3	3	4	2	1	5	NI	NI	NI	NI	2	5	1	6	NI	NI	1	3
Lack of improved breed supply	NI	NI	2+1+1	4	0	6	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	3	1	NI	NI
Lack of transportation to market place	NI	NI	NI	NI	3	3	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Lack of veterinary clinics	NI	NI			2	4	NI	NI	NI	NI	NI	NI	3	3	1+1	5	NI	NI	NI	NI
High price of improved breeds	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	2+1	4	3	3	NI	NI	NI	NI
Low supply of improved forage	1	5	2	6	NI	NI	NI	NI	NI	NI	3	2	1	6	NI	NI	NI	NI	NI	NI
Seasonality of livestock market demand	NI	NI	3+1	2	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	2	2
Traditional way of production	2	4	NI	NI	NI	NI	NI	NI	2	3	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Unproductive nature of AI	3+1	2	NI	NI	NI	NI	NI	NI	3	2	1	4	NI	NI	3+1+1	1	NI	NI	NI	NI
Leech (“*dhulandhula*”)	NI	NI	NI	NI	NI	3	2	4	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
High price of check(kela) point (even for unsold cattle)	NI	NI	NI	NI	NI	0	4+1	1	NI	NI	0	5	NI	NI	NI	NI	1	3	NI	NI

Source: PRA report 2016, NI=Not identified (i.e. not mentioned as a top 5 priority constraint in the district), + used to break Tie

Livelihood System and Household Economy

Livelihoods and Income

Agriculture (crop farming) and livestock production provide major source of diversified livelihood of the societies in the study areas and income generated is relatively high. Bee keeping, fishing, trading and employment as daily laborer are also supporting the livelihoods of the population in the study areas. Based on the information from group discussions, the main income source of farmers in all districts is generated from crop production followed by livestock rearing/production. It is also understood that farmers sale their crops and livestock to pay for different obligations. The major source of livelihoods and percentages of population engaged in the activities is summarized in table 21.

Table 23. Sources of livelihoods and percentage of population engaged in the activities

Source of livelihood activities	(%) Percentage of population engaged in these activities			
	Gida Ayana	Guto Gida	Horro	Bako Tibe
Crop farming	95	90	95	95
Cattle rearing	90	85	90	95
Bee keeping	25	20	25	20
Fishing	0.01	0.02	1	0.02
Trading	30	35	30	35
Daily laborer	5	10	5	15

Source: Respective districts offices of agriculture and natural resource, 2016

Assets of Farm Households

The major productive assets owned by farm households in the study areas include; livestock, Crops (perennial crops like coffee, mango, banana, khat, and etc), household equipment like furniture, radios, televisions, etc., farm equipment like plough, sickle and different type of houses (Irion/corrugated sheet roof and grass roofs).

Infrastructures

The length of gravel road in Gida Ayana district during 2015/16 was about 87 km and that of the rural road in the year 2012/13 was 19.6km connecting Kebele with kebele and with the district main town Ayana. Telephone service started in 2001/2002 at this main town of the district. From 2016 onwards the telephone and postal service in the district is expanding to its small towns and even to nearby kebeles (Table 22).

In Guto Gida district, there is no asphalt road except the one under the town administration of Nekemte and the gravel road existing in the district during last two years is about 170km in the year 2015/16. There is also 81 km rural road in the district that connects kebeles with the town and/or other kebeles. Furthermore, there were 21 semi-automatic telephone services in the year 2012/2013 and postal service agent in the district (Table 22). Secondary data indicated that Bako Tibe and Gida Ayana have better schooling compared to other study districts. Accordingly; 2^{nd} cycle, high schools and preparatory schools in Bako Tibe and Gida Ayana in the year 2015/16 were 37, 5, 2 and 46, 4, 1, respectively (Table 22).

Health institutions are very important for any development (economic, social, cultural and political) and among the basic needs to be available for a society of any nation. Farmers also perform any activities: provided that they have good health during farming, trade, & any economic and non-economic activities. Therefore, the presence of well facilitated health institutions in any district most likely show that they provide well organized health services for the communities living in and around those districts to ensure and protect the health of the society. The secondary data collected from each district; except Horro district (data was not available), owns health post, health stations and clinics at a district level. During the survey time; June, 2016 it was observed that Gida Ayana owns a hospital which is functional while Bako Tibe's hospital is under construction for many years and is not ready to be functional even for the coming year (Table 22).

Table 24. Distribution of Infrastructures of the Study Districts

Infrastructures		Distributions of these infrastructure in study districts		
		Gida Ayana	Guto Gida	Bako Tibe
All weather roads (in km)	Asphalt	None	None	25
	Gravel	87	170	112
Schools	1st cycle	20	6	57
	2nd cycle	37	29	46
	High school	5	2	4
	Preparatory	2	1	1
	TVET	None	None	None
	University	None	None	None
Health institutions	Health post	1	24	1
	Health station	22	48	22
	Clinics	1	None	5
	Hospitals	1	None	Under construction

Source: Respective district Administration Office, 2016

Markets

The study identified farmers in different districts of the study areas produce different crop varieties and reared different livestock species. Most importantly, they produce most cereal crops, pulses, oil seeds, fruits, vegetables, root crops, spices and other cash crop like coffee in all study districts with different level of production. They produce crops for home consumption and sale in order to cover their household expenses such as fertilizer, clothes, school fee and materials for their children, land use fee (tax) and others. In all districts there are village markets where mainly women sell their crop and livestock products like butter and eggs as well as chicken to purchase industrial products (oils, sugar, soap, salt and etc). Likewise, young & adult men sell their chicken and all livestock species in the local markets.

In all the study areas, market infrastructures such as shades, drinking water, feeds and other modern services for livestock and traders are lacking. The only marketing service provided at all the study areas are fenced places where to sell and buy livestock species organized by the market development office of each district to collect income tax from seller or buyers.

Cooperatives and Input Supplier Institutions

Productivity and production increase and food self-sufficiency initiatives calls for increased recognition of the importance of supply of agricultural inputs, particularly the production and distribution of high quality seed, fertilizers and other inputs. Subsequently, farmers' service cooperatives and unions in Ethiopia were established to serve their members and farmers in their vicinity in fields of agricultural development. These cooperatives or multipurpose service cooperative and unions provide services like distribution of inputs, grain marketing, grain mill, credit and saving services to their members.

In this regard, in Guto Gida, the cooperatives identified includes agricultural Service, Saving and credit, Consumers, irrigation, minerals, rural electrification and fishery cooperatives. The multipurpose cooperatives in this district possess a total capital of 22,792,954.27 birr in 2013. In Gida Ayana there are 53 different cooperatives serving the members of the cooperatives and other non-members of the society living in the district mostly in supplying agricultural inputs, construction and building material and saving and credit services. The 21 Famers' multipurpose cooperatives; which exist in the district possess a total capital of 2,376,076.82 birr in 2013. In Horro and Bako Tibe districts, farmers' cooperatives and four major unions, respectively, provide three major services which include agricultural input distribution, grain marketing and credit. Among the three unions in Bako Tibe, Bore Bako union is the strongest of all in terms of financial and institutional arrangements. Private investors also supply inputs mainly improved seeds in this district. Such private seed suppliers were not reported in other study districts except for Guto Gida where private traders supply improved maize seeds.

Oromia Credits and Saving association, Wasasa, cooperatives and private traders (with and some times without interest) are the main sources of credits for farmers in the study areas. These credits are commonly used for purchase of agricultural inputs, household expenditure (credit from private only), fattening of different livestock (cattle and small ruminants), poultry production and etc based on the busines plan proposal submitted to these service providing institutions. The amount of credit depends on the amount of saving at their disposal and long time membership with in these credit and saving instituttions especially for Oromia Credits and Saving associations. Collaterals like assets such as land, home, number of livestock, etc are the other important requirement considered for the credit to be arranged by the association. For example, Oromia Credit and Saving association follow the regulation for the credit to be arranged with the interest rate of 17/100 birr.

Farm Household and their Survival Strategies

It is already discussed that the main livelihoods of farmers in the study areas are crop production and livestock rearing with very few support coming from activities like fishing and small trading. Never the less, there is inadequate food supply in some months particularly (rainy season) of the year. Farmers use all their crop produce for seed and sale to purchase agricultural inputs during the summer/rainy season in addition to using different mechanisims like selling small ruminants (sheep and goat) to get cash. Moreover, considerable number of them are employed as daily laborers, some of them borrow crop or take loan from the relatively wealthy farmers to replace in kind and allivate the food shortage epecially during this season and pay back after the harvesting season.

In all the study areas, there is fluctuation of rainfall onset and early off set of rainy seasons that results in decreases of production and productivity of crops and livestock as well as dry up of springs and some streams though drought is not common. Therefore, during such hardship period farmers of the study areas use large rivers for livestock watering and still some streams which tolerate the dry season are used for human drinking water.

Gender Roles and Decision Making

The study indicated that due to socio-cultural barriers, there exist huge gender imbalance between men and women in the study areas. Women and child girls are the most disadvantaged in rural areas regarding access to resources, income, education and other services for very long time generally in the country. But due to the strong and unlimited involvement from governmental and non-governmental organizations, the stated scenario is gradually improving.

According to the study, the resource ownership and decision making is currently made by consultations between husband and wife. Any private action by the husband on property without the knowledge and agreement of the wife can take him to court that could even result penalty. Nevertheless, the family members like young boys and girls are yet not part of decision making unit though they can share their idea on decision making which may or may not be accepted by their parents. On the other hand, if these young boys and girls are educated (at least attended high school or higher commission), they highly influence the decision made by their parents getting consideration and respect by their families.

The unsolved gender imbalance between women and men especially between young girls and boys were the work division among the gender. Cooking and processing foods, milking, making cheese and butter, cleaning homes, fetching water from river or stream, taking care of babies, etc. are solely the works of women or young girls. Such types of works are taboo for men and young boys in all the study areas.

Nutrition

Human nutrition refers to the provision of essential nutrients necessary to support life and health. Poor nutrition is a chronic problem often linked to poverty, deficient sanitation and food insecurity. Lack of proper nutrition contributes to lower academic performance and less success of students, lower agricultural production, finally a less productive and poor competitive economy. Malnutrition and its consequences are immense contributors to deaths and disabilities worldwide. Promoting good nutrition helps children growth, promotes human development and advances economic growth and eradication of poverty (https://en.wikipedia.org/wiki/Human_nutrition).

Main food crops utilized in the study areas are teff, wheat, barley, maize, finger millet, sorghum, potato, faba beans, field beans, cabbages and other crop types. The major food crops vary from one agro-ecological zone to the other. Cereal crops are processed to make *injera* or "*budena*", bread, porridge, "chumbo", etc. These food items would be eaten in combinations with main livestock products like milk, butter, meat, cheese, yoghurt, egg, and oils from pulse crops. The combination of crop products with livestock products to utilize as daily diet varies from one farm household to the other depending on the relative wealth status of those farm households. In all the study areas, the more the wealthier the farm household, the more the combination of consumption food items consumed were observed.

Climate Smart Agriculture (CSA)

FAO defines climate smart agriculture (CSA) as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes greenhouse gases (mitigation) where possible, and enhances achievement of national food security and development goals". In this context mitigation means a human intervention to reduce or prevent emission of greenhouse gases (e.g. by using renewable energies, improve energy efficiency, changing management practices or consumer behavior) or to protect (e.g. forests and oceans) or create carbon sinks (e.g. through conservation agriculture or agro-forestry). Therefore, CSA is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change (FAO, 2013).

It is clear that while agriculture is the sector most vulnerable to climate change, it is also a major cause of climate change, directly by global greenhouse gas (GHG) emissions, and indirectly much more as agriculture is also the main driver of deforestation and land-use change. FAO stated that even if emissions in all other sectors will be eliminated by 2050, growth in agricultural emissions in a business-as-usual world with a near doubling in food production would perpetuate climate change (FAO, 2013).

To cope up with the challenges of climate change, crop production must adapt (e.g. crop varietal selection, plant breeding, cropping patterns and ecosystem management approaches) and become resilient to changes (frequency and intensity) according to CSA principles. Climate-smart crop production contributes to food security through different aspects of current and projected climate change impacts applying adaptation and mitigation activities. Greenhouse gas (GHG) emissions could be reduced with caution or less use of inorganic fertilizers, avoiding soil compaction or flooding to reduce methane emissions and sequestering carbon (e.g. planting perennial crops and grass species).

Adapting such cropping practices and approaches will be related to local farmers' knowledge, requirements and priorities. Sustainable crop production provides farmers with options for farming sustainably, taking into account the local ecosystem. Integrated approaches, such as crop-livestock systems, and agro forestry- diversify food sources and consequently strengthen the resilience of farmers' livelihoods as well as provide opportunities for mitigating climate change.

In all the study areas, even though awareness of farmers about their environment is changing (mainly the change in onset and duration of rainy season for crop production), their determination to improve this scenario is inadequate. In all the study areas, deforestation was reported as the main problems for the purpose of crop land expansions. As a result; flooding, different types of soil erosion, soils fertility loss, dry up of streams and other direct and indirect impact on climate change were observed in all districts under the study. Particularly, Bako Tibe and Horro high land farmers are expanding their farm land to very steep slope areas causing sever erosion and landslides. There are various reports of afforestation from the study areas, neighboring districts and zones every year. Nevertheless, the survival rate of those transplanted/planted seedling was negligible due to poor post planting management and thus high flooding, land slide and deforestation are not minimized as much as required.

Diverse early maturing crop varieties have been under adoption to cop up with the ever changing climatic situations with various degree of efforts in all the study areas. Farmers have been using different soil fertility managements like applying organic manures, compost, inorganic fertilizers, crop rotations and different soil conservation mechanisms. The main production system in the study area is mixed production of crop and livestock. Both of them are mutually complementary to each other where livestock provides traction power for land preparation, manure for soil fertilization, transport service for input and output and power for threshing of crops. Whereas, crop also provides feed for livestock. Such type of situations in the study areas supports the climate smart agriculture. The study indicated that the livestock can make large contribution to climate-smart food supply systems by providing mitigation options available along the entire supply chain. Their roles in adaptation practices relate primarily to the management of organic matter and nutrients and the diversification of incomes.

Conclusions and recommendation

The present Participatory Rural Appraisal (PRA) study prompted smallholder farmers to explain their past and present agricultural production situations; major challenges facing agricultural productions and natural resources endowment, livelihood and socio-cultural matters and their aspiration in the future. The tool improved active participation of farmers in problem identification and prioritization, close interaction between researchers and farmers, the potential usefulness of farmers' to contribute more directly and creatively to the design and evaluation of new technologies. Besides, PRA techniques improved the potential of researchers in systematization of farmers' knowledge and opinions, understanding the actual researchable and non-researchable issues and problems existing at community level and take-home assignment to work with and for farmers.

Farmer's interest to implement improved agricultural technologies for grain production is gradually increasing due to the continuous effort of governmental and non-governmental organization on awareness creation. However, the rate of adapting and adopting improved agricultural technologies are still stagnated and limited coverage. This is mainly due to weak research extension and scaling-up system.

Farming systems currently implemented by farmers are strongly biased towards short-run productivity. This will leads livelihood towards demolishing the long-run ecologically sustainable farming system. Therefore, researchers and development partners should be highly concerned about possible conflict between strategies designed to improve short-run productivity and those aimed at ensuring long-run ecological sustainability. This should be coincided with the current farming system of study areas with the farming systems approach into natural resource-related issues. This approach should also be implemented in line with the current CSA system to conduct adequate research findings for the various agro-ecology, soil type, rainfall pattern, farming system, temperature and moisture ranges.

Rain-fed agriculture is the dominant and almost the only crop production system across all study districts. Erratic and intermittent rainfall occurring in most of the study districts affected farm gates and livelihoods of farmers.

All the study areas were endowed with relatively abundant water resources, favorable climate and potentially irrigable land. But the actual achievements are almost negligible. Despite the potential available to intensify irrigation farming, almost all crops are grown under rainfed condition and crop production is dominated by cereal (maize, teff, sorghum, wheat and barley). The productivity of crops other than cereal is low when compared to other areas of the country. Therefore, diversification of crop production and strengthening the irrigation sector institutionally, financially and technical capacity is paramount. Low cost water harvest and irrigation technologies such as construction of earth dams, river diversions, and hand pumps should be expanded and encouraged. On the research side, crop varieties and management practices for irrigated agriculture should be given due emphasis. Moreover agricultural research approaches towards small scale irrigation schemes should be also improved accordingly by identifying the major gaps of this sector.

The priority areas for crop production practices include: assessment of seasonal cropping calendar of each study district, updating and popularizing good agronomic practice, integrated soil fertility improvement, Post-harvest managements and pest managements. Those crop management practices are directly or indirectly Climate Smart Agriculture (CSA) technologies

CSA also involves innovative practices such as improved weather forecasting, early-warning systems and climate-risk insurance. CSA aims to get existing technologies off the shelf and into the hands of farmers, as well as to develop new technologies such as drought-tolerant or flood-tolerant crops to meet the demands of the changing climate. Therefore, any tactics designed to improve agricultural practices should include integrated watershed management, integrated soil fertility management, sustainable land management, conservation agriculture, agroforestry, crop residue management, composting, promotion of improved livestock feed and rangeland management.

It is inconceivable to think of increasing agricultural production without the use of improved, high yielding and disease resistant seeds of crop varieties. In all study districts most farmers still depend primarily on farmer-to-farmer exchanges or saved seed. For improved open-pollinated varieties such as wheat and teff, farmers do not necessarily need to purchase seed each season as they would do for hybrid maize. Local varieties currently at the hand of farmers are low yielding and susceptible for pests and diseases. The development and dissemination of improved varieties are of utmost importance to boost agricultural production. Therefore, research priority regarding improved seed must focuses toward generating of stable, high yielding, biotic and abiotic stress tolerant varieties. In line with this research approach seed multiplication, delivering and supply system should also be improved targeting on the need of farmers.

Improved agronomic practices such as fertilizer and seed rate, weeding and plowing frequency, planting method for each crop should be also implemented based on research recommendations. Inorganic fertilizer supply and use by farmers are other major constraints of agricultural inputs of study districts. High price of fertilizer, reliance of farmers on in-organic fertilizer, untimely supply of fertilizer, use of fertilizer regardless of recommended application rate and time of application is the prioritized constraint regarding fertilizer issues. Fertilizer need assessment and supply chains should be focusing the real need of small holder farmers. The price of this fertilizer must consider the purchasing capacity of farmers. Remote sensing, GIS and actual soil nutrition test based fertilizer supply and recommendation should be strengthened in order to enhance economically and ecologically feasible crop productivity.

The favorable environmental condition for crop production in the study areas also create conducive environment for pest resurgences. Abundant weed flora, different species of insect and complex disease pressure frequently occur in the study districts. Early scouting of pest pressure helps to take immediate intervention before disease outbreak (economic threshold level). Regular inspection and detection of pest in farmer’s field should be focused and immediate management options should be availed for farmers. To this end, pest management practice of the study areas is mostly traditional and fail to kill the target pest. Weed management is mostly by hand weeding and use of herbicides. Insect and disease management is rarely practiced using pesticide options and field sanitation.

Any intervention for confrontation of pest pressure should have Integrated Pest Management approach that includes all possible pest control measures such as Cultural, Physical, Biological and chemical means. Agro-pesticide technologies, including insecticides, fungicides and herbicides, formed one of the driving forces behind boosting crop productivity. Coupled with high-yielding crop varieties and increased land for crop production, significant yield improvements were achieved (Hoi *et al*. 2013; Ahouangninou *et al.* 2012). However, this PRA based study indicated that much misuse (abuse and overuse) of pesticides by farmers were reported particularly when applying to control storage pest and weeds. These problems can be attributed to farmers’ lack of technical knowledge, the absence of extension services and lack of training on safe pesticide use. Addressing the problem of pesticide misuse requires the active involvement of important stakeholders such as environmental protection, NGOs, agricultural researchers, health practitioners, private entrepreneurs and agrochemical companies to provide training and technical support for farmers, hired sprayers, retailers and extension workers. Mandatory prescription for pesticide sales could be a mechanism for safe selection, handling and use of pesticides and reduce pest resistance, environmental risks and human exposure.

The major research intervention on areas of natural resources conservation practices including: reducing termite infestation via planting termite tolerant tree and grass species, reduce deforestation, practicing biological and physical soil and water conservation structures on agriculture and abandoned lands, and practicing any conservation techniques that helps to rehabilitate degraded lands are the major focused areas which need intervention. In line with this, land use policy must be implemented in the country and particularly in the study areas to avoid the problem of ploughing mountainous lands which is highly aggravate for soil erosion and land slide. Finally, practicing conservation agriculture is also another intervention techniques which helps to minimize the problem of mono-cropping through practicing crop rotation, maintain crop residues, and minimum soil disturbance are some of the major intervention areas regarding to maintain the potential of natural resources.

Livestock production in the study villages are mainly based on production of indigenous livestock breeds. Livestock are commonly used for draft power; sources of meat, milk and eggs; sources of cash income and also provide manure for crop production. However, the productivity level of all livestock species is very low. The present PRA discussions identified different constraints that affect productivity of livestock sectors. Thus it is important to design an intervention that would alleviate the prevailing livestock production constraints so as to enhance the productivity and contribution of the livestock resources to the livelihood of the households in the study area. To this effect, it is suggested that future interventions take the following issues into consideration.

Shortage of feed in terms of quantity and quality are the most important constraint for all the study kebeles. Naturally occurring and collected feeds are the main feed resources and their availability varies highly from season to season. The availability and use of improved forages and concentrate feeds is insignificant. Since cereal crop is the main crop grown in the area and green feed is in excess during some months, introducing conservation of crop residue with urea/effective microorganism treatment and silage making would be an important entry point. Introduction of new forage species and strengthen the fodder development practices already existing in the area by providing continuous training and linking to strategic feeding practices. Introduce appropriate crop residue management and fodder conservation methods when green feed is in excess during some months. Provide farmers with training on appropriate utilization of available feed resources and establishment and use of improved forages. The study identified that forage development at farm household level was not adopted well by majority of the farmers in the study areas mostly due to poor extension system on this commodities. Therefore provision of strong extension services and training on improved forage and fodder trees had better option.

Livestock management practices in the study areas are mainly based on the traditional knowledge of the farmers and limited/no skills in improved livestock management practices. Therefore, rearing and keeping of larger number of livestock should be based on modern rearing practice. Indigenous livestock species (cattle, sheep, goat and chicken) have poor production and reproduction performance. Provision of improved livestock species, selection breeding of indigenous animal those having genetically superior and adaptive to the environment are some starting point for livestock development.

Major animal diseases, particularly on cattle such as trypanosomiasis, anthrax, blackleg and foot and mouth disease (FMD), and parasites were identified through PRA group discussions in all districts. Chicken are severely affected by fowl cholera, Newcastle disease and predators while sheep and goat pox, contagious caprine pleuropneumonia (CCPP), FMD and Foot rot are major challenge in sheep and goats. Ticks, mites and flies are reported as major external parasites whereas gastrointestinal nematodes and liver fluke are major internal parasites causing considerable loss of animals in these areas. Therefore, intensive epidemiological studies, validation of ethno-veterinary practices, establishments of veterinary clinics and promotion of veterinary services are some possible solution. Absence of veterinary clinics and service, lack of drug supply in veterinary clinics, high price of veterinary medicine, shortage of skilled human power and capital to purchase medicines are factors contributing to severity of animal diseases in the study areas.

Bloat and circling disease are also identified as major health problems which are common gastrointestinal disorder that causes sudden death of ruminant in the study areas when animals graze lush grass in and around the marshy areas. For frothy bloat, antifoaming agents that disperse the foam should be given by stomach tube. Old-fashioned remedies such as linseed oil and turpentine are effective but newer treatments such as dimethicone or polaxolene are easier to give as the effective dose is much smaller and also passing a stomach tube is the best treatment for gassy bloat. Once the gas has been released, the cause of the obstruction should be looked for.

Circling disease is a major problem of small ruminants in the study areas mainly in sheep and goat most probably caused due to coenerus cerebrals as respondents confirmed that they frequently found the cyst when the head of dead animals opened. Therefore to identify the causative agent, the assessment is paramount important.

Mastitis was reported to be the most severe disease of high prevalence in the study areas resulting in decreased milk yield, premature culling of cows, milk discard thus needs high treatment; while high incidence of lumpy skin disease was also reported in calves and dairy cows. The poor hygiene of cows' shelter, shortage of space and absence of mastitis control measures such as udder disinfection and dry-cow therapy, as well as low level of management were discussed with various groups as the major reasons for the high prevalence of mastitis in the study areas.

Artificial insemination services practice in the study areas have been very poor efficiency and effectiveness most likely due to the accessibility and distance to AI station, limited capacity of AI technicians, poor body condition of inseminated animal and poor facility for AIT. Therefore strong attention should be given on artificial insemination service. Awareness creation of farmers on heat detection of animals, controlling from local bulls and timely presenting animal on AI service station and communicating with AIT. Training of AIT, synchronization and insemination of good body condition animal are some possible solution for improvement of AI of cattle. Livestock products (milk and milk products, meat and honeybee products) processing, handling and transporting is entirely based on traditional practices though the farmers of these areas are highly enthusiastic to use improved technologies. Improved Livestock products handling and processing technology should be introduced to small holder farmers and different end-users. The major constraints of fishery production in most of the districts of the study areas are lack of knowledge on fish production, management practices, feeding system of fish and lack of knowledge on appropriate species for warm and cold water. Therefore strong extension service should be given on fish production, management and feeding system technologies.

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White Mango scale (*Aulacaspis tubercularis Newstead*): the most production constraint of Mango and its Management options

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Introduction

Mango (*Mangifera indica* L) is a fruit crop known to have originated in tropical Asia and distributed to other tropical and sub topical areas of the world, following human distribution (Dirou 2004; Crane *et al.*, 2013;Ubwa *et al*., 2014). Following citrus and banana, mango is the third most important fruit crop in the tropics (Louw *et al.* 2008). The mango commonly known as the *king of fruits* is the most popular and relished fruit. Mango grows well under a great variety of hot, humid and temperate climatic conditions in over 100 countries of the world.

Introduction of mango to east Africa dated back to 10th century, when the Persian traders who used to visit the region for business purposes had brought the seed (Ofgaa, 2014). The total production area of mango in the world is around 5.64 million hectares and produces 45.25 mill. tonnes. Asia accounts for approximately 76% of global mango production and the Americas and Africa account for approximately 13% and 11%, respectively (FAO, 2014). The leading world mango producer is India followed by China and Thailand. Mango is traditionally grown in Ethiopia primarily for family consumption and local markets, but some emerging modern farms have started to produce mango for both local and export markets (Alemayehu *et al*. 2014). Ethiopia exports mango to Djibouti, Saudi Arabia, Yemen, Sudan and the United Arab Emirates (Tewodros *et al*. 2009).

The mangoes are grown on largest area in Ethiopia second only to banana of fruit crops. It covers about 14,791 ha with a total production of 100,351 tonnes. Mango production is steadily expanding in Ethiopia. However, its productivity is below the international average. Oromia shared 45.3 % in area coverage and 44% of the yield produced mangoes of the country (CSA, 2016). The three leading mango producing zones of Oromia according to the CSA (CSA 2016) are west Wellega (1390.38 ha); Jimma (1229.27 ha) and Ilu Aba Bora (1200.01ha).

The practice of mango production in Ethiopia is generally unprofessional (Yilma, 2009; Seid and Zeru, 2013). Absence of patterns and recommended spacing, growing mangos with bushy and weak branches, practice of harvesting the fruit after peak maturity and consequent short shelf life, none or very rare introduction of improved varieties are some of poor management practices of mango. Furthermore, mango production in Ethiopia was reported to have been constrained by various pests and diseases, and yet management practices such as pruning and application of insecticides are not put in to effect (Tewodros *et al*., 2014).

Mango production is constrained by a variety of pests and pathogens. In Ethiopia, thrips, fruit flies, termites, and various fungal diseases constrain mango production, in the absence of proper management practices (Tewodros *et al.*, 2014). The Tephritid fruit flies, an enormous threat to fruit production throughout the world (Mohamed, 2003) have been the only major economically important insect pest of mango in Ethiopia (Tsedeke, 1994, Ferdu *et al*., 2006). However, among mango insects white mango scale which was the most devastating insect of mango in Ethiopia (Ofgaa *et al*., 2017).

Importance of Mango

Mango is the third most important fruit crop in the tropics after citrus and banana (Louw *et al.*, 2008). In Ethiopia it is the second fruit crop next to banana (CSA. 2016). Mangos are a highly nutritious fruits containing carbohydrates, proteins, fats, minerals, and vitamins, in particular vitamin A (beta carotene), vitamin B1, vitamin B2, and vitamin C (ascorbic acid), and especially phenolic compounds (Nabil *et al.*, 2012). Mango fruits are very much relished for their, exotic flavor and delicious taste. Mango serves as a fruit crop and as a subsistence crop for family farms (Yilma, 2009). Mango is widely consumed as a fresh fruit and various forms of beverages. Mango possesses antidiabetic, anti-oxidant, anti-parasitic, cardiotonic, hypotensive, anti-inflammatory and antispasmodic properties (Shah *et al*. 2010).

Mangos can be processed into a number of unique products such as dried mango pieces, chutney, jam and mango leathers (Azeredo, *et al.*, 2006). Apart from its economic importance, it is forest and environmentally friendly to fight against drought, use as shade and fire wood. The role of mangoes in environment, source of income, food security, agro industry, export, etc is high (Yilma, 2009; Ofga and Emana, 2015).

Mango production is constrained by a variety of pests and pathogens. Medina and Garcia (2002) depicted that over 492 species of insects, 17 species of mites and 26 species of nematodes were reported to have been damaging mango trees. Of 260 species of insects and mites that have been recorded as minor and major pests of mango, 87 are fruit feeders, 127 are foliage feeders, 36 feed on the inflorescence, 33 inhabit buds, and 25 feed on branches and the trunk (Pena *et al*., 1998). Moreover, pathogenic fungi and bacteria cause diseases to mango plantation (USDA, 2006).

In Ethiopia, thrips, fruit flies, termites, and various fungal diseases constrain mango production, in the absence of proper management practices (Tewodros *et al*., 2014). Mango anthracnose, caused by *Colletotrichum gloeosporioides* was reported to be 100% prevalent in the humid agroecology of southwest Ethiopia, and found causing severe damage to the fruit crop (Ayantu *et al*., 2014). White mango scale is among insect pests inflicting damage to mango in Ethiopia (Alemayehu *et al.*, 2014; Ofgaa and Emana, 2015).

White mango scale (*Aulacaspis mangiferae* Newst.)

White mango scale (*Aulacaspis mangiferae* Newst.) is a pest of mangoes and causes damage throughout the year. Since mango *(Mangifera indica* Linn. Anacardiaceae) appears to be the only host plant, the name *Aulacaspis mangiferae* is preferred to *Aulacaspis tubercularis* (= *cinnamomi),* although it is not certain whether these are different species (Brown, 1965). White mango scale is a tiny armoured scale which feeds on plant through sap sucking (Abo-Shanab, 2012). There are records of the *Aulacaspis tubercularis mangiferae* group attacking Lauraceae, Sapindaceae and Anacardiaceas (particularly *Mangifera indica)* from many Mrican, Asian and Latin-American countries. In Ghana, *Aulacaspis mangiferae* is more numerous in the coastal savanna than in the interior savanna zone. The insect normally feeds on the upper surface of the leaves and young stems. It is also found on peduncles, lower leaf surfaces and fruits.

Scale insects injure mangoes by feeding on the plant's sap through leaves, branches and fruits. Direct damage by scale insects results in defoliation, drying up of young twigs, and poor blossoming. Direct damage also affects the commercial value of fruit and their export potential. Some species of scale insects excrete honeydew, which accumulates on the upper leaf surfaces. Under damp conditions, this honeydew can be colonized by a black, non-parasitic fungus known as sooty mold which decreases photosynthesis by the leaves. In addition, because scale insects are often difficult to control and remove from produce such as fruits, they are of quarantine concern, requiring management to prevent their spread through export of plant products (Miller *et al.* 2005).

This insect pest affected the production and expansion of mango in Ethiopia. According to the information obtained from farmers, they are harvest up to 10qt of fruits per tree before the occurrence of this new insect pest. But the current condition of the trees suggest that fruit yield of 2-3qt per tree may not be obtained due to the heavy infestation of white mango scale (Tesfaye *et al*, 2014). The insect infested mango at all stages, including improved varieties at Green Focus Ethiopia causing yellowing and drying of leaves, leaf drop and die-back of twigs. Mango trees that affected by white mango scale insect, especially mango plantation of small holder farmers production was becoming less productive and low in quality as well (Temesgen, 2012).

Biology of White Mango Scale Insect

White mango scale of the Order Hemiptera, Super family Coccoidea, Family Diaspididae, and Genus *Aulacaspis* is known by its accepted name *Aulacaspis tubercularis* Newstead, 1906 (Varshney *et al*., 2002). However, this inset was named by several different names at different time, namely, *Aulacaspis cinnamomi* Newstead, 1908, *Aulacaspis cinnamomi mangiferae* Sasscer, 1912, *Aulacaspis mangiferae* MacGillivray, 1921, *Aulacaspis sinnamomi* Kuwana, 1926, *Aulacaspis tubercularis* Sanders, 1909, *Diaspis cinnamomi* Hall, 1928, *Diaspis cinnamomi mangiferae* Newstead, 1911, among others (http://scalenet.info/catalogue/Aulacaspis %20tubercularis/).

A variety of sexual and asexual modes of reproductions are present in scale insects (Ross *et al*., 2012). Hermaphroditism is among the sexual modes of reproduction in this group of insects. Adult female of some scale insects may lay eggs or give birth directly to live first instars (Gyeltshen and Hodges, 2006). The development of female scale insects undergo incomplete metamorphosis with a total of three to four instars; whereas the male passes through five instars exhibiting a metamorphosis which resembles complete.

The overall generation time (from egg to egg) is reported to be 35-40 and 23-28 days in the female and male white mango scales, respectively, indicating relatively longer period in the female (Halteren, 1970). Females lay 80 to 200 eggs depending on temperature. After hatching crawlers move to feeding sites settling within 24 hours. Female crawlers settle randomly, male crawlers settle in groups close to females. Up to 80% of crawlers become males (Abo-Shanab, 2012).

White mango scale secretes waxy protective covering under which it lives and feeds. The coat is attached to the plant surface, while the insect is free within the cover. The waxy cover is tough; thus, white mango scale is known as armoured or hard scale insect. Sizes of scale insects range from 1.5 mm to 25 mm in length, and they also vary in shape and colour (Varshney *et al*., 2002; Moharum, 2012). The body of fully-grown adult female *rosae* type, as its prosoma (the fused head, prothorax and mesothorax) is swollen and wider than the postsoma (the fused metathorax and abdomen) (Takagi, 2010). Adult female has no wings for movement and glues itself to the plant by the use of its armour and remains sucking sap from the plant tissues. The male mango scale possesses one pair of wings. They occur in groups gathering around the female, while the female usually occurs singly (Ben-Dov, 2012).

Post embryonic development of the white mango scale comprises of two larval instars and an imago in the female, and two larval instars, two pupal instars (prepupa, pupa), and an imago in the male. The sex of the organism can easily be determined in the first instar (Labuschagne, 1993). White mango scale can produce five to six generations per year, at a maximum day time temperature of 26°C and night time minimum of 13°C. The eggs hatch in 8 days, producing red-orange nymphs or crawlers that spread to branches, leaves, and flowers and attach themselves to feed on plant tissue where they grow and reproduce.

The newly hatched nymph has well developed functional legs, antennae and eyes. Claws and tarsus on the legs have setae. The presence of such structures may help the nymph to attach itself to body of other animals to disperse phoretically. It was reported that crawlers of armoured scale insects could remain attached to flying insects for certain periods of time, which may be an indication that phoresy might help them disperse (Magsig-Castillo *et al*., 2010).

Geographical distribution of white mango scale

The mango scale, *Aulacaspis tubercularis*, is found throughout the world where mango is cultivated, including the northern part of South America, the Caribbean, the east and west coasts of Africa, and India, and Italy. The scale is distributed in more than 60 countries in tropical Africa, Oceania, South America, the Caribbean, and Asia, where it feeds on more than 40 plant species (www.plantwise.org). It was recently introduced into mango in Nayarit, Mexico. In South Africa, *A. tubercularis* was first recorded on one cultivar of mango in 1947 and has since become a pest throughout all mango producing areas of South Africa (Joubert *et al.*, 2000).

Occurrence of white mango scale in Ethiopia was first reported in August 2010 in an orchard of the Indian company Green Focus Ethiopia PLC in western Ethiopia (Mohammed et *al*., 2012). The pest was identified in April 2011 by Gillian Watson (California Department of agriculture, USA) as White mango scale, *Aulacaspis tubercularis* newstead, 1906 (Hemiptera: Diaspididae) (Mohammed *et al*. 2012). The pest had not remained confined to western Ethiopia where it was first observed. It was intercepted from mango seedlings brought from elsewhere in June 2013 at Melkassa Agriculture Research Center (Gashawbeza et al. 2015). However; he indicated it was destroyed while the seedling was in the nursery. He also indicated that white mango scale insect was noticed in Eastern Ethiopia (Adama district) in 2015. *A. tubercularis* was also intercepted in Tigray region of Ethiopia from seedlings purchased from Arbaminch area of southern Ethiopia for plantation purpose (Gashawbeza, 2014). Survey made by Babege et al (2017) indicates white mango scale insect was intercepted in south Ethiopia, Bench-Maji zone.

Hosts of white mango scale

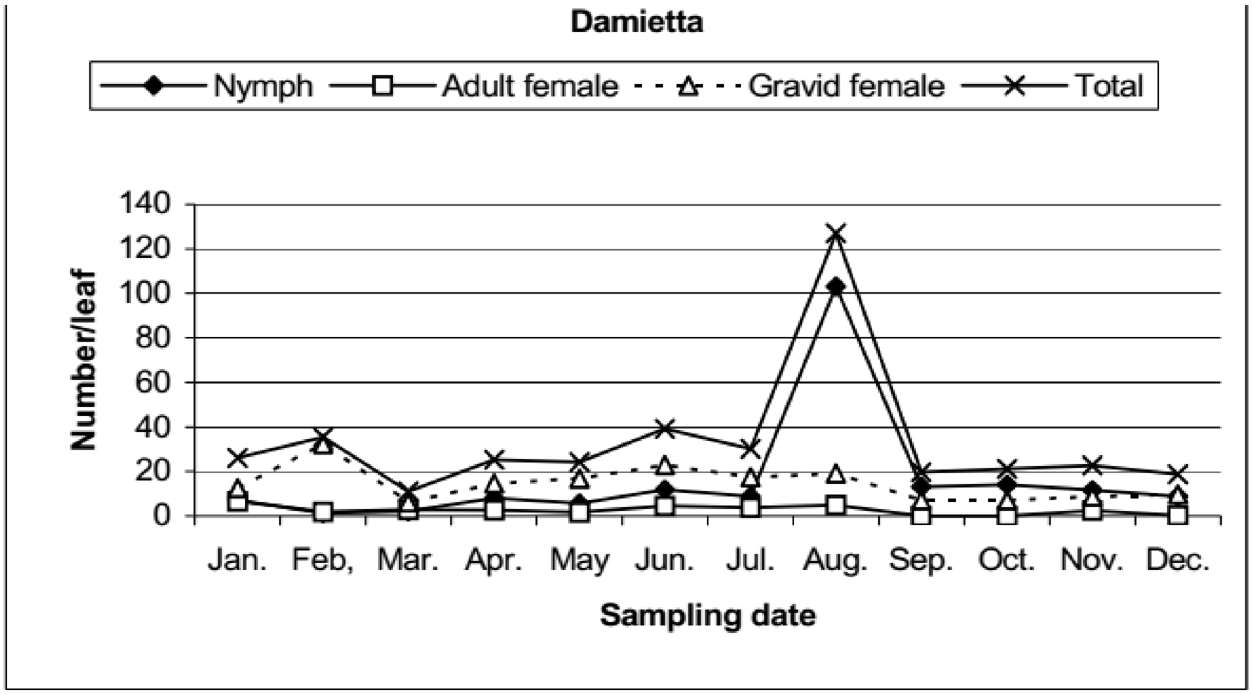
White mango scale insect is polyphagous, feeding on plants belonging to 18 families and serious pest of mangos (Stocks, 2013). The white mango scale insect has been recorded mainly from host plants belonging to four plant families: Palmae, Lauraceae, Rutaceae and Anacardiaceae (Borchsenius, 1966). This insect is a serious pest in mango (Fam.: Anacardiaceae) especially on the late cultivars. *Aulacaspis tubercularis* attacks hosts in at least seven plant families. Mango is one of many hosts reported with significant losses, especially in Brazil, China, India, and Pakistan (Hodges and Hamon 2004).

Population Dynamics of White Mango Scale Insect

Population of white mango scale were studied in different parties of the world. It was affected by direction within canopy, surface of leaves, season, level of the tree, temperature, rainfall. Several studies showed the effect of temperature on dispersion, distribution, and reproduction of insects, as well as increased longevity, resistance to insecticide, reproductive cycle, fertility, population size, and sex ratio (Grossen et al. 2010).

In Egypt Mostafa *et al.* (2011) indicates that total population white mango scale has peak at August in 2010 at Damietta governorate and at April in Gharbya in the same year (figure 1). As shown in Fig. (1), in Gharbyia governorate, the total population of this pest recorded two peaks with 48.9 and 32.6 individuals at April and July. While in Damietta governorate these were three peaks recorded at February, June and August when 35.5, 39.1 and 127.1 individuals /leaf were recorded. Females were most abundant between 18 and 22°C and 73 and 78% relative humidity, while males were most abundant between 25 and 28°C and less than 70% relative humidity. More of females prefer temperature between 21 and 23°C.

In cardinal direction the highest total population of white mango scale occurred at the south direction of the tree. While Mostafa *et al.* (2011) indicated that the armored scale insect, *A. tubercularis* and its natural enemies concentrated in eastern side of the trees.



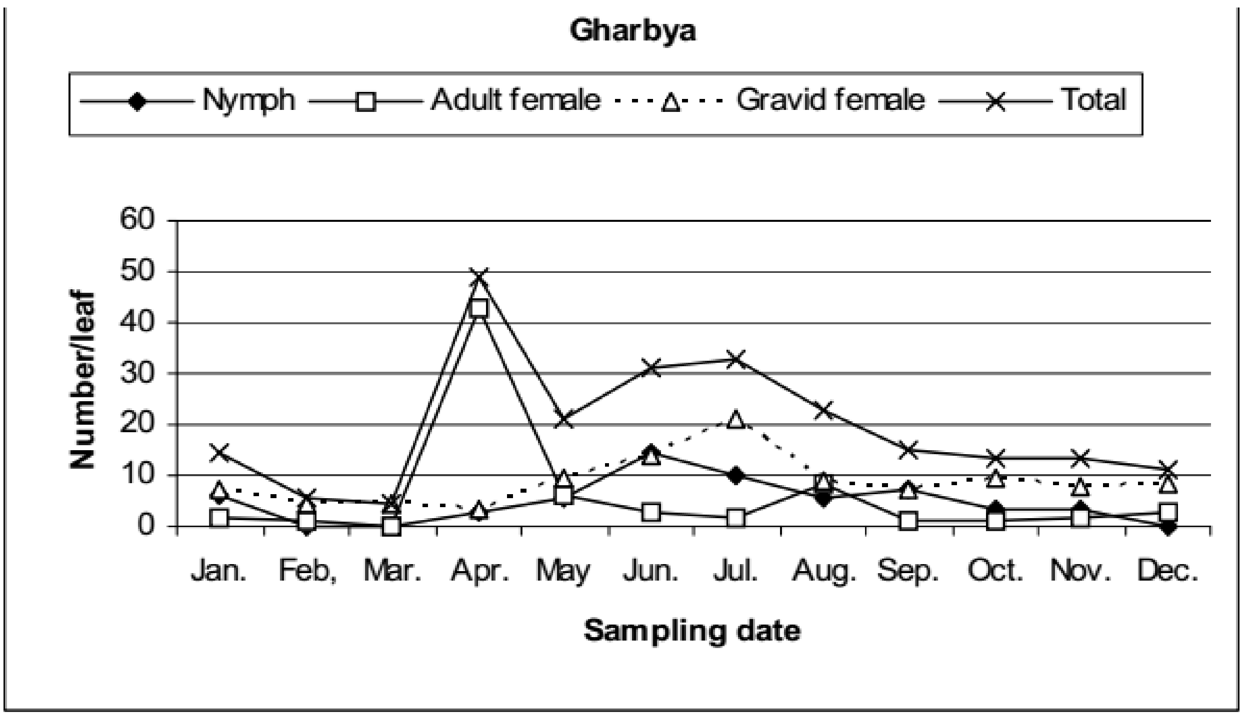


Figure 1: Population fluctuations of *A. tubercularis* stages in mango orchards at Damietta and Gharbayia governorates during 2010 year

Mostafa *et al.* 2011 indicated that population *A. tubercularis* and relative humidity and temperature were not significantly correlated. However, relative humidity significantly correlated at Damietta.

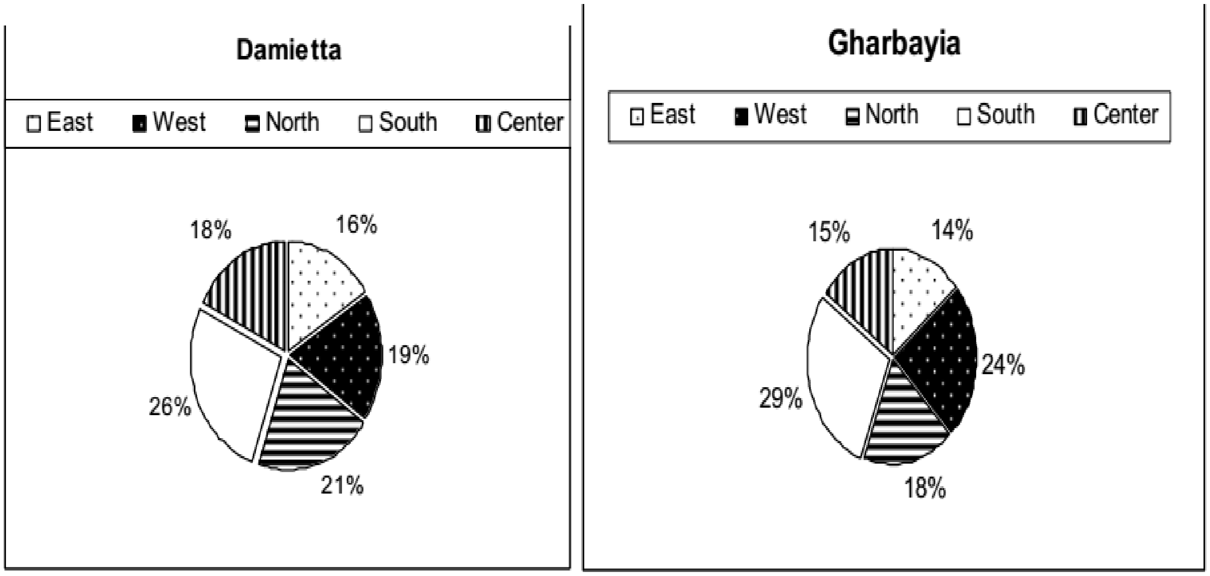


Fig. 2: Present of *A. tubercularis* at different cardinal directions (north, south, east and west) and center of mango tree canopy all over 2010 year at Damietta and Gharbyia Governorates.

Males were mostly in the lower canopy of the trees, while females were distributed more homogenously. But as the temperature warmed, females moved toward the lower canopy, which is the coolest area of the tree (Bautista-Rosales *et al*., 2013).

A. tubercularis preferred the upper surface of leaves during the cold months and preferred the lower surface of leafs during the hot months. This may be attributed to the address effect of the sun rise during the hot months (Mostafa et al 2011). Nabil *et al.*, (2012) indicated that total number of alive stages white mango scale with light intensity and temperature negatively correlated at both upper and bottom level of mango trees. Also it was showed that total white mango scale mortality were highly negatively correlated with light intensity and temperature (Table 1).

Populations of A. *tubercularis* began to grow from around March and increased to the maximum values in April and May when precipitation started to increase. However, the population size of *A. tubercularis* dropped in Bako, during heavy rains of June and July that probably washed out the crawlers (Ofgaa *et al.*, 2017) and in Mexico (Urias-Lopez *et al.*, 2010). Both *A. tubercularis* and *Chilocorus* sp. (the predatore) populations reached their peaks in April and May with a drastic decline from august to February, when precipitation was low or entirely absent (Figure 3).

Table 1: Correlation coefficient (r) indicating the effects of climatic factors on different stages of *Aulacaspis tubercularis* and its natural enemies on mango trees (Nabil *et al.* 2013)

	Temp (^{O}C)		RH (%)		Light intensity(Lux)		Explained var.		Combined effect	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom		
Year 2007-2008										
Number of females	-0.33	-0.318	0.218	0.235	-0.671	-0.689	63.14	68.80		
Number of males	-0.44	-0.418	0.262	0.913	-0.744	-0.774	65.56	80.76		
Number of nymphs	0.403	0.223	0.309	0.081	-0.012	-0.172	51.01	50.40	RH%	Light inten
Total no. of alive stages	-0.374	-0.367	0.266	0.195	-0.702	-0.736	63.19	77.66	Temp -0.048	0.817
Total no. of dead stages	-0.812	-0.854	0.322	0.258	-0.960	-0.937	92.46	90.22	RH%	-0.347
Total mortality %	-0.917	-0.939	0.193	-0.020	-0.845	-0.753	87.39	88.68		
Predator pop.	0.820	0.885	0.285	0.332	0.540	0.619	78.07	92.46		
Parasitism %	-0.661	-.0635	-0.350	0.075	-0.273	-0.351	67.63	54.14		
Year 2008-2009										
Number of females	-0.635	-0.557	-0.207	-0.243	-0.718	-0.560	51.72	33.68		
Number of males	-0.478	-0.593	-0.164	-0.249	-0.607	-0.631	38.44	41.13		
Number of nymphs	-0.506	-0.404	-0.079	-0.154	-0.559	-0.429	32.10	18.91	RH%	Light inten
Total no. of alive stages	-0.503	-0.585	-0.170	-0.247	-0.625	-0.616	40.20	39.44	Temp 0.428	0.868
Total no. of dead stages	-0.713	-0.607	-0.352	-0.307	-0.665	-0.659	52.39	45.88	RH%	0.235
Total mortality %	-0.360	-0.062	-0.381	-0.265	-0.026	0.008	46.99	47.57		
Predator pop.	0.888	0.777	0.611	0.561	0.656	0.543	87.90	70.72		
Parasitism %	0.123	-0.091	-0.335	-0.420	0.454	0.248	55.46	49.67		

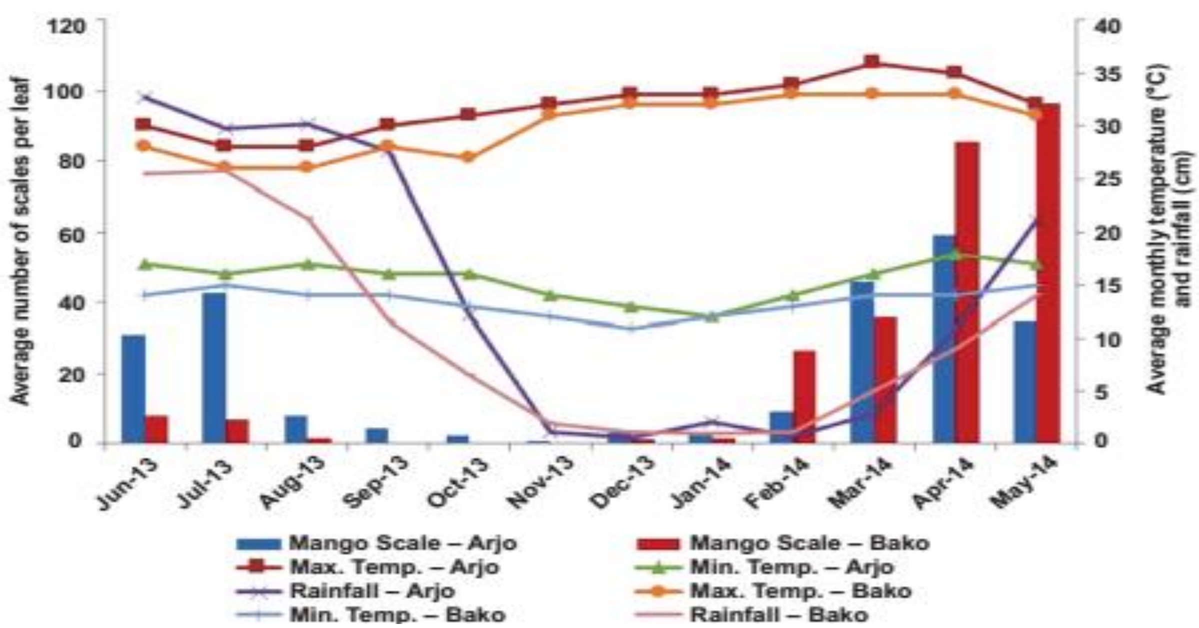


Figure 3. Population fluctuation of *A. tubercularis* on mango trees in the study area (Ofgaa *et al.*, 2017)

Management Options of White Mango scale insect

White mango scale needs its host for food, oviposition site, and shelter. In the process of exploiting the host plant for the aforementioned purposes, it poses deleterious threats to the host plant which interferes with mango growers' interest and as a result the management of the pest critical.

Cultural control

Simple modifications of a pest's environment or habitat often prove to be effective methods of pest control. Since these control tactics usually modify the relationships between a pest population and its natural environment, they are also known, less commonly, as ecological control methods. In relevance to control of scale insects, cultural control includes practices such as pruning, smoking and area clearing, application of soaps and homemade oils, use of humus as supportive plant nutrient, among others (Tesfaye *et al*., 2014). Bautista *et al* (2013) in Mexico indicated that pruning reduced the number of females from 1.8813 to 0.6456 per leaf. Temesgen (2014) states that farmers in Ethiopia used pruning, smoking and area clearing as cultural management practices to control white mango scale. However, there is no information regarding the level of their efficacy in these instances.

Biological Control

Biological control is the intentional use by humans of an insect pest's natural enemies such as beneficial insect predators and parasitoids as well as pathogens (bacteria, viruses, protozoa, fungi, nematodes, etc.) in order to lower the population level of the insect pest below the economic threshold so that crop loss is reduced and the farmer can have a successful harvest (Capinera 2008). Predators such as ladybird beetles and green lacewings, and tiny parasitic wasps may be used to suppress scale insect population.

The predators such as *Chilocorus circumdatus* Sch., *Chilocorus nigrita* (Fab.), *Rodolia amabilis* Kapur, *Pseudaspidimerus trinotatus* (Thunberg) Motsch., *Scymnus quadripunctata*, *Ortalia octopunctata* Gorham, *Cybocephalus* sp., *Triommata coccidivora* (Felt) and *Mallada boninensis* (Okamoto) are identified as natural enemies of white mango scale (Mani and Krishnamoorthy, 1998). Nabil *et al*. (2012) recorded *Aphytis* sp. and *Encarsia* sp. (Aphelinidae), *Habrolepis diaspidi* (Risbec) (Encyrtidae) as parasitoids and *Cybocephalus micans* Reitter as predator of white mango scale in Egypt.

Similarly, Abo-Shanab (2012) recorded little numbers of natural enemies which included parasitoids such as *Aphytis mytilaspidis* (Le Baron) and *Encarsia citrina* (Craw), and a predatory beetle, *Scymnus syriacus* Marseul in the same country. The predatory thrips, *Aleurodothrips fasciapennis* (Franklin) and parasitoid *Encarsia citrina* (Craw) were also recorded as natural enemies of white mango scale in South Africa. However, the report indicated that the indigenous parasite *Encarsia citrina* (Craw) couldn't control the pest, despite record of over 80% parasitism. On the other hand, the ectoparasitoid *Aphytis chionaspis* Ren (Hymenoptera: Aphelinidae) which was introduced from Thailand was known to have been established and made valuable control in South Africa. White mango scales are well regulated by parasitoid *Chilocorus nigrita* (Fab), *C. circumdatus* Sch and *Pteroptrix koebeli* How in India (Mani, 2016).

Chemical Management

Insecticides are used in agriculture to prevent, inhibit or kill insects. The use of insecticides may give faster solution temporarily. However, it is obvious that the use of toxic insecticides in pest control bears adverse effects on the ecosystem in general, and affects non target species including natural enemies of the pest under consideration, in particular. Many experiments have been conducted to test some chemicals which were thought to have been effective in suppressing white mango scale. Abo-Shanab (2012) describes that a series of field test of three mineral oils against white mango scale showed effectiveness by the following descending order of efficacy Diver > CAPL2 > super masrona. Buprofezin, Lambda-cyhalothrin and Malathion were tested for the management of white mango scale insect. Buprofezin and Malathion were effectively managed white mango scale insect (figure 4). Use of two sprays at spring and summer enhanced the efficiency of each insecticide in controlling insect in mango orchard (Salem *et al.* 2009).

Organophosphates insecticides and mineral oils to control white mango scale on mango tree match with many earlier studies in which chloropyrifos, methidathion, Dimethoate 40%EC, (Howard 1989), Diver and CAPL2 oils have been found successful in reducing the population of white mango scale (Abo-Shanab . 2011).

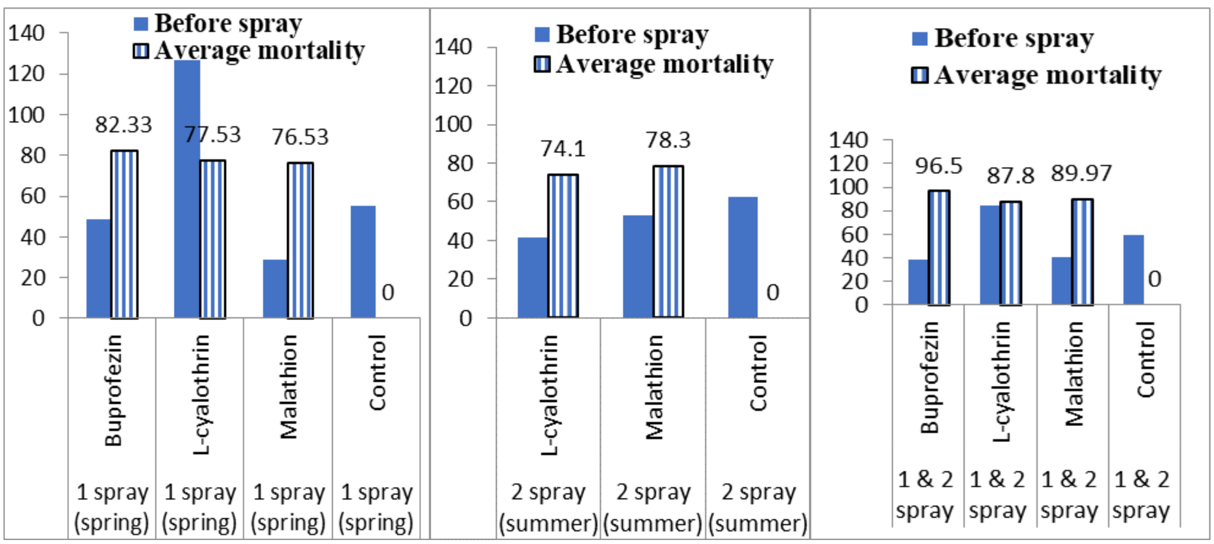


Figure 4. Effect of different insecticides on white mango scale (Salem *et al.* 2009)

In Ethiopia Gashawbeza *et al*. (2015) tested Movento and Methidathion, and reported they had equal efficacy in reducing white mango scale infestation on mango in Central Rift Valley of Ethiopia.

Managing by Formulations from plant extracts

Plant extracts and formulations were tested for management of *A. tubercularis* (Abdel-Aziz *et al*. 2016). Formulations such as Demso, Oregacide, Citrocide, Lemocide and Trilogy which are prepared from essential oils of *Ambrosia maretima, Origanum minutiforum, Cymbopogon nardus, Cymbopogon citratus* and neem oil respectively are tested for management of white mango scale (Table 2). However, some plant formulations have side effects on tree chlorophyll content (Table 3)

Tested formulations	Reduction percent in insect populations			Average
	A. tubercularis	A. citrina	K. acuminata	
Demso	77.97	96.53	50.5	75
Oregacide	88.28	97.07	99.75	95.03
Citrocide	83.41	75.72	60.48	73.2
Lemocide	79.25	65.36	8.78	51.13
Trilogy	78.67	79.54	84.74	80.98

In a field test, 5.0 ml/l of Nimbecidine as neem plant extract caused 92.7% reduction increasing to 100% reduction after the first and second application, respectively in Egypt in (Haggag, 2014). Rosemary plant oil was more efficient on *A. tubercularis* and mealybug *Icerya seychellarum* than commercial oil.

Table 2. Effect of different plant formulations for management of white mango scale (Abdel-Aziz *et al*. 2016)

Treatment	Chlorophyll a (mg/g)						
	Demso	Oregacide	Citrocide	Lemocide	Trilogy	Control	lsd
Pre-spray	11.49	11.46	11.27	13.23	11.59	11.62	Ns
3	9.25b	7.54bc	7.17bc	12.25a	6.64c	11.72a	2.25
9	15.68a	12.42ab	6.78c	9.47bc	7.71c	11.45b	3.63
15	13.20a	11.61a	6.13c	11.19a	11.55a	12.36a	2.89
21	16.76a	14.93ab	9.92cd	8.19d	12.6bc	13.14bc	3.40
$Lsd_{0.05}$	ns	2.66	3.16	2.14	1.74	ns	-
	Chlorophyll b (mg/g)						
	Demso	Oregacide	Citrocide	Lemocide	Trilogy	Control	lsd
Pre-spray	3.43	4.79	5.38	5.95	2.35	5.09	Ns
3	3.07cd	8.9a	4.38bcd	4.75bc	2.15d	5.64b	2.56
9	6.21ab	7.8a	4.82bc	3.86c	1.71d	5.72abc	2.08
15	6.88a	4.12bc	4.33b	3.03cd	2.34d	6.06a	1.22
21	6.26ab	6.71	5.84	4.53	3.37	4.90	ns
$Lsd_{0.05}$	2.12	Ns	Ns	Ns	0.45	ns	-

Table 3. Effect of plant formulations on chlorophyll a and b (Abdel-Aziz *et al*. 2016)

Integrated pest management

Biological control by conservation can be implemented using natural enemies of the insect pest, combined with products such as soap and citroline that have low toxicity and less environmental impact than insecticides such as Malathion. An integrated pest management alternative could be applied that would consist of a combination of pesticides, cultural practices and the use of biological control agents (Dale, 2002). Integrated pest management is a pest management philosophy that utilizes all suitable pest management techniques and methods to keep pest populations below economically injurious levels.

Recommendation

A number of insect pests attack mango plant at all its growth stages. However, white mango scale insect was the recently reported most economically important insect pest of mango in Ethiopia. Limited management actions for this pest were practiced by producers to control. Chemical insecticides Movento 150 OD and methidathion 400 EC are recommended for white mango scale management and effective in Ethiopia. Therefore, these insecticides should be used as an option for management of the pest. Additionally cultural control practice such aspruning, sanitation, smoking reduces white mango scale. Integrated pest management options which are safe for natural enemies and the environment should be practiced.

Gaps and Challenges

- Losses and economic threshold levels are not determined for this pest in the country and somewhere else.
- Mango trees in most parts of Ethiopia are developed from seedlings and are tall in height which makes the application of insecticide, harvesting difficult; and poor quality.
- Adequate attention was not given for this pest control/management.
- Screened and registered insecticides for the pest were limited.
- Application of insecticide was difficult because of plant height.
- Absence of introduced effective biological agents (natural enemies).
- Weak Quarantine system the country.

Future Direction

- Losses due to the pest should be quantified and economic threshold levels should be determined.
- Development of cultural control methods, use of botanicals and bio-control agents should be given due attention.
- Effective Natural enemies should be introduced.
- Effective insecticides for drench application should be introduced and screened.
- Commercial mango varieties which are grafted mango should be planted to make easy for pesticide application and agronomic management.
- Developing IPM strategies.
- Attention should be given from research institutions, policy makers.
- Strengthening quarantine system.

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Participatory Agricultural Production Constraint Analysis in Selected AGP-II District of Dire Dawa City Adminisrative Councile, Ethiopia

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Abstract

Participatory agricultural production constraint analysis was conducted in AGP-II project supported Biyo-Awale district of Dire Dawa Adminisrative Councile (DDAC) in July 2016, to assess the existing agricultural production system and identify major production constraints and opportunities for future research and development interventions. The study was used various Participatory Rural Appraisals (PRA) tools which included reviewing secondary data, focus group discussions, pair-wise ranking and field observations. Results of the PRA study and secondary data review revealed that mixed crop-livestock farming and alley cropping of maize and sorghum are common practices in the study areas. Maize and sorghum are the major Staple food crops while vegetables, fruits and khat are produced as major sources of cash. Major bottlenecks to cop production include lack of improved crop varieties, low soil fertility, shortage of rainfall, diseases and insect pests. Livestock production in the area is constrained by shortage of feeds, diseases and parasites and lack of improved breeds. Soil erosion, deforestation and soil fertility depletion are among the major natural resource constraints endangering the crop and animal productions in the study area. Furthermore, shortages and high prices of agricultural inputs and poor outputs marketing system particularly for vegetables, middlemen involment in marketing,shortage of capital, poor performances of farmers' cooperatives and inadequate institutional supports in income source diversification have been identified as major socio-economic, and institutiona constraints that are limiting the capacity of the livelihoods of the communities. Hence, future research and development interventions should address these bottlenecks to improve production and productivity and livelihood of the farming community in the study area.

Key words: Participatory Rural Appraisals (PRA), Production constraints

Introduction

The Ethiopian government has been making significant efforts in transforming the agricultural sector through various developmental programs such as agricultural growth program (AGP-II) in different parts of the country, including the Dire Dawa Administrative Council (DDAC), where the Agriculture is continuing as a means of livelihood for rural households. Despite its importance and potential, yet the agriculcultural sector of the area has faced several constraints and is characterized by low production and productivity mainly due to socio-economic, technical, environmental and institutional factors. These constraints need to be solved in order to bring substantial changes in production and productivity of the sector and livelihood of the farming communities in the area.

Thus, this participatory assessment of agricultural production system was initiated with the objective of assessing the existing agricultural production system and identifying major production constraints and opportunities for future research and development interventions in the AGP-II supported Biyo-Awale district of the council, in July 2016, by using participatory rural appraisal (PRA) approaches. Since, the report has highlighted the main findings and implications to AGP-II interventions in the staudy area, thus, the information generated through this study will be used for designing research interventions geared towards solving the identified priority problems.

Methodology

Description of the study area

Biyo awale is one of three rural clusters found in the DDAC. The district is located in the south east of the administration council. The administration of the district is found in Biyo Awale Kebele; which is located at a distance of 24 km from the capital city of the administration, Dire Dawa city. The district comprises of 21 rural kebeles, of which 12 Kebeles were selected by office of agriculture for AGP-II intervention. The district is estimated to have a total area of 54,522 ha which accounts to 35 % of the total area of the DDAC. The district has a total of 17,851 household heads of which 2,552 female headed households (DDAC-BOA, 2014/15). According to the 2007 CSA projection as of 2014 the population of the district is about 90,557 of which 52% are male and 48% female. The district is mainly categorized in three agro-ecological areas, of which 76% of the total area is dry midland, 19% is dry lowland and 5% is high land (DDAC Office of agriculture, 2014).

The rainfall pattern of the district has a bimodal characteristic. The small rainy season is from March to April; while the main rainy season extends from August to mid-September with average annual rainfall of 500 mm and ranges of 900 mm and 700 mm average maximum and minimum rainfall, respectively (DDAC-BOA, 2014). The ltitude of the district has a range of 1000 to 3000 masl (DDACBOA, 2016).

Topography of the area is dominated by mountains, hills, valley and flat plains. According to the Bureau of Agriculture, Soil type of the area is dominated by sandy soil (about 80%), which has low water holding capacity and very little amount of clay and silt. The mountains' and hills' soils are shallow and infertile while deep and fertile soils are the major features of the valley, and flat plains of the district.

The Biyo Awale district is potentially rich in spring and surface runoff water resources especially during rainy season. The district is also endowed with groundwater resources abstracted mainly from upper sandstone and limestone aquifers that act as reservoir of the groundwater. According to Dire Dawa Integrated Natural Resource Master Plan Study of 2005, water resource utilization of the area is by far less than the estimated annual recharge in the district. Land use of the district can be grouped into three major classes, which are designated as cultivated land, grazing land and bare land. According to the Dire Dawa Bureau of Agriculture, the district has 24,384 ha of cultivated, 10,732 ha of grazing and 19,406 ha of bare lands out of the 54,522 ha total areas.

Selection of sites and PRA participants

Prior to going into the survey, a team of experts consisting of five members was established. . Purposive sampling technique was used to select representative AGP-II supported districts, Kebeles and farm households from the administration. In the first stage of the selection, Biyo Awale district was selected purposefully based on potential in agriculture, agro ecology and available resources. Then three Kebeles namely Adada, Awale and Bishan Bahe were selected for the survey. Throughout the PRA 27-30 households were used at a time to make up a group. A total of 100 farm households were participated during the survey, out of these; about 18% of the participants were female farmers.

Sources and method of data collection

The survey was started with review of different published and unpublished documents and reports about the DDA. The secondary data on area description of AGP-II districts were collected from Agricultural Offices. Focus group discussions (FGDs) were used to collect the primary data from farmers on crop production, livestock production, marketing, natura resources and socio-economic constraints.

Data analysis

The qualitative and quantative data collected from primary and secondary sources were entered into Microsoft Excel® spreadsheet, and analyzed using descriptive statistics includes percentage, maens, frequency and ranking. The results of the analysis were narrated and presented using tables, graphs and texts.

Results and Discussion

Farming Systems, Natural Resource Management and Livelihoods

This part presents results of the PRA assessments on farming systems practices (crop and livestock production), natural resource management, and livelihood system and major income sources of the study district.

Crop production

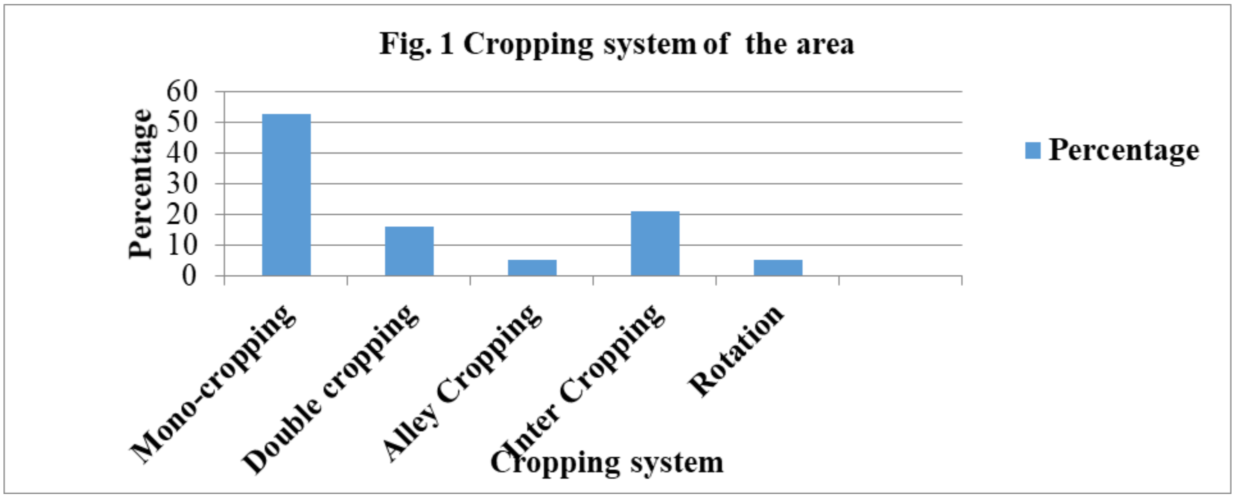
Sorghum and maize are the commonly grown cereal crops of the area. The sorghum, which is the major crop, is mainly cultivated under rain season, whereas the maize is grown both under rain and irrigation conditions. Finger milet is another cereal crop, but produced in limited area. Besides the cereal crops, vegetables and fruit crops such as potato, tomato, onion, cabage, chilli paper, papaya, banana, and mandarin are grown as cash crops using irrigation and rain conditions.,Groundnut, haricot bean and sesame are the puslses grown as potential cash crops of the area, often by sowing under sorghum and maize plants. But the production of the seasome is limited to few farmers and area. Beside these crops, stimulant crops such as khat and limited coffee production is also identified in the studied area.

Relative importance of the major crops grown in the district was identified and ranked by the farmers. Accordingly, the FGDs and secondary data shows that from cereal crops, sorghum is the most important crops followed by maize in all Kebeles, while from pulse/oil crops groundnut is the most first ranked and followed by haricot bean in all Kebeles. Similarly, from vegetable and fruit crops, tomato and papaya are the most important grown crops in most studied Kebeles of the Biyo Awale district.

Cropping systems and pattern

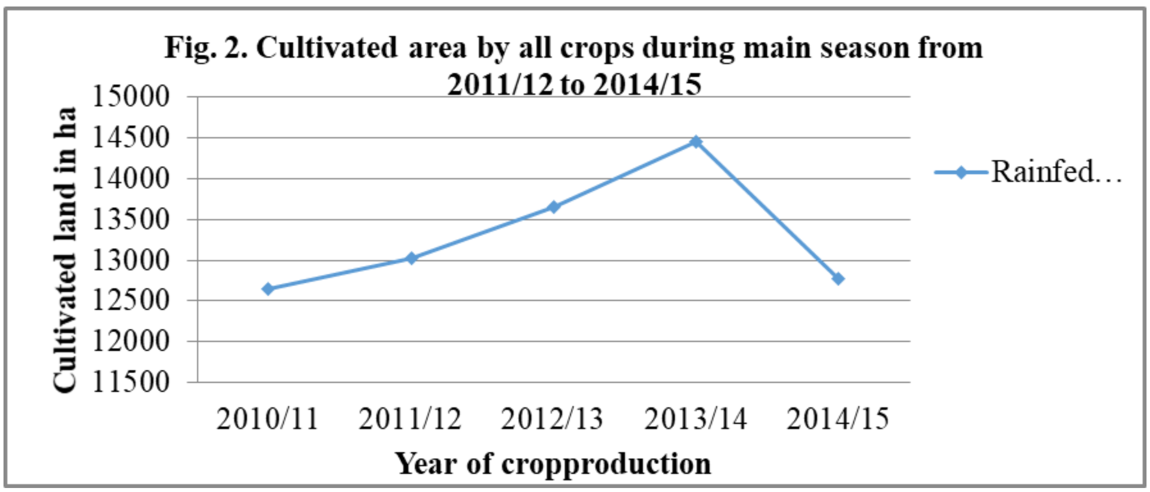
The district is characterized by diverse and intensive cropping system where most farmers usually grow two or more crops on the same field per year. Figure 1 show that, the most dominating cropping system was mono cropping, practiced by about 53% of farmers, followed by intercropping (21%) and double cropping (15%). The mono-cropping is dominantly practiced by growing one or two crops (sorghum, maize, or groundnut) on the same field per year without practicing crop rotation. During FGDs, the farmers mentioned that if the farmers allocate a plot of land for sorghum or groundnut, then they grow sorghum or groundnut year per year.

In addition, some farmers also indicated that, they practice double cropping in areas where irrigation access is there. It is usually done by growing tomato during dry season by the irrigation and maize after the harvest of tomato. However, these cropping system practiced by farmers without considering crop combinations, planting times, spacing and planting patterns using their indigenous knowledge.



Source: DDA Office of Agriculture, 2016

In the study area, secondary data shows that, average crop land holding is less than 0.5 hectare. The cultivated land area of all crops during the main rain season of the district shows an increasing trend with decreasing rate from 2011 to 2014 and decreasing after 2014, in the last five production years, 2010/11 to 2014/15 (Fig.2).



Source: DDAC- BOA, 2016

The cultivated area of irrigated land under all crops also shows a tremendous incremental trend in both modern and traditional irrigated land for the last five year of production (Figure 3). However, the irrigated area under modern irrigation shows smooth incremental trends as compared to the traditionally irrigated lands in area. Figure 3 also shows that, total irrigated area under modern and traditional irrigation increases from 1469 hectares in 2010/11 to more than a double after five years (about 3205 hectares) in 2014/15.

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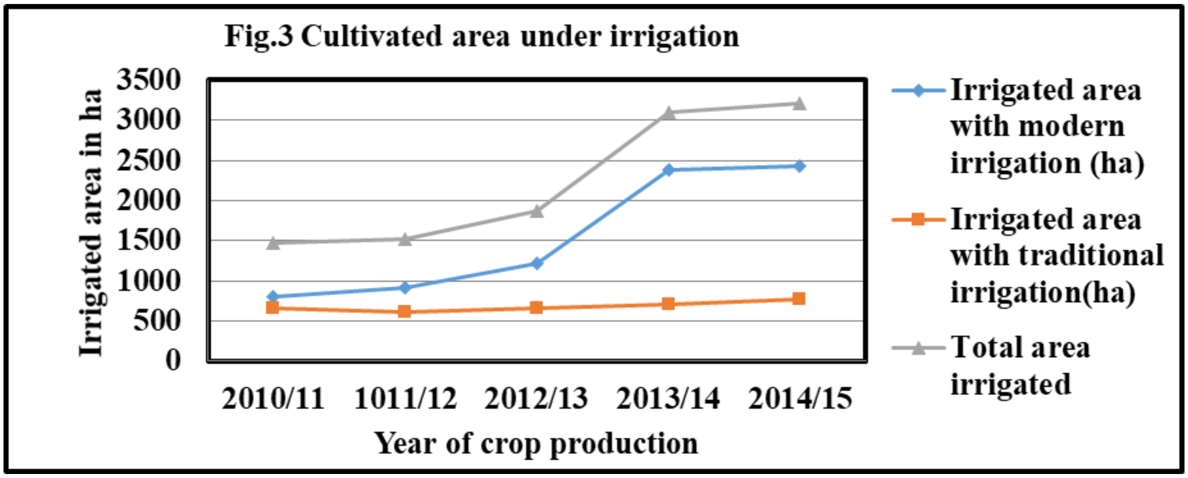
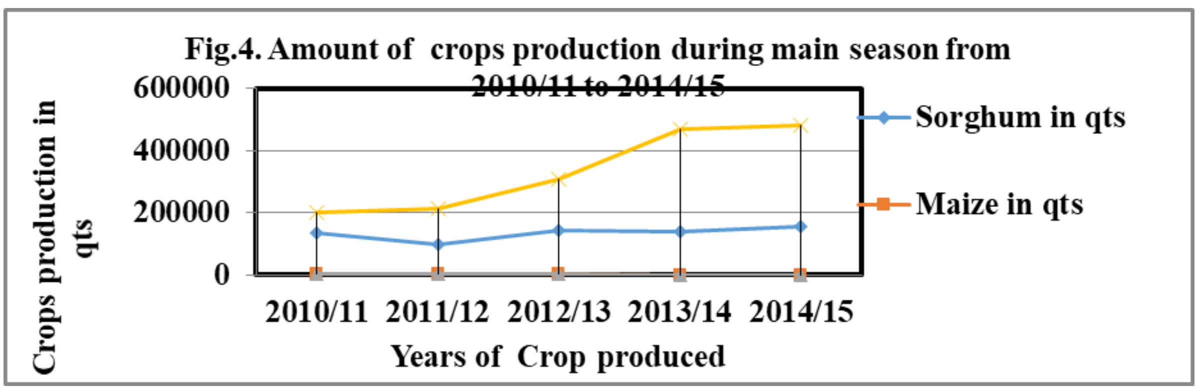


Source: DDA, Office of agriculture, 2016

Trend of major crop production and productivity

The production of sorghum, maize and others crops in the district shows an increasing trend with some fluctuations in the last five years 2010/11 to 2014/15(Fig.4). In this result, sorghum has a lion share among the cereal production of the area. The trend of vegetable and fruit production of the area was also shows increasing rate for the last five years.



Source: DDA Office of Agriculture, 2015

Despite the increasing trends of the major crops in the area, the study result also shows the low productivity these crops as compared to the national averages (table 1). The reason for the low productivity might be generally associated with moisture stress, inadequate use of inputs such as improved seeds and organic fertilizers,, pressure of pests and diseases and inadequate management practices.

Table 1. Crop yield of major crops in the area (qt/ha), 2014/15

Major crops	Yield (qt/ha)
Cereal crops	
Sorghum	14-16
Maize	15
Pulse/oil crops	
Haricot beans	13
Groundnuts	25
Sesame	8
Vegetables and fruits	
Tomato	155
Potato	192
Sweet potato	200
Papaya	200

Source: DDAC-BoA, 2015

Crop management

Soil fertility improvement by crop types

In the study area, farmers used to practice the use of combination of farmyard manure with inorganic fertilizers on sorghum, maize, tomato, potato and onion farming as the soil fertility improvement (table 2).. Furthermore, although blanket recommendation and other farmers' practices inorganic fertilizers applications are the most common in the area, some farmers also noted the contribution of application of fertilizers at recommended rate for higher crop yield increment in the area.. Compost making and utilization is not common practices in the study area, except few farmers who are using it, only on vegetables, maize and kahat, by decomposing manure and weeds in pits.

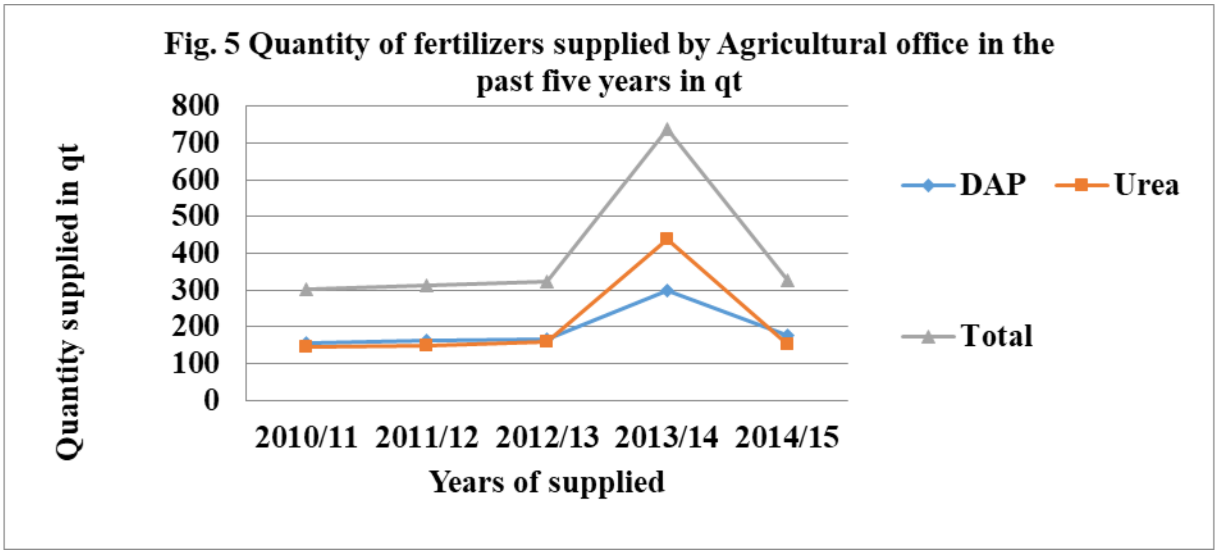
Table 2. Soil fertility management for major crops in the study area, 2016

Crop types	Fertilizer management	Amount of fertilizer application/ha	Method of fertilizer application	Time of application
Sorghum	Manure +DAP +Urea	DAP = 50-80kg/ ha Urea = 40-50kg/ ha Manure= 10-12qt/ha	DAP = broadcasting/ mixing with seed and drilling,Urea = side dressing at knee stage of the plant/at 6 leaf stage Manure=broadcast	DAP = at planting Urea = at cultivation Manure = before planting
Maize	Manure +DAP +Urea	DAP = 50-80kg/ ha Urea = 40-50kg/ ha Manure= 10-12qt/ha	DAP = broadcasting/ mixing with seed and drilling, Urea = side dressing at knee stage of the plant/ at 6 leaf stage Manure=broadcast	DAP = at planting Urea = at cultivation Manure = before planting
Groundnut	Manure	Manure 8-10qt/ha	Manure=broadcast	Before planting
Sesame	Manure	Manure 8-10qt/ha	Manure=broadcast	Before planting
Tomato	Manure +DAP +Urea	DAP =100-120kg/ ha, Urea = 80-100kg/ ha	DAP = broadcasting Urea = side dressing at transplanting and	DAP = at planting/ transplanting, Urea = at flowering stage
Potato	Manure +DAP +Urea	DAP =80-100kg/ ha, Urea = 100-120kg/ ha	DAP = band/drilling Urea = side dressing	DAP = at planting/ transplanting, Urea = at 1st & 2nd inter cultivation
Onion	Manure +DAP +Urea	DAP =60-80kg/ ha Urea = 50kg/ ha	DAP = band/drilling Urea = side dressing	DAP = before seedling Urea = at 1st inter cultivation practice

Source: FGD Survey, 2016

Trend of inorganic fertilizer supply

During FGDs, farmers noted that application of in organic fertilizers on major crops is getting low in the area due to high cost of fertilizers and erratic rainfall distribution. However, supplies of the fertilizers were increased from 2012/13 to 2013/14 and then failled sharply after the same cropping year (Fig.5). The reason for sudden fall of the supply of the fertilizer in the area might be due to the above mentioned reasons of the farmers and or due to shortage of rainfall or other unknown reasons.



Source: DDAC- Bureau of Agriculture, 2016

Types of crops seeds and supplying source

Most Farmers of the study area generally used local crop seeds for planting. Common sources of the local seeds in the area include; own/recycled seeds, other farmers and village markets, while some improved seeds of sorghum, maize, haricot bean, tomato, papaya and mango can be obtained from Office of agriculture, NGOs, and town market (for tomato and onion). Generally, farmers of the group discussion noted that there are no improved varieties for most crops in the cluster, except limited improved varieties of sorghum, maize, haricot bean, vegetable and fruit crops provided through bureau of agriculture.

Agronomic practices

The land preparation methods of study area are more or less similar for all crops in the target Kebeles. Land preparation (primary tillage) for sorghum and maize crops is carried out using oxen plough (maresha plough) and hand tools such as Hararghe Akafa and Dangora for moisture conservation and weed control purposes. Whilst for vegetables, perennials and garden crops (homesteads) digging or hoeing tools are used. Majore crops seed planting methods of the area is dominated by broadcasting, but row planting is also common for vegetables, groundnuts and improved seeds of maize. Seed rates of the majore crops such as sorghum and maize are in the order of 15-20kg/ha and 25-30kg/ha respectively. The identified farmers' crop management practices such as tillage frequency, planting methods, and cropping practices for each crop types are presented in the Table 3.

Table 3. Major agronomic practices used by farmers in the study area, 2016

Crop types	Method of plough	Tillage frequency	Planting methods	Cropping practice
Sorghum	Ploughed with ox ploughs/hand hoe	One to two	Broadcasting	Mono cropping
Maize	Ploughed with ox ploughs/ hand hoe	One to two	Row, planting Broadcast	Mono cropping for rainfed fields, -Rotation for irrigated
Groundnuts	Ploughed with ox ploughs/ hand hoe	One to two	Row, planting is common	-Sole cropping is common -Intercropped mixed with sorghum/maize
Tomato	Land is ploughed with ox ploughs/ hand hoe	3 times	Row planting	Sole cropping
Potato	Land is plough with ox ploughs/ hand hoe	3 times	Row planting	Sole cropping
Onion	Ploughed with ox ploughs/ hand hoe	3 times	Row planting	Sole cropping
Chili Pepper	Land is ploughed withox ploughs/hand hoe	3 times	Row planting	Sole cropping
Cabbage	Land is ploughed with ox ploughs/hand hoe	3 times	Row planting	Sole cropping

Source: Survey result, 2016

In this area, harvesting of the crops is usually done by hand either by using sickles for cutting, hoe for digging and bare hand for picking. Threshing of some crops suchas sorghum, maize and ground nut is done by using stick for beaing and/or bare hand stripping.

Pest management practice

The major weeds such as Striga, *Parthenium, Amaranthus hybrid, Cocklebur and Spotted spurge (Marare)* on sorghum and maize, and Orobanche on tomato are among weeds identified by PRA farmers in the area. The farmers also noted that these weeds are not manageable by thier practice in the study areas. The major disease such as *Leaf spot, Leaf* *blight* on sorghum and maize, *Powdery mildew*, *down mildew, blight* on tomato and, *blight*, on potato and onion, and *Anthracnose* on mango are among the serious disease reducing crop yields in the *area*. Insects like stalk borers on maize and sorghum, leaf minor (*Tuta absuluta*) and aphids on vegetable and thrips, fruit fly on mango were the major insect pests reported by farmers. Farmers used various cultural pest management practices like smoking, and removing the affected plant/branches. In addition, they listed different pesticides such as DDT, Marshal, Malathion, and *Mankozeb* for vegetable crops' pest control. The most important insect pests and diseases of crops and their management practices in the targeted area are provided on the (Table 4).

Crop production constraints

The major constraining of the crop productions and first ranked problmes by the farmers in the study area is shortage of improved seed varieties for most crops (Table 5). The result of PRA study also indicated that the moisture stress due to erratic rainfall is the second and third factor that limits crop production in Adada and Awale, and Bishan Bahe Kebele, respectively. Weed infestation was ranked by farmers as third constraint in Adada and Awale Kebeles, and fourth in Bishan Bahe Kebele. Similarly, insects and diseases outbreak were ranked by farmers, third in Adada and Awale Kebeles, and second in Bishan Bahe Kebele as a constrain for crop prodction. Moreover, harvesting, threshing, and storage were identified as major post harvest problems during the PRA study in all kebales.

Furthermore, the results of this study indicates that, access to free market for crop products particularly for vegetables and fruit products are the first most important constraint in the study area. High cost of inputs, lack of access to and use of market information and lack of organized marketing system were also identified as main marketing constraints in the study area.

Table 4. Major types of pests and management practices used in study area

Major Pest	Sorghum and Maize	Sesame	Tomato	Potato	Onion	Mango
Weed	*Striga hermonthica, Striga asiatica,Parthenium hysterophorus, Amaranthus hybrid, Couch grass, Cocklebur, Common nettle(Anamale) Oxalis (wanjalii), Cyprus Spotted spurge (Marare),Argimon Mexicana (Arama qore)*	*Cocklebur, Spotted spurge (Marare), Spotted spurge (Marare)*	Orobancha (Tomabasho)	-	-	-
Time of weeding	March-September	July-September	-	-	-	-
Frequency of weeding	Three to four times (hand weeding and cultivation using hand hoe for weeding)	Two to three times (cultivation	Two to three times (cultivation using hand hoe)	-	-	-
Insect	Stalk borer, Aphids/Macur (sorghum), African ball worm (Sorghum), Cut worm, White fly, Butterfly, Termite, Shoot borer, Fruit fly, Grubs(Qumbursii)	Army worm (Geri)	Spider mite, Cut worm, Fruit fly, *Aphid*, white flies	Spider mite, Fruit fly, *Aphid*, white flies, *Moth*	Cut worm, *Thrips*, Mites and Worm	Fruit fly, termite Aphid, *Thrips Midge*
Management	Farm site cleaning, 2-3 times ploughining, cut/uprooting and remove the affected plant, and pesticides (DDT, Marshal, Malathion-spraying 2 to 3 times)	Late planting, sprayed chemicals(Malathion)	Farm site cleaning, manuring, Spraying of chemeical (Mankozyeb : 2-3 times in a month)	Farm site cleaning, manuring, Spraying chemical (of Mankozyeb: 2-3 times in a month)	Farm site cleaning, manuring, Spraying of Mankozyeb : 2-3 times)	Site cleaning and removing affected part of the plants
Disease	*Leaf spot, Root rot, Root knot, Leaf blight, Head smut(on sorghum)*	-	*Powdery mildew, Down mildew, Early blight ,Leaf spot, Fruit decay, Root knot, bacteria wilt rust*	*Late blight, Fungal rot, Leaf spot, Root knot*	*Late blight, Fungal rot, Leaf spot, Root knot*	*Fruit decay, root knot, Dawny mildew Die back powdermildew,Anthracnose*

Table 5. Pair-wise ranking of crop production constraints in the study area

Constraints	Name of Kbeles		
Production	Adada	Awale	Bishan Behe
Shortage of improved varieties	1st (4)	1st (4)	1st (4)
Crop insect and disease	3th (2)	3th (2)	2nd (3)
Weed	3th (2)	3th (2)	4nd (1)
Moisture stress due to erratic rainfall	2nd (3)	2rd (3)	3rd (2)
Knowledge and skill gap	4th (1)	4th (1)	4th (1)
Post harvest problem			
Harvesting technique	1st (3)	1st (3)	1st (3)
Transportation	2nd (2)	2nd (2)	2nd (2)
Storage	3rd (1)	3rd (1)	3rd (1)
Processing (quality)	4th (0)	4th (0)	4th (0)
Marketing constraint			
Market access	1st (4)	1st (4)	1st (4)
High price of inputs	2nd (3)	3rd (2)	3rd (2)
Credit access	4th (1)	5th (0)	5th (0)
Lack of market information	3rd (2)	2nd (3)	2nd (3)
Lack of organized marketing	4th (1)	4th (1)	4th (1)

NB. Figures in the parenthesis indicates score values and Numbers outside the parentheses refers to ranking

Recommendations

The PRA results indicated that, the exsisting crop production and productivity level of the study area are very much lower than the national averages, mainly due to lack of improved varieties and other inputs, pests, moisture stress, erratic rainfall, and lack of institution and information in the study area. Moreover, lack of postharvest management and marketing problems are also limiting the benefits they could get from the crop production in the area.

Thus, based on these findings, the following recommendations were given:

- Introducing and promoting of improved crop varieties should be a research priority area, by focusing toward generating of high yielding, early maturing, and pests resistant varieties in the area.

- Establishing and promoting of improved seed producing farmers’ cooperatives for better delivery of improved crop seed varieties in the area.
- Introducing and promoting of improved agricultural water management practices to reduce moisture stress problem, and enhance crop productivity in the area.
- Promotion of integrated pest management for controlling of pests of cereal, and horticultural crops in the area.
- Participatory promotion of improved farm implements, threshing and storage technologies for major cereal crops to reduce their post harvest losses.
- Promotion of harvesting, handling and smallscale processing technologies for horticultural crops such as mango should also be a priority area.
- Strengthening market facilities development and market regulations for horticultural crops is a priority intervention area.
- Promoting and capacitating of farmers’ organizations for input and output marketing and creating linkages with value chain actors should be facilitated to enhance market performance and benefit of farmers in the area.

Livestock production

Livestock types and population

In Biyo Awale district, the farmers are engaged in cattle, goats, sheep, camel, donkeys, and poultry rearing for supporting and sustaining their livelihoods. Based on the information of the local Bureau of agriculture, the total livestock population in the district is estimated to be about 89089. Out of this, the goat constitutes about 43.8% followed by sheep (18.8%), poultry (14.6%), cattle (14%) and others constitute about 9% (Fig 6). The main purpose of keeping these animals is mainly for cash income; milk, draught power, and manure in their order of importance. Poultry production and bee keeping are also a common practice in the area. Camel and donkey are reared and used mainly for transporting of crop products, woods for charcoal, water and other goods from place to place.

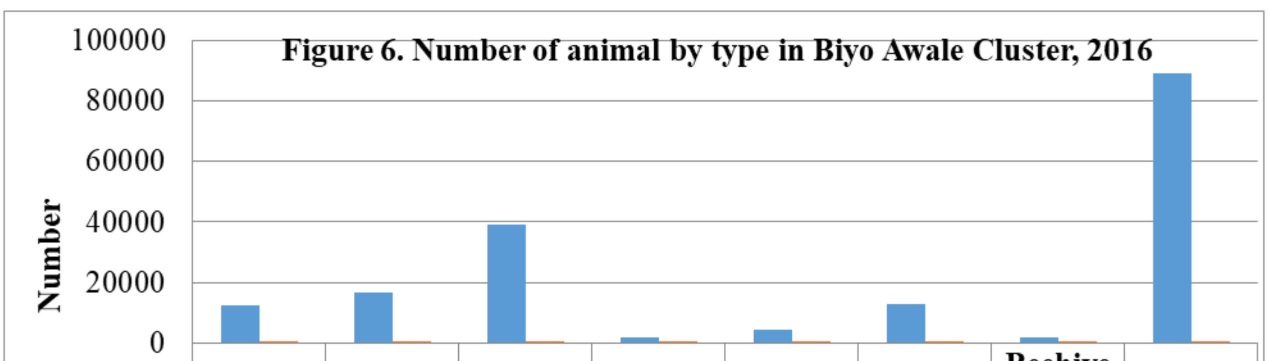


Figure 6. Number of animal by type in Biyo Awale Cluster, 2016

	Cattle	Sheep	Goat	Camel	Donkey	Poultry	Beehives	Total
Number	12437	16548	39060	1973	4271	13011	1789	89089
%	14.0	18.6	43.8	2.2	4.8	14.6	2.0	100.00

Source: DDA Office of agriculture, 2016

Livestock production systems

In the study district, livestock production system is dominated by extensive type of dairy, and poultry production with traditional management practice and indigenous breed. The information from Bureau of agriculture (2014) shows that, 92 % of the farmers are practicing traditional while only 8 % are following improved and intermediate livestock production system. Large numbers of farmers manage their dairy cow, poultry and others under extensive system with poor feed resources such as grazing and crop residues. However, some farmers were provided purchased concentrate feeds such as wheat bran, and green feeds, and improved forages grown on their farm fields such as cow pea, lablab, susbania-susban and elephant grass for milk cow, goats and fattening bull.

Livestock productivity

During FGDs, the farmers were estimated that, daily milk yield of an indigenous breed cow is ranging from 1 to 3 liters in the area. The information received from DDAC Bureau of agriculture also indicated that the average milk yield of indigenous cow and camel is 1.73 and 4.47 liters per day, respectively. The participants of FGD also reported that, the annual egg production per hen is about 65 to 80 egg and the honey bee productivity is 3 to 5 kg of honey per hive/year in the area. In general, the FGDs participants pointed out that, the products obtained from the local livestock is decreasing year after year due to drought, feed shortage, lack of improved breed, disease and water scarcity.

Livestock management

Animal feed source and feeding system

In the Biyo Awale cluster, the major animal feed sources are small private grazing land near the farmers' homestead and small plots of grazing lands at the edge of croplands and communal grazing area. However, these common sources of feeds and types can be varied in the two seasons (wet and dry seasons), for different animals. Furthermore, the FGD participants pointed out that feeding system of diry and fatening livestocksa are different from the common purpose animals. Thus, farmers who have livestocks for family level fattening and dairy buisneses, have been using improved forages in cut and carry method, and industrial by-products in different forms (cake, mix with other feeds) during dry as well as wet seasons (Table 6). But Scavenging is reported as the main feeding system of poultry production in the area.

Water source

During dry season, farmers have been using water from springs and surface water for all livestock types, while during wet season, seasonal rivers, and surface water are used as a source of drinking water for the animals. However, during FGDs the participant farmers pointed out that water shortage, especially during dry season as the main problem due to drought and high livestock population existed in the area. As a result, they have been forced to bring water from distance (long way) during the dry season.

House management

Majority of the farmers in the study areas were used a combination of both separate and group housing for all types of livestock. During FGDs, the participants mentioned that the animals such as cattle and equine were managed under loosely fenced traditional barn near the home without shade and wall, but keeping of small ruminants and calves during night in home or separate housing attached to residential house is common in the area.

Breeding management

During the FGDs, participants pointed out that, majority of the farmers' cattle are breeding in uncontrolled mating without selecting better productive breeds, while few farmers used indigenous methods of better type selection on the bases of milk yield, fast growth (size) and adaptability to local conditions.

Table 6. Animal feeding and management by livestock category in the study area

Season	Major animal feed source		Livestock type
Dry season feeding and management	Pasture land: private owned /free grazing		Cattle,
	Browse trees, bushes and shrubs , grasses at hilly and sloppy, and valley bottoms areas		Cattle, goat, sheep , camel
	Crop residues: sorghum, maize, h/ bean, tomato		Cattle, camel
	Natural pasture/communal grazing		All animals
	Improved forages: elephant grass, susbaniasesban		Milk cows, calf
	Industrial by-products: wheat bran/frushka		Milk cows, beef fattening
	Water source: springs and ponds		All animals
	House type: houses attached with the main house or separately built near the main house		Cattle, goat, sheep,
	Breeding management:	Controlling	Cattle
		Un controlling	Goat, sheep, camel
		AI	Cattle-but it has a problem
Wet season feeding and management	Natural pasture/communal grazing		All animals
	Graze on meager herbage along roadside and hill sides		All animals
	Thinning out crops, up-rooted weeds and grass		Cattle,
	Improved forages: elephant grass, Alfalfa and rhodes		Milk cows, calf
	Browse trees, and bushes and shrubs-grasses at hilly and sloppy, and valley bottoms areas		Cattle, goat, sheep
	Improved trees: sasbaniasesban		Milk cows, calf
	Water source: Seasonal river, surface and spring water		For animal
	House type: attached with main house, thorn fence,		Cattle,goat,sheep
	Breeding management	Control mating	Rarely used for cattle
		Uncontrolled/free mating	Cattle, goat, sheep, camel
		AI	Cattle-but it has a problem

Source: survey result, 2016

Health management by animal type

According to respondents of the PRA study, Anthrax, Foot and Mouth, Blackleg, Lumpy Skin Disease and Pasteurellosis are the common livestock diseases in the area, that are rampant in their order of importance. Likewise Ticks, Lungworm, Mites, and Fasciolosis were reported as the widly available parasites of the livestocks in the area (Table 7). Despite the prevalences of the diseases, it was also identified that, there was irregular animal health services and weak institutional support in capacitating the animal health facilities in the area.

Table 7 Major livestock disease and parasites in the study area, 2016

Livestock type	Major Diseases	Major parasites	Traditional management	Modern (Vaccine & medicament
Dairy	Anthrax (Abbaa sangaa)	Lice (Injiree)	Skin burning for anthrax	Invermectin
	Blackleg (Abbaa gorbaa)	Ticks(Shilmi)	Use traditional medicinal plant	Vaccination
	Foot and Mouth	Lungworm		Vaccination
	Lumpy Skin Disease	Mage mites		Vaccination
	Mastitis (Jigoo)	Fasciolosis		Vaccination
	Mastitis	Mange mite		Vaccination
Poultry	Silisa	-		
	Usili	Poultry mite		
	Maasa	mite	Fumigating with coffee	
	Dhulaa	No disease		
	Circle	-		
	Diarrhe	-		
Gaot and sheep	Lumpy Skin Disease	Ticks/Injjiire e		Vaccination
	Bovine and ovine pasturollosis	silmi	-	Chemical spray
	Diarrhea	Buzarfi	-	-
	Circling	-		
	Furii	-		
Apiculture	Wax moth	Birds		
	-	Ants		

NB: Some major diseases and parasites were written in local name

Livestock production constraints

According to the farmers of Biyo Awale kabales, shortages of improved breeds, breeding services such as artifitial insemination (AI) and limited institutional support for technological interventions are the main livestock production constraint in their area. Similarly, problems of the feed shortages, which was mainly associated with drought, grazing land shortage, limited institutional support on technological intervention such as improved forage promotion, pasture improvement, and processing technologies, were also identified as a limiting factor for the livestock production in the area. In addition to these, the animal health problem was also raised as the critical problem due to lack of services and facilities in the area. Equally important to the above constraints, livestocks marketing was raised as a problem of the area due to involvement and unfair price setting of brokers and inadequate support of protection of the resulted large price margins taken away by the brokers.

With the aim of leveling of the seveirity of the above major constraints of the local livestocks production, a pair-wise ranking was made during the FGDs and tabulated below in table 8.

Table 8. Pair-wise ranking of livestock production constraints in the study area

No	Livestock production constraints	Biyo Awale		
		Adada	Awale	Bishan Bahe
1	Shortage of improved breeds	2^{nd} (4)	1^{st} (5)	1^{st}(5)
2	Availability of feed(forage)	1^{st}(5)	2^{nd}(4)	2^{nd} (4)
3	Water shortage	4^{th}(2)	4^{th}(2)	4^{th}(2)
4	Animal health problem	3^{rd}(3)	3^{rd}(3)	2^{rd}(4)
5	Technological problem	5^{th}(1)	5^{th}(0)	5^{th}(0)
6	Marketing problem	4^{nd}(2)	2^{rd}(4)	3^{rd}(3)

Recommendations

The results of the study revealed that, majority of the identified critical constraints of the livestock production in the study area were created and persisted there due to lacks of accesses of the improved technologies and inadequate institutional supports to the local farmers. Therefore, these indicated that there is a need for research and institutional interventions to allievate the constraints of the livestock production through:

- Creation of accesses of improved technologies and practices for local farmers, particularly on livestocks breeds, forages, feed processing, water resources utilization, and AI and health services in the area.
- Establishing livestock marketing facilities, and enhancing bargaining power of the farmers and market regulations in the area area.
- Establishing and/or strengthening of necessary public institutions for the promotion of the imporoved livestocks production technologies and practices at the village levels.
- Strengthening research, extension and farmers linkages for development and use of the improved livestocks production technologies in the area.

Natural resources and management practices

The PRA study identified that, the major natural resources such as land, water, grazing lands, rocks, sands and forests and as the primary sources of livelihoods for the communities in the study area. However, the land is scarce resource and a common problem in the area due to ragged topograpy (hills, mountains), rock, bare land and population pressure. The local water resources include springs, seasonal rivers and groundwater that can be used for human, irrigation and livestocks. During this assesment, some of the developed spring water irrigation schemes were observed and identified as Bishan Bihe, Kuri and Gabro, and Badaso. The schemes were, used to irrigate vegetables and fruits by sourunding farmers. Despite their small sizes, the local forst resources were also identified as the natural forest, plantation forest and closure areas. In contrary to the others, the abundant sands and rocks were noted by the farmers as the potential resources for construction and income generation in the area.

Soil types, characteristics and management practices

The FGDs participants were identified different soil resource in the area and described their characteristics in terms of their physical properties and management requirements for agriculture. Accordingly, the characteristics of the identified four soil types are indicated in table 9.

Table 9. Soil type, characteristics and management practice in the study area

Soil type	Major soil characteristics		Farmers' management	
	Physical	Chemical	Physical	Biological
Ashawa (sandy soil)	Dominated by sand Low water holding capacity Physical fertility status is low Less response to fertilizers Soil colour is brown Shallow in depth Highly erodible Crops are susceptible to late season moisture stress	Not affected by sodicity and acidity Affected by salt (about 7%) (ethio, SIS, 2008) Has deficiency of Zink and Boron (ethioSIS, 2008)	Bunding such as soil bund Frequent tillage before planting Early planting, Runoff diversion, Hoeing after planting	Application of more manure, Planting of grass species on soil bunds-rare
Suphee (Clay soil)	High moisture holding capacity Medium fertile Brown to black Less erodible Deep soil and good rooting depth Sticky when wet,hard & dry Moderate response to fertilizers	Not affected by sodicity and acidity Less area affected by salt (7% of the area) Has deficiency of Zink and Boron (ethioSIS, 2008)	Tillage at optimum moisture content before planting Bunding -soil bund Hoeing after planting	Planting of grass on soil bund (grass strip). Manuring
Biye Guracha (Black soil)	High water holding capacity High fertile Less erodible Good depth Good response to fertilizers Crops tolerate late moisture stress	No sodicity & acidity Less area affected by salt (7% of the area) Has deficiency of Zink and Boron (ethioSIS, 2008)	Bunding -soil bund Tillage practice	Planting of grass on soil bund (grass strip). Farm yard manure
Biyye dhagaa (Rocky soil)	Poor water holding capacity soil colour: reddish Late season moisture stress Soil is shallow and subjected to severe soil erosion It is located in sloppy areas	No sodicity & acidity Less area affected by salt (about 7% of the area) (ethio, SIS, 2008)	Bunding –stone/soil bund Tillage practice	Frequent manure

NB: Source of the chemical characterstics data of the area was Ethio-SIS, 2008.

Soil and water conservation practices

The PRA study identified that, Gulley, Sheet, Rill and Wind as major soil erosion types in the area. These erosions are eroding the fertile soil and reducing farm and grazing lands productivity. According to the respondents, terraces, check-dams, cut off drains, soil and stone bunds, and watershed management are the common physical structures of the erosion controls in the area. They also mentioned area closures and aforestation of degraded areas as watershed management practices in the area. Moreover, some plantaions of grass strips and multipurpose trees along the physical structures were also identified as a biological erosion control measures, but in very limited extents in the area.

Natural resource management constraints

The Biyo Awale farmers were pointedout that, drought, deforestation, depletion of water resource, soil erosion and depletion of soil fertility as the major constraints of the natural resources in study area. Thus, to level and priorities the gravity of the constraints, a pair-wise ranking of the constraints was made and presented below in table 10.

Table 13. Pair wise ranking of constraints to natural resources in the study area

No	Constraints	Kebeles of Biyo Awale Cluster		
		Adada	Awale	Bishan Bahe
1	Soil erosion	3rd (3)	3rd (3)	3rd (3)
2	Deforestation	2nd(4)	2nd(4)	2nd(4
3	Temperature increase/drought	1st(5)	1st(5)	1nd(5)
4	Depletion of soil fertility	4fd(3)	4th(3)	4th(3)
5	Depletion of water resource	2nd(4)	2nd(4)	3nd(4)
6	Inadequate knowledge on soil and water conservation practices	5th(1)	5th(1)	5th(0)

Recommendations

Based on the PRA study results of the Biyo Awale district, there are urgent needs for research and institutional interventions to halt the identified problems through:

- Strengthening agroforestry practices through verification and promotion of multipurpose trees species that can be adapted to the agro-ecologies of the area
- Verification and promotion of appropriate bio-physical and biological soil and water conservation technologies for the area
- Strengthening Soil fertility management practices through agricultural soil testing and utilizations of organic and inorganic fertilizers
- Developing and Promotion of small scale irrigation water utilization technologies for surface, underground and rainwater resources
- Establishing sustainable linkages of research-extension and Farmers for the empowering of local farmers in verification and utilization (application) of the improved climate smart agriculture technologies in the area.

Livelihood system and major income sources

According to the FGDs, the main livelihood and income sources of the study area is mixed agriculture (cereals, vegetables, fruits and livestock products). Beside this, there are also some community members who have engaged in off-farm activities (petty trading) of vegetables, live animal and their products, and firewood and charcoal. Nevertheless, the other farmers pointed out the challenges of financial support, market problem, inadequate infrastructures and lack of required supports from few institutions of the area, with regards to diversification of the income source.

Farm household and survival strategies

The PRA discussions revealed that, the communities of the study area have developed different copping strategies as measures against drought, food and water shortages, outbreak of crop and animal disease and pests.. The measures include, selling of animals, working as daily labourers, and collection and selling of fire wood. In addition to this, women are involved in petty trades of buying local agricultural products and selling them to nearby districts and/or DireDawa city. The participants also mentioned that developing of spring and ground water, rainwater harvesting using plastic ponds which is very rare, and community ponds as the another survival strategies for water shortage they faced in the area.

Institutions

Community based Informal Institution

The PRA results show that, the communities have established different informal institutions with the objectives of safeguarding their members against social and economic shocks in the study area. During the FGDs, the participants loudly described the inistitutions as the sole supporter of the community for survival in the area. These informal institutions provide a range of services related to agricultural production and rural development table 11.

Table 14. Informal institutions and their objectives and roles in the study area

Institutions	Objectives	Their roles in the community
Afoosha	To render the members of the community in social and economic services	Supporting each other during weeding, funeral and other social issues in form of kind, monetary and labour Resolving conflicts among community members
Guuza	Accessing more (mass) community labour	Supporting each other in mass by contributing labour to solve shortage in agricultural and other activities
Marro	Organizing young men to work together	To perform agricultural activities based on labour exchange system
Iqubi	Providing saving services	Group/s of women contributes money and providides it for each other weekly on term base

Source: Survey result, 2016

Input and credit supply institutions

Some of the formal institutions working in the community of the study area include Bureau of agriculture, cooperatives/union, and Credit and Saving Association (Table 12). However, the Farmers were complained services of the local cooperatives for inadequate inputs provision and output marketing (buying), and operating with limited members of the community. Thus, farmers sell their agricultural products for middlemen in the village market in low price to cover farm and other expenses due lack of the effective financial services.

Table 12. Formal agricultural institutions in the study area

Institutions	Major roles
Office of Agriculture	Facilitation of agricultural input delivery Provide extension services on improved agricultural practices facilitates stakeholders linkage on agricultural dev't
Cooperatives/Unions	Provide different agricultural inputs for the farmers
Credit and saving association	Accessing financial services to the community
Women groups	Conducting trading activities, and providing saving and credit services for their members

Source: Survey result, 2016

Infrastructure

Review of secondert data revealed that, Biyyo Awale district has 87km all weather roads accesses, which connected its kabales (Pas) to each other and to the other districts. The district has also other infrastructures including: 21 FTCs, 10 KGs, 20 primary schools of 1-8 grades, secondary schools of 9-10 grades, 1 high school, 21 health posts and 5 health stations in its 21 total Kabales (DDA-BoA, 2016),

Market services

The PRA result indicated that, most farmers of the study were used to sell their produces at nearby towns, village markets and farm gate through middlemen. In the later case, since it is the middlemen who set prices of the produces, thus, the farmers indicated that, large part of the price margins of their produces are unfairly taken away by the middlemen. In adition to the involvement of the middlemen, limited market access and market infrastructures like market place, shades, drinking water, feeds, price information for products and other modern services are lacking in the study area.

Gender roles and decision making

Despite the existing socio-cultural barriers based gender imbalances, but the PRA results indicated that, decisions on agricultural activities, selling and buying of farm products, resource utilization and other family matters are done through consultation between husband and wife in the study area. Other farm activities such as land preparation up to post harvest handling, conservation, water source development, and tree plantations are mostly done by male, while female serves male in food, coffee and tea. But, inputs preparation, weeding, vegetable and fruit harvesting and marketing are commonly performed by female. Similarly, household activities such as preparing food, cleaning houses, milking cows, fetching water, carrying for children and others are carried out solely by female. Feeding and watering of livestock's is done both by men and women, when women usually made major decisions on incomes obtained from selling of the livestock and their products.

Nutrition

During the FGDs, male and female farmers noted that cereals like sorghum and maize are the staple food source throught the year in the area. In addition, vegetable and fruit such as potato, tomato, mango, and papaya and livestock products such as milk, egg and meat are eaten by the community, however, the consumption trend of animal products are limited. This situation has lead to malnutrition, which primarily is affecting children, pregnant and breast feeding women. Some of the major contributing constraints are lack of awareness on nutritional importance of the vegetables and livestock products in the area.

Climate smart agriculture (CSA)

The livelihood activities of farmers are constraining by various challenges such as such moisture stress, drought, poor soil fertility and lack of access to inputs and improved seeds in the study area. However, some farmers perceived these challenges and made limited efforts of coping through growing various cereal crops, pulse, vegetable and fruit trees on a plot of land. In addition, soil and water conservation measures like constructing soil bunds and indigenous ridges, planting grasses and multi-purpose trees, on-farm water management, small-scale irrigation, and integrated soil fertility and watershed managements are some of the identified climate smart agricultural practices in the study areas.

Recommendations

- The result of PRA revealed the various socioeconomic and infrastructural constraints that have been affecting the livelihood of the rural communities in the study area. To solve these problems, there is a need for:
- Strengthening the capacity of farmers' cooperatives and unions to provide effective input and output market to the farmers in the area
- Improving access to financial services through strengthening the capacity of financial institutions in the area
- Strengthening the involvement of local institutions in research and development activities,
- Increasing awareness, knowledge and skill on nutrition through demonstration trainings of different food recipe
- Supporting the socio-economic services provided by formal and informal institutions to the communities
- Support farmers' Climate Smart Agriculture practices through conducting research and providing improved technologies and trainings of in the area.

Participatory Agricultural Production Constraint Analysis in Selected Districts of Harari Region, Ethiopia

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Abstract

Participatory rural appraisal (PRA) was conducted in July, 2016 in AGP-II project target districts; Erer waldiya and Dire Teyara districts of Harari National Regional State to assess the existing production system and identify major agricultural production constraints and opportunities for future research and development interventions. PRA tools such as review of secondary data, focus group discussions, field observations, transact walk and pair-wise ranking were used to collect primary and secondary data required for the study. The PRA result and secondary data review revealed that mixed crop-livestock farming and alley cropping of maize and sorghum with khat (*Catha edulis* Forsk) are common practices in the study areas. Maize and sorghum are the major Staple food crops while vegetables and khat are produced as major sources of cash. Major bottlenecks to cop production include lack of improved crop varieties, low soil fertility, shortage of rainfall, diseases and insect pests. Livestock production in the area is constrained by shortage of feeds, diseases and parasites and lack of improved breeds. Soil erosion, deforestation and soil fertility depletion are among the major environmental constraints jeopardizing crop and animal production in the study areas. Furthermore, unbalanced and fluctuating prices of agricultural inputs and outputs, poor marketing system particularly for vegetables, shortage of storage facilities for vegetables, shortage of capital, and farmers' distrust in cooperatives were identified as major problems that need to be addressed. The presence of poor institutional support system on one hand and poor collaboration among the existing institutions on the other are the other constraints to agricultural development. Hence, future research and development interventions should address these bottlenecks to improve production and productivity and livelihood of the farming community in the area.

Introduction

As for the other parts of the country, agriculture is the main sources of livelihood for the majority of people in the Harari National Regional state. Despite the importance of the agriculture sector to the livelihood of the people in the region, however, the sector is still characterized by low production and productivity mainly due to socio-economic, technical, environmental and institutional factors. These constraints need to be solved in order to bring substantial changes in production and productivity of the sector and livelihood of the farming communities in the area. Hence, this participatory assessment of agricultural production system was initiated to assess agricultural production systems and its constraints in selected AGP-II districts of the region using participatory rural appraisal (PRA). The information generated through this study will be used for designing research interventions geared towards solving the identified priority problems.

Methodology

Description of the study areas

As this particular study mainly focuses on assessing the existing production system, it is paramount important to describe the study areas from different angles. Hence, the following sections describe the study areas in terms of location, climatic conditions, land use system, soil types, vegetation and other aspects.

Location and size of the study districts

Erer Waldiya district is located North East of Harar town, the capital of the region at 13 km distance. It is bordered by Jarso in the North, Gursum in the North East, Babile in East, Dire Teyara in West, Sofi in the South West. The total area of the district is 84.19 km^2 accounting for 26.01% of the total rural areas of the region. The district comprises of one urban and three rural kebeles. Dire Teyara district is situated North East of Harar town, the regional capital. The district is located 8 km away from Harar town. The district is bordered by kombolcha in the North, Jarso in the North East and Haramaya in the West. The total area of the district is about 70.54 km^2 and accounts for 21.79% of the total rural area of the region. The district comprises of one urban and five rural kebeles.

Climatic conditions

Erer weldiya distict has two major agro-ecologies; the mid-altitude (25%) and the lowland (75%). The district is found at an altitude of 1300-1800 meters above sea level. The mean annual rainfall is 400mm while maximum and minimum rain fall is 500mm and 300mm respectively. The district lies in the semi-arid belt of the Eastern lowlands of Harari Region. As in most parts of the Horn of Africa, Erer Waldiya district has two rainy seasons. The first is short rainy season (Belg) which takes place between March and May while the second and the most important one is the main rainy season (Meher) which extends from July and

October. The rainfall distribution is bi-modal with a dry-spell period during the months of June and July which depending on its duration may affect crop growth (Canali and Slaviero, 2010). The annual average temperature ranges from 30 ^oC with minimum and maximum 25 ^oC and 35 ^oC, respectively. The land scape of the district is 70% mountainous and undulating, while the remaining 30% is hilly.

Like Erer Waldeya, Dire Teyara district has also two major agro-ecologies; the mid-altitude (83.3 %) and the lowland (16.7%). The district is found at an altitude of 1200-2000 metres above sea level. The district has bi-modal type of rain fall. The rain fall records of Harar metrological station of the last nine years (2000-2009) shows that annual rain fall ranges from 636.7mm to 917.9mm with the average rain fall being 757.7mm. The rainfall intensity vary from season to season with the Belg season (February to May) contributing 42.1%, Maher season (June to September) and the dry season (November to January) contributing 48.8% and 9.1% of the total annual rain fall respectively. Due to scarcity and unevenly distribution of rain, frequently dry spell occurred in the middle of Belg and sometimes at the end of Maher season affecting crop production and productivity.

The metrological data of 2000-2009 of the region indicates that monthly temperature ranges from 22.6oc to 28.4oc to with the warmest months extending from February to May and the coldest months from October to December. The fall in temperature in months of October, November and December sometimes have a negative impact on crops particularly in Sukul, Hasengey and Dire Teyara areas. The land escape of the district is 75% flat land, 10% undulating, 5% mountainous and the remaining 10% is hilly.

Major Soil types

The major soil types in Erer Waldiya district include Luvisols (Sandy soil) and nitisols (clay soil) with a proportion of 90% and 10% respectively. Whereas the major soil types in Dire Teyara district include Sandy, sandy loam, clay and black soils with sandy loamy soil being the dominant one. Erer Waldiya has a number of small streams and two seasonal rivers. Dire Teyara district has no rivers at all but there a number of ground water and pond water constructed by farmers. The problem of ground water and pond water is associated with capacity of ground water is very low and shortage of geo membrane plastic for pond construction.

Land use system

According to the information obtained from demographic and socio-economic profile of district, the total area of Erer Waldiya district is 8419 hectares. Of this, total arable land, cultivated land, forest land, area closure and land used for construction constitute for about 25.3%, 24.7%, 12.7%,12.7% and 5.9% respectively. About 1619 hectares (19.2%) of the total land area of district is not suitable for agricultural production. The average land holding for midland parts of the district is 0.35ha while that of the lowland 0.52ha. More than 85% of farmers in the district have land holding of less than 0.5 ha.

Dire Teyara district has a total area of 7054 ha. Out of this, total cultivated land is estimated to be about 2,180 (31%) hectares while forest land, grazing land and land under construction constitute 0.35%, 0.51% and 1.7% respectively. About 4693 hectares (66.5%) of the total land area of district is partly not suitable for annual crops and is used for perennial crops such as

Khat. The average land holding of the district is 0.35ha. Majority (69.9%) of farmers of the district have land holding of less than 0.5 ha.

Major Vegetation types

In both districts, there are natural forests, bush and shrubs and planted trees. Some of the tree species found in Erer Waldiya district include Cordia, Acacia, muka Garbi, Gravellia (Shawshawe), sesbania sesban and various fruit tree species are grown on the farmlands as agro-forestry trees.

Site selection and sampling procedures

Prior to the field survey, a team of experts consisting of five members was established and the team held a series of discussions to sort out issues pertaining to the survey and establish common understanding among all members of the team. More specifically, the discussion held on the checklists provided by regional team, PRA approach and tools to be used, procedures to be followed during the PRA and roles of each team members during the PRA. Following this, AGP-II targeted districts and Kebeles were identified and listed in consultation with experts of the regional aagricultural development office.

Accordingly, Dire Teyara and Erer Waldeya districts were selected purposefully based on their potential in agriculture, agro ecology and available resources such as land and irrigation water. Two kebeles from Erer Waldeya and one kebele from Dire Teyara districts were then selected for the survey. Finally, a total of 100 farm households were selected based on stratified random sampling techniques. Of the total sample households, female accounts for 18%. In addition to farmers, a total of 11 DAs have also participated in PRA.

Method of data collection

Review of secondary data, Focus group discussions (FGDs) and Field observations were used to collect the required data for the study. Secondary data were collected from Agriculture Offices of the selected districts using a detailed checklist prepared for this purpose. Moreover, thorough discussions were made with development agents and experts of respective districts.

Data related to constraints to crop production, natural resource management, livestock production, marketing, institutions, and socio-economic conditions were collected through intensive focus group discussions. The FGDs were held with elders and young male and female farmers, community leaders, development agents and experts from district offices. In addition to secondary data review and FGDs, the survey team made visual field observations of existing resources, existing cropping practice and constraints to crop production, natural resources management practices and problems, livestock management, marketing facilities.

Data analysis

The data and information collected from different sources were checked for errors and completeness and analysed using descriptive statistics.

Results and discussion

Farming Systems and Natural Resource Management

This part presents results of PRA exercises on farming systems practices (crop and livestock production) and natural resource management activities of the study districts.

Crop production

Sorghum and maize are major crops commonly grown in both districts whereas wheat and barley are only cultivated in midlands of Dire Teyara districts. Sorghum, wheat, barley, haricot bean and ground nut are cultivated in the main field and are the major cereal and pulse crops grown under rain fed conditions, whereas maize is grown on limited area both under rain fed and irrigation at Erer Waldiya districts . Groundnut is the major pulse crop grown in the stud area and is the potential cash crop next to Khat.

In addition to cereal and pulse crops, varieties of horticulture crops such as potato, tomato, Avocado, Guava, mango, papaya and others are grown in the area. Potao and cabbage from vegetables and Avocado and Guava from fruit crops are the most important horticultural crops in the mid altitude areas of Dire Teyara district while Mango and Papaya are the major and important fruit crops grown in low lands of Erer Waldiya district. These crops are produced as cash crops under rain fed during main season and using irrigation in both districts. Because of shortage of land, these crops are mainly intercropped between sorghum and maize. Sugar cane is the major cash crop produced under both by rain fed and irrigation in Erer Waldiya district.

Cropping systems and pattern

Alley cropping of different crops with khat and intercropping are the most dominant cropping systems in the study areas. Intercropping is mostly made between the major cereals; sorghum and maize and pulse and oil crops such as haricot bean and groundnut. But, sometimes there is also sole cropping of maize and sorghum and intercropping of sorghum with maize. Wheat and barley are the only crops produced under sole cropping system. In both districts, crop production is mainly practiced under rain fed conditions.

Trends in crop production and productivity of major crops

Information obtained from review of secondary data and focused group discussion (FGD) shows that productivity of local and improved sorghum ranges from 15.94 to 20 and 24.9 to 30 qt/ha respectively and that of local and improved maize ranges from 24.6 to 30 and 36 to 45 qt/ha, respectively in low lands of Erer Waldiya district. Similarly, the productivity of local sorghum and maize ranges from 22 to 40 and 30 to 45 qt/ha respectively in midlands of Dire Teyara districts.

As indicated in figure 1&2 below, the productivity of major crops shows an increasing trend. However, it is still low as compared to the attainable yield mainly due to shortage improved varieties, low soil fertility, low soil moisture due to erratic rainfall and its poor distribution in the area.

Crop management practices

Soil fertility improvement

The low soil fertility in the study districts is attributed to low inherent soil fertility, loss of nutrients through erosion, intensive cultivation of the land which encourages oxidation reaction, total removal of crop residues for animal feed and source of energy and little or no addition of organic matters and inorganic fertilizers. To solve soil fertility problems, farmers in the area use inorganic and organic fertilizers and soil conservation measures. Details of the PRA results are presented below.

Use of inorganic fertilizers: DAP, NPS and Urea fertilizers are the major inorganic fertilizers applied by farmers. Band, broadcasting and top dressing are common methods of fertilizer application for all crops in both districts. Use of the inorganic fertilizers depends on the availability of rainfall and the cost of fertilizers. Most of the discussants of both districts noted that use of inorganic fertilizers under moisture stress burns the crops.

Use of organic fertilizers: Use of animal manure is a common practice in both districts. Most farmers use combination of manure with inorganic fertilizers for major crops like sorghum, maize and cash crops such as tomato, potato and onion. However, the amount of manures used depends on the number of livestock owned by the households. Farmers who own more number of livestock have better chance of using more manure than those who own less number of livestock. Manure is collected from the barn and directly transported and spread over the fields before planting vegetables in both districts. However, for sorghum and maize, farmers keep manures for certain months and later transport and spread on fields before planting. Soil conservation measures: Soil conservation is a common tradition in the study areas. Because of the undulating and fragile nature the land, farmers construct terraces and soil bunds to prevent soil lose due to erosion. In addition to soil conservation activities, farmers in the area also use animal manures for improving fertility of their land. According to FGD discussants, soil conservation measures are practiced to conserve the top soil from being eroded and to conserve moisture. Soil and stone bunds are the common soil erosion control measures practiced by the farmers in the study areas.

Agronomic practices

In the study areas, land is prepared by oxen and human power. FGD participants in both districts reported that cultivation is performed with traditional local maresha and hand tools such as Hararghe Akafaa and Dongora. Tillage frequency for most of the crops is 2 to 3 times. Both broadcasting and row planting methods are used for planting maize and sorghum. Wheat and barley are planted using broadcasting method while vegetable crops such as tomato, onion and potato and fruit crops like mango are planted in row.

Pest management practices

Insects, disease, and weeds cause significant yield and quality losses of crops. The pest management practices of the study areas are described as follows.

Weed management practices

Parthenium, Cyprus and Striga species such as *Striga hermonthica and Striga sciatica* are the most economically important weeds in the area. Striga is a serious constraint to sorghum and maize production particularly in dry areas of the study districts. In the study area, farmers control weeds using hand weeding, deep ploughing, and repeated cultivation of maize and sorghum fields using an oxen and hand hoe. Deep ploughing is done for uprooting parthenium and burring into the soil with its seed to allow crops to grow up before parthenium infestation. Roundup and herbicides are used for different weed types such as couch grass, Bermuda grass and Cyprus grass whereas 2-4D is used for broad leaf weeds. High value crops like tomato, onion and potato require repeated hand weeding to keep the fields clean from any weed infestation. Use of chemicals for controlling weeds is not a common practice in the case of sorghum, maize, wheat, barley and sesame. In both districts, weed control practices is usually undertaken 2-3 times manually by hand. The most important weed species, time of weeding, weeding frequency and their management practices for AGP-II targeted crops are presented in Table 1&2 below.

Insect pest management practices

The major insect pests prevailing in the study areas include stalk borer, grubs, aphid, army worm and grass hoper for sorghum and maize, shoot fly, grubs and grass hopper for wheat and barley and army worm for sesame. Similarly, the major insect pests for vegetable crops include tomato leaf minor (*Tuta absuluta*), aphid and white flies for tomato, thrips for onion, aphid and moth for potato. Mango is highly affected by thrips, midge, fruit fly and termite whereas aphid is known to be the major insect affecting banana in Erer district.

Insecticides like DDT and MALATHION are applied for vegetable and fruit crops to control aphid, leaf minor (Tuta absuluta), white flies, moth, spider mite, thrips, midge, fruit fly and termite. No insecticides used for controlling insect pests affecting cereal crops. Farmers spray insecticides two to four times per season. In addition to insecticides, traditionally farmers do practices such as farm cleaning, removing and burning of the affected plant, burying into the soil and then applying urine for three days for controlling insect pests. Removing and burning of the affected plant is a common practice to control maize and sorghum stalk borer while burring into the soil is for grubs. Farmers of the Dire Teyara district reported that cattle urine is used to control all cereal worms.

Disease management practices

PRA result has indicated that there are various diseases in the study area affecting crop production. The major diseases identified include smut, leaf spot, root rot, rust, powdery mildew, downy mildew, early blight, late blight, Purple blotch, dieback, anthracnose and white mold. Smut, leaf spot and root rot are major diseases affecting maize and sorghum production while rust is the major disease for wheat and barley. Similarly, powdery mildew, down mildew, early blight were reported to be the major diseases for tomato while downy mildew and Purple blotch and Late and Early blight were found to be important diseases for onion and potato respectively. Dieback, blight, powdery mildew and anthracnose are diseases affecting mango and while white mold is the type of disease affecting banana. In addition to the above mentioned diseases, there are also unidentified diseases locally called "Deyma and waab" affecting sorghum and maize. No diseases were reported on sesame.

Farmers in the study area use chemicals such as DDT, Mencozeb and Malathion for sorghum, maize and mango and Mencozeb for vegetable crops such as tomato, potato and onion to control diseases. They also use traditional practices like farm cleaning, removing and burning of the affected plant for controlling crop diseases. Farmers in Erer Waldeya reported that they also use smoke and ash to control blight, powdery mildew, anthracnose and white mold.

Crop production constraints

Various production constraints were identified through the PRA study conducted in the two districts. The identified constraints were generally categorized into three categories as production, Post- harvest handling and market related constraints. The major bottlenecks identified include lack of improved crop varieties, shortage of rainfall, low soil fertility, deforestation, disease and insect pests, knowledge and skill gap on agronomic practices and soil fertility management, poor post- harvest handling, market related (Table 1).

Table 1. Matrix ranking for crop production constraints in Erer Waldiya and Dire Teyara district

Crop production constraints	Erer Waldiya kebeles		Dire Teyara kebele
Management related	Waldiya	Dodota	Dire
Shortage of improved variety	1st (5)	2nd(4)	3rd(3)
Insect and diseases	4th (2)	3rd(3)	2nd(4)
Weed	3rd (3)	3rd(3)	1st(5)
Shortage of rainfall	2nd (4)	1st(5)	2nd(4)
Poor Soil fertility	6th (0)	5th(2)	4th(2)
Knowledge and skill gap	5th (1)	6th(1)	5th(0)
Post-harvest related problems			
Harvesting and threshing	1st (3)	1st (3)	1st (3)
Transportation	2nd (2)	2nd (2)	4th (0)
Storage	3rd (1)	3rd (1)	2nd (2)
Processing (quality)	4th (0)	4th (0)	3rd (1)
Marketing related problems			
Access to market	1st (4)	1st (4)	1st (4)
High price of inputs	2nd (3)	2nd (3)	4th (1)
Access to Credit	5th (0)	5th (0)	5th (0)
Market information	4th (1)	4th (1)	3rd (2)
Lack of organized market	3rd (2)	3rd (2)	2nd (3)

N.B: Figures in the parenthesis are the score values and numbers outside the parentheses are matrix ranking.

Recommendations

- The present study has identified a number of problems affecting crop production in the study area. Hence, to solve these problems, there is a need to;
- Give emphasis to research interventions that focuses on generating drought tolerant crop varieties, moisture conservation and water harvesting
- Give emphasis for on-farm demonstration and popularization of the existing improved crop production technologies.
- Improve supply of improved seeds of existing drought tolerant varieties
- Encourage farmers through training and awareness creation to use drought tolerant varieties, plant trees and do in-situ moisture conservation.

- Conduct research on soil fertility improvement and other agronomic management practices and also sstrengthen knowledge of extension staffs of agricultural office on soil fertility management for specific crop (rate, time and space of application)
- Develop location specific fertilizer recommendation for major crops.
- Identify and recommend the existing disease, insect and weed controlling technologies for crop and coffee
- Further identify and document indigenous knowledge of farmers related disease and pest control
- Capacitate farmers on pest identification and application of integrated pest management techniques.

Livestock production

Animal production is an important component of the farming system of the study districts. In both districts, different types of animals are kept which include, cattle, sheep, goat, camel, poultry and donkeys. As for the other parts of the country, livestock in the area are used for different purposes such as for traction, food and sale. Oxen are mostly used for traction purposes. Poultry are used mostly for egg production and sale. Donkeys are used for transportation.

Livestock types and population

Secondary information indicates that there is significant number of livestock population in both study districts (Table 2). However, livestock in the area is predominantly indigenous breeds. There are only very few crossbred cattle of different exotic blood level registered in Dire Teyara district and Borana breed (only 1.13%) registered at Erer Waldiya district. The number crossbred animals are relatively higher in Dire Teyara district. In terms of population, Dire Teyara district had the highest number of cattle, sheep and goat while poultry, camel and honey bee colonies are higher in Erer Waldiya district. It was also observed that poultry production using improved chicken breeds and honey production from modern bee hives have been expanding in the study areas.

Table 2. Livestock population of Erer Waldiya and Dire Teyara districts

Livestock types	Erer Waldiya district	Dire Teyara district
Cattle	10630(+120*)	10000(+6000*)
Sheep	83	10000
Goat	4475	6000
Donkey	750	600
Poultry	5315	3000
Camel	6731	-
Honey bee hives (both traditional and modern)	885	-

*Crossbred or improved breed

Livestock productivity

The current study indicated that livestock productivity is generally low. As shown in table 3 below, the average dairy milk yield of indigenous breed across different agro-ecologies of Dire Teyara and Erer Waldiya districts was 2 and 2.5 liters, respectively. The results were also supported by secondary information which indicates daily milk production from indigenous cow to be 2 to 3 liter at lowlands of Erer Waldiya district and 1.5 to 2 liters at midland of Dire Teyara districts. The relatively higher milk yield in Erer Waldiya could be related to management and availability feed in the area. In contrast to the local breeds, the average milk production from improved breeds of different exotic blood levels was as higher as 8 to 10 liters per day.

Secondary information from study districts revealed that lactation period for the local cattle at Erer Waldiya and Dire Teyara districts ranges from 6 to 10 and 6 to12 months respectively. Whereas the lactation period for the cross breed cows in the same districts ranges from 8 to 10 and 12 to15. Age at first lactation for heifers is 5years for local breed and 2 to 3 years for cross breed cattle whereas 4 years for local breed and 1.5 to 3 years for cross breed cattle. The average weaning age for the local and cross breed calves in Erer Waldiya is about 10 and 12months respectively while it is about 8 and 6 months in Dire Teyara district. Local bulls are trained for draught power at age of 3 to 4 years and begin service at age of 4 years. It serves for 5 to 6 years. The cross breed bulls usually fatten for meat production but sometimes also used in draught power when they reach at age of 2 to 3 years.

Looking at the performance of other livestock types, secondary information obtained from district office of agriculture shows that egg production from improved chicken ranges 144 to 160 while that of local chicken ranges from 50 to 70 eggs per year. Similarly, honey production per year from modern bee hives was 18 kg while that of traditional hive is only 5kg. The highest annual honey harvest from modern bee hives was reported at Dire Teyara than Erer Waldiya district. According to the PRA discussants, honey production, however, shows a decreasing trend mainly due to unavailability of bee forages and increased losses of honey bee colonies through agro-chemicals and deforestation. The existing bee forages are decreasing from time to time mainly due to drought and deforestation and hence could not support the existing bee colonies in area. As a result, there is frequent absconding of the colony particularly from modern hives .Use modern hives is limited due to the high price and lack of knowledge on the importance of the technology.

Table 3. Mean productivity of milk, eggs and honey in Erer Waldiya and Dire Teyara districts

Livestock types	Erer Waldiya kebeles		Dire Teyara kebele
	E/Waldiya	E/Dodota	D/Teyara
Cattle, indigenous (kg, milk)	2	3	2
Cattle, improved (kg, milk)	10	15	12
Chicken, indigenous (N, eggs)	65	50	70
Chicken, improved (N, eggs)	150	144	160
Amount of honey produced from traditional hives	5	5.0	5
Amount of honey produced from modern hives	15	15	18

Livestock management

Livestock feeds and feeding system

Livestock production in the study area depends on different feed sources the major ones being crop residues, thinned crop plants of maize and sorghum and natural pasture. During the dry seasons, animals are fed on natural pasture, thinned plants of maize and sorghum, elephant grass, weeds, bushes and shrubs. During this period, animals are allowed to freely move and are fed through cut and carry system.

During the dry season, animals mainly depend on crop residues, crop aftermath and grazing. The major crop residues available for livestock feed include maize stalks and cobs; sorghum stalks and chaffs and dry leaves of sorghum and maize. However, the feed resources used both during wet and dry season are generally poor quality roughage feeds. Use of concentrate feeds and industrial by-products is very limited. There is also limited use of improved forages for dairy cattle and oxen in both districts.

In the area, animals are mostly fed to similar feed types except some special feeding management done for lactating and fattening animals. Some farmers in the area use industrial by-products, crops thinning, hay and improved forages for lactating and fattening animals. There are also some experiences of using maize, sorghum and haricot bean grain for cattle fattening maize and sorghum grains to feed chicken.

Sources water for livestock

In the study area, animals get drinking water from different sources. Farmers in Erer Waldeya district depend on rivers, ground water and rain water for drinking their animals while those of Dire Teyara district use ground water and rain water. Rivers and rain water are available only during the rainy season. Ground water is the only source of water for livestock during the dry season. There is critical shortage of drinking water for livestock in the area.

Animal health management

Livestock diseases and parasites

Results from review of secondary data and PRA study shows that there are different diseases and parasites in the area affecting livestock production (Table 4). These include anthrax, blackleg, Bovine and Ovine Pastrulolosis, Foot and mouth disease, Lumpy Skin Disease, Dermatophylosis, Paralysis, Diarrhea, foot rot and small poxes. Among these, anthrax and blackleg are the most common diseases affecting dairy cattle. Similarly, bovine and ovine pasturollosis are the two most common bacterial diseases affecting dairy cattle and sheep respectively. Dermatophilosis was reported as common diseases for dairy and poultry in Dire Teyara district and foot rot and pox reported on goat and sheep in Erer Waldeya district.

Other diseases in the area include Paralysis, diarrhea and bleeding for poultry and Lumpy Skin Disease and Diarrhea for sheep and goats. In addition to diseases, there are also internal parasites such as Nematodes, epidermal worms and leeches and external parasites such as mange mite, ticks and poultry mites, lice and fleas. Nematodes were reported to be major internal parasites affecting sheep and goats in both districts while epidermal worm and leeches were reported on dairy cattle in Erer Waldeya and Dire Teyara districts respectively. Similarly, lice, ticks, fleas and poultry mites were identified as major external parasites for dairy and poultry in the study areas.

Table 4. Major livestock diseases identified in Erer Waldiya and Dire Teyara districts

Livestock species	Type of disease/parasites	Internal parasites	External paeasites
Dairy cattle	Anthrax, Black leg, foot and mouth disease, Mastitis, Bovine Pasturollosis and	Epidermal worm, Leeches	Lice,Ticks and Fleas
Sheep and Goat	Ovine pasturollosis, Diarrhea, Lumpy Skin Disease, Foot rot, Goat & sheep Pox	Nematode	-
Poultry	Paralysis,Diarrhea, Bleeding, Dermatophilosis	-	Poultry mite

Housing management

In the study area, farmers mostly keep their animals in their own living houses by making certain partitions in a house. However, there also cases where farmers keep animals in a separate house and small open barns.

Livestock breeding management

Breeding management is an important practice in livestock production, but usually not well managed due to various reasons. In the study areas, due to poor access to shortage of AI services, farmers use uncontrolled natural mating.

Livestock product processing

Farmers in the area use traditional storage and transportation materials locally known as ‘Buqqee’’ and different small plastic and aluminum cans. Churning of milk is also performed using traditional materials.

Livestock production constraints

There are various constraints affecting livestock production in the area (Table 5). These include shortage of livestock feeds, shortage of improved breeds, lack of improved forages, prevalence of livestock diseases and parasites and market related problems.

Table 5. Matrix ranking to crop production in Erer Waldiya and Dire Teyara district

Livestock production constraints	Erer Waldiya kebele		Dire Teyara kebele
	Waldiya	Dodota	Dire
Shortage of improved breeds	2nd(4)	2nd(4)	4th(2)
Shortage of livestock feeds	1st (5)	1st (5)	1st (5)
Water shortage	4th(2)	4th(2)	2nd(4)
Animal health problem	3rd(3)	3rd(3)	3rd(3)
Technological constraint	5th(1)	5th(0)	5th(1)
Market constraint	2nd(4)	3rd(3)	3rd(3)

NB: Figures in the parenthesis indicate score values and numbers outside the parentheses indicate ranks given to the identified constraints.

Recommendations

As discussed earlier in this report, livestock is an important component of the farming system of the study area. However, the farming communities are not getting the required benefits from the sector due to various problems. Hence to solve these problems, there is a need to;

- Strengthen livestock extension system
- Work more on livestock feed improvement through introduction improved forage varieties to the area
- Improve access ti AI services
- Conduct research to identify the potential of existing breed for dairy, beef, and etc. for future breed improvement work
- Develop drinking water for livestock
- Improve livestock marketing system
- Improve access to micro finance institution to enhance farmers' access to credit
- Identify and document indigenous fattening practices in order to integrate with current scientific knowledge
- Further investigate the severity and incidence of major livestock diseases in the area.
- Enhance the capacity of veterinary technician both technically and materially will help in controlling the outbreak of the disease.

Natural resources management

Common property resources

Common property resources in the area include water (surface and ground water), forest (natural and plantations), communal grazing areas and area closure. There are two rivers; Laga fal'ana and Gafirerivers in Dodota kebele of Erer waldiya district one river namely Amaressa in Dire Teyara districts. In addition to these, Dire Teyara district has ground water that can be used for domestic and irrigation purpose by local communities. In Erer Waldiya district, there are also traditional small surface irrigation schemes used for production of sugarcane and various vegetable crops. In the area, there are also forest trees and shrubs scattered on mountain and hill sides.

Soil characteristics

Farmers in Erer Waldiya district have identified three soil types namely Luvysoils (Sandy soil), nitosoils (clay soil) and petazonesoil (black soil, very small area). Similarly, farmers in

Dire Teyara district have identified four soil types namely sandy loam, sandy, loam and black soils. The classifications are based on soil color, ease of tillage, texture, and production potential. Due to the sandy nature of soil and salinity problem, the soil in the area is characterized by low water holding capacity and low fertility which affect crop production.

Soil erosion

The most dominant form of erosions in Erer Waldiya district are sheet erosion, rill erosion and gully erosions while that of Dire Teyara district are sheet and rill erosions. Sheet erosion is the dominant of all forms of erosion occurring in both districts and it is more serious where the vegetation cover is severely depleted especially in cultivated land. Rill erosion is also the other important form of erosion in both districts. Gully erosion is a serious problem in Erer Waldiya district. Gully formations have devastated most areas in the district due to the topography (more than 70% of the land of is undulated).

Soil and water conservation practices

Soil and stone bunds are the most common physical structures used for soil and water conservation in the study areas. It is a common practice for farmers to construct new soil and stone bunds or maintain the existing ones every season at the time of land preparation for protecting their fields from runoff and for *in-situ* moisture conservation. They also build these structures on the uncultivated sloppy areas to prevent erosion from uphill. Farmers in the area also practice biological conservation such as uses of organic fertilizer, reforestation and also growing of grass strips along the bunds to control soil erosion. Soil bunds are constructed along the contour for ease of carrying out farming operations such as land preparation, planting and all cultural practices. Farmers in Erer Waldiya district reported that elephant grass and other locally available grasses as biological soil conservation measures and animal feed.

The most commonly grown perennial and stimulant crop, Khat is also an important crop for conservation. The alley cropping pattern and trenches made along the strip (locally called *Katara*) for khat are commonly used to conserve soil and water. Farmers also intentionally grow and keep some multipurpose agro-forestry trees on farm lands for the purpose of soil and water conservation. Some farmers make ridges on their fields to conserve moisture which is highly beneficial for the crops especially during the dry spells. Only very few farmers construct ponds to collect water for irrigating khat at both districts.

Water harvesting activities

Farmers in the area reported that rain water harvesting (runoff and roof water harvesting) and use of ground water (ponds) the most common practices in the study areas. Farmers usually construct ponds and traditional furrows before the rainy season for collecting surface runoff (floods) and roof water. They also develop ground water based small scale irrigation.

Natural resource management constraints

Constraints related to is frequent occurrence of droughts and availability of rain and ground water, deforestation, severe soil erosion, open and over grazing, population pressure and diminishing land holding, shortage adaptive multipurpose trees and grass, in adequate knowledge of soil and water conservation and use of modern irrigation system and poor extension services related to natural resource management.

Table 6. Constraints to Natural Resource in Erer Waldiya and Dire Teyara districts

Natural Resource Management Constraints	Erer Waldiya district		Dire Teyara district
	E/Waldiya	E/Dodota	Dire Teyara
Soil erosion	3rd (3)	3rd (3)	2nd (4)
Deforestation	2nd (4)	2nd (4)	2nd (4)
Temperature increase /drought	1st (5)	1st (5)	1nd (5)
Soil fertility decrease	2nd (5)	2nd (5)	3nd (3)
Depletion of water resource	3rd (3)	4th (2)	3nd (3)
Technology constraints	4th (2)	5th (1)	4th (1)

Recommendations

Based on the PRA results, the following recommendations have been given for future natural resource improvement in the study areas.

- Deforestation, crop residue removal, over grazing, continuous cultivation, soil erosion and lack of conservation measures are some of the major challenges leading to severe droughts, low soil fertility and hence low production. So, to revert this situation, there is a need to give emphasis to lowland and midland tree plantation, reforestation, soil and water conservation practices. Hence, research and development efforts should focus on development and promotion of suitable agro-forestry practices by integrating indigenous and scientific knowledge.
- Soil and water conservation researches should be initiated to generate alternative soil and water conservation technologies. Soil fertility management researches based on soil test recommendations must be launched with the integration of organic and inorganic soil fertility improvement strategies.

Livelihood System and Household Economy

Livelihoods and Income

Communities have engaged in diverse economic and livelihood activities across the study areas which include agriculture, off-farm, and non-farm activities as means of livelihoods. There are also very few formal institutions involved in agriculture and rural development activities across the study districts. The major sources of staple food in the area are maize and sorghum. Farmers grow cash crops like groundnut, vegetables, fruits and khat (Catha edulis) to generate cash. In addition to crop and livestock production, bee keeping, trading and working as daily laborer are also supporting the livelihoods of farmers in the study area. According to the PRA group discussions, the main sources of income for farmers in all districts are crop production followed by livestock rearing.

Farm Households Assets

The major assets owned by farm households in the study areas are productive assets like livestock, Crops (perennial crops like mango, banana, khat, and etc), residential houses ((Irion sheet and grass roofed), household furniture such as beds, radios, televisions, etc and farm equipments like plough, sickle and others.

Access to different institutions

Results of FGDs revealed that farmers in Erer Waldiya and Dire Teyara have relatively poor access to agricultural inputs and output marketing facilities for their produce. Agricultural inputs are supplied to the community mainly by Union via the primary cooperatives. Lack of temporary storage and transportations, especially for tomatoes and mangoes, farmers' lack of trust in cooperatives, middlemen, and a shortage of capital to purchase agricultural inputs are some of the problems related to vegetable marketing.

Community based informal institutions

In addition to formal institutions, there are different community-based institutions such as Idir (Afosha), Iqub and Guza established to safeguard their members against social and economic shocks. These informal institutions provide a range of services related to agricultural production and rural development. 'Edir' established to assist members especially during funerals. 'Iqub' takes a form of weekly money contribution where members receive the contributed money on random basis until all members get their share. It also lends money to the members without any interest rate. Whereas,'Guza' is contribution of labor to solve labor shortage. Organizations working in the areas can use these institutions as entry point to achieve agricultural and rural development objectives.

Input and credit supplying institutions

There are formal institutions working on agricultural and rural development issues particularly on supply of agricultural inputs (Table 7). These institutions include bureau of agriculture, unions and primary cooperatives, Harari Credit and Saving Association and safety net programs.

Table 7. Common formal institutions working in the community on agricultural and rural development

Institutions	Roles	Target group
BoA	Facilitates agricultural input provision Provides technical extension services	All categories of people in the community
Union	Organizes & links farmers to service providers Provides agricultural inputs through primary cooperatives established in each village Supplies edible oil, sugar, grain and seedlings to the community at affordable prices Facilitates marketing of inputs & outputs on a very limited scale	All categories of people in the community
Harari Credit and Saving Association	Provides credit services to potential groups of farmers in the community for economic activities like fattening, purchasing oxen, etc. It is also involved in mobilizing savings	Specific categories of people who have the capacity to pay back the loans
HABP(Dire Teyara)	Provides food for food in secured areas through BoARD to needy members of the community	Needy members of the community
CRS(Erer Waldiya)	Providing assistance to the poor to alleviate their immediate needs, supporting self-help programs which involve people and communities in their own development,Helping those it serves to restore and preserve their dignity and to realize their potential	Assists persons on the basis of need, not nationality.

Road infrastructures

In Erer Waldiya district, there is 60km gravel paved and unpaved road that extends from the regional capital to the different kebeles of the district of which 15 km is gravel paved. Similarly, in Dire Teyara district, there is 101 km gravel paved and unpaved road that extends from the regional capital to the district's kebeles. Out of this, all weather road, gravel paved and asphalt constitute 24, 50 and 27 kilometers respectively. Because of the existence of roads, all rural and urban kebeles in both districts have access to Harar and other district markets.

Access to markets

Review of secondary data shows that generally there is better access to market in the region. Markets are available at a distance of less than one kilometer for about 43 percent of rural and 87.5 of urban households in the region. More than 85 percent (100 % 0f urban and 77% of rural) of the population could access these markets in a distance of less than 5 kilometers and only 4 percent of rural households have markets located within10-18 kilometers distance and less than 5km from the district. In both study districts, farmers sell their produces in Harar, Awaday and village markets in the district. Women in both districts sell their crop and livestock products like milk and egg as well as hens in nearby village markets. In both districts of the study areas, the market infrastructures like shades, drinking water, feeds and other modern services are lacking.

Farm Household and their Survival Strategies

As for many other rural areas, agriculture is the major source of livelihood in the study area. However, people participate in different off and non-farm activities to generate additional income required for making their livelihood. For instance, women are engaged into petty trade such as selling mango, banana, khat, cooked cereals (Nifro), roasted groundnut, fire wood and charcoal to buy food for the family. Some women also go to town to work as daily laborers by carrying water containers, washing clothes and others. Men are also work as daily laborers in the area or by travelling to other places. They transport khat from farm to the market or collect stones used for construction purposes. In this case, female headed households are most affected than the male headed household as the entire burden to support the family falls on the shoulders of the women.

Gender roles and decision making

Due to socio-cultural barriers, there exists huge gender imbalance between men and women in the study areas. According to information collected from each district, decision on farming activities, resource utilization and other family matters are through consultation between husband and wife. But, other family members like young boys and girls are not part of decision making process. Activities that require more energy such as land preparation, conservation, pond construction, ground water preparation and tree plantations are mostly done by male while most market related activities are accomplished by women. Household activities such as preparing food, cleaning houses, milking cows, fetching water, carrying for children and others are carried out solely by women and young girls. Feeding and watering of animals is done both by men and women. Women make major decisions on income obtained from selling some agricultural products such as hen, egg and milk.

Household nutrition

The major staple foods in the area are sorghum and maize. Fruits, vegetables, livestock products are rarely consumed by the farming communities. This situation has lead to malnutrition, which primarily is affecting children, pregnant and breast feeding women. Culturally, husbands are the ones given priority followed by children and women come last in terms of access to food.

Climate smart agriculture (CSA)

Use of improved varieties, multiple cropping systems and use of organic manure is also limited. However, some farmers use a combination of farmyard manure with mineral or inorganic fertilizers especially on maize and high-value vegetable crops. In general, soil and water conservation measures like planting elephant grass and agro forestry practices, conservation tillage, on-farm water management, integrated soil fertility management, small-scale irrigation, and integrated watershed management are some of the climate smart agricultural practices existing in the study areas.

Recommendations

The result of PRA indicates that various socioeconomic and infrastructural constraints are also affecting the livelihood of the rural communities in the study area. To solve these problems, there is a need for:

- Strengthening the involvement of local institutions in research and development activities,
- Strengthening the capacity of cooperatives, and unions to provide effective input and output market for the farmers,
- Improving access to financial services
- Strengthening institutional involvement in the cooperatives and financial providers to improve their delivery of services,
- Increasing awareness, knowledge and skill on nutrition through demonstration of different food recipe
- Capacity building for farmers and experts on climate smart agriculture.

Identification and Prioritization of Agricultural Constraints for Intervention in Selected Districts of West and Kellam Wollega Zones

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Abstract

Agricultural production constraint analysis were conducted in Gidami and Sayo districts of Kelem Wollega zone and Lalo Asabi district in West Wollega zone. The objective was mainly to identify the major agricultural production constraints for strategic intervention. PRA tools such as review of secondary data, *focus group discussions, field observations, transact walk and pair-wise ranking were used to collect primary and secondary data. The PRA result and secondary data review revealed that farming system of Gidami, Sayo & Lalo Asabi districts are characterized by mixed crop-livestock production system in which crop production and animal husbandry are mutually interdependent. Major bottlenecks to cop production include lack of improved crop varieties, low soil fertility, shortage of rainfall, diseases and insect pests. Most of the production system relies up on rainfall and as a result, delays or a lack of rain often adversely affects crop production. Prevalence of major diseases, shortage of improved breeds, shortage of feeds etc are the principal constraints which the livestock production system is currently facing. Consequently, the production and productivity of the livestock has been declining from time to time and needs intervention. The natural resource of the study district is under serious threat due to deforestation, soil erosion and shortage of water for both human and the livestock. The magnitude of these problems is becoming even worse and worse from time to time. Almost all farmers in the study areas use hand-tools and traditional tillage equipment and no modern farm implement is in use. Crop production, livestock production and none-farm and off-farm activities from which farmers earn cash like petty trade, selling of charcoal and gold mining. Analysis of the gender division of labor in different farm tasks has revealed that women across the three study districts take part in almost all farming activities except ploughing with oxen, which is exclusively done by men. Hand cultivation or hoeing and hand weeding is often done by both men and women. Besides, children are also engaged in most of the activities to help their parents despite their enrollment in school. The present study indicated that the whole family has access to different resources such as land and water. However, the power to make various decisions on the use of resources is traditionally owned by men. Women are usually under-represented in the decision-making process. While men tend to dominate decisions regarding the use of crops, cattle and apiculture products, women are relatively better empowered to make decisions regarding small ruminants, poultry and livestock products such as milk and butter. On the other hand, men appear to have absolute control over high value crops and cattle. But women have full control over the money obtained from the sale of small products such as poultry and livestock products such as milk, butter, egg, etc when it is surplus from home consumption.*

Introduction

Haro Sabu Agricultural Research Center (HSARC) was established in 2009 G.C by Oromia Agricultural Research Institute (IQQO) with the objective of conducting agricultural research on crops and livestock improvement as well as management of natural resources, mainly in West and Kellam Wollega Zones of Oromia. Agricultural Growth Program (AGP-II) project, which was launched in September 2015, is jointly implemented by HSARC and the respective Zonal offices of agriculture and natural resources in order to improve agricultural productivity. Before embarking on the actual project implementation, the first key activity agreed up on was to conduct problem identification and prioritization in the project intervention areas. To meet the intended objectives, a bottom-up approach of collecting information was employed based on the problems raised by the target farmers. The study mainly aims to address the identification and prioritization of major agricultural constraints and the available opportunities. The main objective of the study is, therefore, to identify constraints of crops and livestock production, natural resources management and Agricultural mechanization in the study areas to support participatory planning processes for intervention of the AGP-II project.

Methodology

Sampling procedure

The study covered three selected districts namely Sayo & Gidami from Kelem Wollega Zone and Lalo Asabi from West Wollega Zone. Participatory Rural Appraisal (PRA) and Key Informant Interview (KII) method was employed to carry out the study. A two- stage sampling technique was used to select the districts and Kebeles (the smallest administrative unit). In the first stage, the three districts were purposively selected because they have been included in AGP-II intervention areas. From the selected districts, seven representative Kebeles were selected based on agro-climatic (Table 1) and socio-economic profiles. Accordingly, two Kebeles were selected from each of Sayo & Gidami districts and three Kebeles were selected from Lalo Asabi district. Although the lowland Kebeles offer high potential for agricultural production, they were found to be inaccessible and hence the study focused mostly on the highland and midland Kebeles.

Table1: Agro-climatic conditions of the districts and Kebeles selected for the study

Zone	District	Kebele	Agro-climate	Altitude (masl)
West Wollega	Lalo Asabi	Jarso Damote	Highland	2000
		Harojji Sardo	Mid land	1930
		Ale Bareda	Lowland	1500
Kellem Wollega	Sayo	Meta Tabor	Mid land	1740
		Bele	Highland	2107 l
Kellem Wollega	Gidami	Worakoyya	Midland	1700
		Kunbabi Shapi	Highland	2200

(Source: own survey, 2016)

Data source and collection methods

Primary data were collected from group of key informants and farmers. PRA discussions were held in each of the Kebeles involving a maximum of 20 farmers composed of male, female and different age groups. The PRA was guided by checklists. Matrix score ranking, seasonal calendar, trend line, gender analysis and focus group discussions were the PRA tools used for this study. Secondary data were collected through review of various reports, published papers, and various documents related to the field of study. Various offices were visited in West and Kellem Wollega Zones to acquire these documents. Discussions were also made with key informants, including the AGP II focal persons for the selected districts.

Data analysis methods

Both qualitative and quantitative data were analyzed to obtain the intended information from the target districts. The qualitative data were analyzed and summarized based on the results from specific PRA tools. Quantitative data were used to explain cropping patterns and agricultural potential as well as livestock population of the target districts. In this regard, for quantitative analysis, descriptive statistics such as frequency, percentages, and graphs were used.

Description of the study areas

Gidami district

Gidami district is located in the western part of Kellam Wollega Zone. It is located at about 650 km West of Addis Ababa and 100 km from Dambi Dolo town. It shares boundaries with the Sudan in the West, Anfilo district in the South, Jimma Horro district in the East and Begi district in the North. It is generally characterized by flat to undulated landscape with hills and valleys. Its geo-referenced location is in between $34^{0}12'0''$E-$34^{0}33'0''$E and $8^{0}42'0''$N-$9^{0}3'0''$N. The district has a total area of 2,576.2 km^2. At present, the district has 30 Kebeles of which 28 are rural and the remaining two are urban.

According to the recent Population and Housing Census Report, Gidami district has a total population of 104,948; 52,941 are male and 53007 are female. About 46.98 %, 49.91% and 3.11% of the population is young and dependent (0-14 years), economically active or adult (15-64 years) and old age (65 and above), respectively.

In terms of agro-climatic classification, the district is divided into three zones: the highland ranging from 2500-3500 masl, the midland ranging from 1500-2500 masl and the lowland ranging from 500-1500 msal. The larger proportion of the area (69%) is midland while the highland and lowland areas constitute only 7% and 24%, respectively. Average annual temperature is about 22^{o}c while the range is from 18-25^{o}c. Annual rainfall ranges from 800-1200mm. The rainfall pattern is bi-modal with two distinct rainy and cropping seasons. The main rainy season (meher), which is also main cropping season, extends from June to September. The short rainy season is known as *Bone* and extends from March to May. In this season, rainfall often peaks in April.

The soil types vary from locality to locality based on the parent materials, climate, vegetation, altitude, latitude and interaction among these factors. According to the information obtained from district office of agriculture and natural resource, there are three types of soils: loam, sandy and clay which cover about 65%, 15% and 20% of the total area, respectively.

Sayo district

Sayo district is located in Kellam Wollega Zone at 652 km West of Addis Ababa and bordered by Gambela Regional State in the south, Ilubabor Zone in the south east, Hawa Galan & Yemalogi Walal districts in the North and east and Anfilo district in the West and North West. It has a total area of 1278 km^2 comprising 28 Kebeles. Sayo district is located between $8^{0}12'$-$8^{0}44'$ north latitude and $34^{0}41'$-$35^{0}00'$ east longitude. According to the recent Population and Housing Census Report, Sayo district has a total population of 140,241; 70,064 are male and 70,178 are female.

In terms of agro-climatic classification, about 34.6%, 26.9%, 38.5% is highland, midland and lowland, respectively. The altitude of the district ranges from 1300 to 2000 masl. The area is endowed with natural forests and animals. The major rainy seasons in the district include spring (April-May), summer (June-August) and autumn (September-November). The average annual temperature ranges from 15^{0}c to 25^{0}c while the annual rainfall varies between 1100-1200mm with bimodal pattern of distribution. According to the information obtained from district office of agriculture and natural resource, there are three types of soils: loam, sandy and clay covering about 70%, 16% and 14%, respectively.

Lalo Asebi district

Lalo Asebi district is located in the western end of West Wollega Zone at about 451 km away from Addis Ababa and 20 km from Gimbi town. It has common boundaries with Guliso and Boji Chokorsa districts in the West, Genji in the South West, Gimbi in the East and Boji Dermeji districts in the North. The district is generally characterized by flat to undulated landscape with hills and valleys. Lalo Asabi is located in between N $09^{0}09.163'$ and E $035^{0}36.296'$. At present, it has 31 Kebeles of which 27 are rural and the remaining four are urban. According to the recent Population and Housing Census Report, Lalo Asebi district has a total population of 87,355; 42,856 are male and 44,499 are female.

The altitude of the Woreda ranges from 1500 to 1900 masl. The rainy seasons are spring (April-May), summer (June-August) and autumn (September-November). The average annual temperature is 25^{o}c with maximum and minimum of 28^{o}c and 20^{o}c, respectively. Average annual rain fall is 1750 mm with maximum and minimum of 1100mm and 2000mm, respectively. The rainfall pattern is bimodal. There are two types of soils: loam and sandy soils covering about 68% and 32%, respectively.

Results and Discussion

Land holding and land use system

The average land holding of households in the three districts is indicated in table 2. In Gidami district, about 41.5% of the households own below one hectare, 30.8 % own between one and two hectares, 25.4% own between two and five hectares and only very few households own above five hectares of land. In Sayo district, about 24.5% of the households own below one hectare, 54.3 % own between one and two hectares, 20.5% own between two and five hectares and only very few households own above five hectares of land. In Lalo Asabi district, the majority of the household (84.4%) own less than one hectares of land. The remaining 15.6% of the households own between one and five hectares of land and farmers rarely own more than two hectares of land.

Table 2: Average land holding (hectares) categorizes and number of housel holds

Land size categories	Number of households		
	Gidami	Sayo	Lalo Asabi
Less than 0.5	2350	544	6517
0.5-1	3700	4903	3491
1-2	4490	12082	1661
2-5	3700	4557	189
Above 5	343	182	-

(Source: district Agriculture and natural resource office)

The land use system of the three study districts is indicated in table 3. In Gidami district nearly all of the arable land (26.3%) is cultivated (25.3%), 15.3% is covered with forest, about 5% is used for grazing and the rest (28.1%) is occupied by construction and swamp or it is degraded land. In Sayo district 33.1% is arable land and 19.1% is cultivated. In this district, both grazing land and forest occupy smaller area, 2% and 5% respectively. In Lalo Asabi district, about 62.8% of the land area is arable, 19.6% is cultivated and the remaining 17.6% is allocated to forest, grazing, area closure and construction.

Table 3: Land Use system of Gidami district

Land use type	Area (hectares)		
	Gidami	Sayo	Lalo Asabi
Arable land	50430.4	64328.06	27,235
Cultivated land	48511.4	37178	8,506
Forest land	29246	8920.44	532.62
Grazing land	10158	3491.5	1014.8
Communal	-	3338.5	-
Area closure	-	-	4335
Private	-	153	-
Land used for construction	24433	24436	514.626
Swamp and marsh land	11000	-	-
Degraded/barren land	17726.9	-	-
Others	-	52360	1216.9
Total	191505.7	194,205.5	43,355

Source: District agriculture and natural resource office

Crop production systems in the study districts

The farming system in the three study areas is characterized by mixed crop-livestock production system in which crop production and livestock husbandry mutually supplement each other. Crop production system is subsistence and is the major component of the mixed farming system. The major crops grown in each of the three districts are discussed below.

Major crops produced by rain fed production system

The production of crops such as tef, maize, sorghum, wheat, barley and millet among cereals; faba bean, chickpea, linseed, field pea and sesame among highland pulses and oil crops; potato, garlic, onion, tomato, fenugreek, and black cumin among horticultural & spices, and coffee are grown in the three districts depending on rainfall (Table 4).

Table 4: Area, production and yield of crops produced by rainfall

District	Crop	Area (ha)	Production (qt)	Productivity(qt/ha)
Gidami	Teff	968	11855	12.24
	Barley	2012	43297	21.52
	Wheat	1019.25	25982.25	25.5
	Maize	4885	196416	40.21
	Sorghum	2564.75	64213.25	25
	Millet	2436	52563.26	21.58
	Faba bean	1291.545	18661.095	14.45
	Sesame	112.05	594	5.3
	Coffee	14,244	125,345	8.8
	Total	29,532.595	538,926.855	174.6
Sayo	Teff	4456.52	62273	13.97
	Barley	1312.95	37373	28.5
	Wheat	3414.75	78240.3	22.9
	Maize	13278.12	517012	38.9
	Sorghum	9119.38	300457	32.93
	Millet	1605.75	37309	23.2
	Faba bean	1291.545	18661.095	14.1
	Sesame	100.05	304	3.04
	Coffee	12,240	120,345	8.8
	Total	46,819.065	1,171,974.395	
Lalo Asebi	Teff	5680	116266	12.1
	Barley	3126	122986	22
	Wheat	2050	49770	22.9
	Maize	300	13500	38.9
	Sorghum	5535	300457	18.93
	Millet	837	37309	23.2
	Field pea	638	1855.095	11.1
	Coffee	15,240	128,340	7.8
	Total	33,406	770,483.095	

Source: Office of agriculture and natural resource, 2007

Crop production using traditional irrigation system

Traditional irrigation practice has a long history being practiced by the community by diverting rivers and streams for production of mainly horticultural crops. Area, production and yield of irrigated crops in the study districts are indicated in table 5. In Gidami district, significant amount of grains are produced using this traditional irrigation scheme. The numbers of households benefited from this irrigation scheme were estimated to 990 of which 946 are male-headed and 44 are female-headed. However, respondents indicated that water scarcity is created during the dry season for crop production as well as for livestock as water is diverted for upstream irrigation.

In Sayo district, relatively fewer farm households have utilized the traditional irrigation system for the production of crops such as maize, tomato, pepper, cabbage, potato and onion. About 3,980.6 hectares of land has been cultivated by traditional irrigation scheme during the recent production year. The average productivity of irrigated crops is quite low as compared to other districts. This might be due to low utilization of inputs like fertilizers and other improved technologies.

In Lalo Asabi district, among annual crops, maize is the most dominant one occupying about 43% of cultivated area and 62% of the total production by traditional irrigation. Onion is the second major crop in terms of area coverage (17%) while cabbage ranks third (15%) in production system using traditional irrigation.

Table 5: Area, production and yield of irrigated crops in the study districts

District	Crop	Area (ha)	Production (qt)	Productivity(qt/ha)
Gidami	Maize	1125.8	49406.5	43.2
	Tomato	225.3	27996	124
	Potato	862	155160	180
	Garlic	373.6	28555	14
	Onion	734.8	103740	12
	Pepper	164.3	10251	12.2
	Cabbage	494.8	67081	124
	Total	3980.6	442189.5	
Sayo	Maize	1712	20090	11.7
	Tomato	120.5	9037.5	80
	Potato	529.5	39301.25	67
	Garlic	289	21675	14
	Onion	459	33352.5	11
	Pepper	86.625	6498.75	5.6
	Cabbage	168.125	12601.875	126
	Total	3364.75	142556.875	
Lalo Asebi	Tomato	225.3	27996	124.4
	Potato	862	155160	180
	Garlic	373.6	28555	38.9
	Onion	734.8	103740	18.93
	Pepper	164.3	10251	23.2
	Cabbage	494.8	67081	11.1
	Maize	340	25000	73.5
	Total	3194.8	417783	

(Source, district agriculture and natural resource offices)

Cropping system in the three districts

Maize-based mono-cropping is the most dominant cropping system across all the three districts. The districts are also characterized by double cropping system where often planting of chick pea, haricot bean and barley follow maize; faba bean and barley follow haricot bean; haricot bean and faba bean and field pea follow barley. The other dominant cropping system is intercropping of haricot bean with maize. In the past, fallowing used to be a common practice but it is no more in practice these days apparently due to land shortage.

Crop rotation

Crop rotation is not a common farming practice in West and Kellem Wollega Zones in general and in the study districts in particular due mainly to small farm sizes. Only few farmers, with relatively bigger farms practice irregular crop rotation. Horticultural crops are produced in rotation with maize in homestead areas. Some crop rotation sequences whenever practiced are:

- Wheat-faba bean-sorghum/maize/barley
- Maize-faba bean-wheat/sorghum/barley
- Sorghum-faba bean-maize/wheat/barley

Intercropping

Farmers in the three study districts often practice intercropping around the homestead where they also rotate cattle barn. The crops grown in intercropping pattern are usually maize/sorghum with haricot bean, cabbage, pumpkin or potato. Other intercropping patterns are coffee with ginger/ haricot bean, anchote with cabbage and linseed. On the other hands, farmlands away from home where there is no cattle barn are dominated by mono-cropping of maize and sorghum

- Double cropping
- Double cropping is very important and commonly practiced in the study districts to increase crop productivity. The sequence of double cropping is usually:
- Early maturing barley (*Samareta*) followed by field pea or faba bean
- Haricot bean followed by faba bean or wheat and
- Maize followed by chickpea

Soil fertility improvement in the three districts

Inorganic fertilizers

Though farmers apply different soil fertility management practices to improve crop productivity, only few of the households have been using inorganic fertilizers for the production of maize, sorghum, teff, wheat, barley, field pea, faba bean and potato. Whenever they used fertilizers, it was often applied at lower-than-recommended rates. During the focus group discussion, farmers asserted that they applied the combination of DAP, Urea and compost for the production of major cereals. For pulses they applied only DAP at lower rates for infertile soils. No chemical fertilizer has been used for some crops such as sesame and horticultural crops in all the three districts. The main reason why farmers are not applying fertilizers or apply at lower rates, whenever they do, is the high price of fertilizer which is unaffordable to them. Farmers indicated that the price of fertilizers has increased perhaps two or three folds while the price of their produce has not shown appreciable increase in recent years.

Organic fertilizers

The major sources of organic fertilizers are manure, compost, bio-fertilizers, pulses and tree leaves or branches. Farmyard manure (FYM) and compost are used by majority of the farmers to enhance soil fertility. Farmers collect cow and shoat dung during the rainy season and store it in a shed for about four to five months. After the FYM is decomposed, it is taken to the farmland and applied. Application of FYM takes place before the start of the rainy season (planting).

Types and sources of improved varieties

Respondents in the PRA group indicated that improved varieties availed to them were BH-661 of maize in most parts of the study area; Hidase, Shoruma, Digalu and Danda'a of wheat in Sayo district and Lalo of sorghum in parts of Sayo and Gidami districts. Only very few attempts were made to introduce improved varieties of pulses and other crops in all the study districts. Those improved varieties and seeds availed so far were supplied by the cooperative unions and office of Agriculture and natural resource.

Major agronomic practices

In the study districts pair of oxen are used as draught power. Traditional *marsha* is used for cultivation. Cultivation for land preparation usually begins after the onset of rain. In planting, both row and broadcasting methods are used (Table 6). The use of mechanized farm operations such as tractors, planters and combiners has not been practiced yet. Table 6 shows the details of agronomic practices and cropping calendar of major representative crops in the study districts. In a nutshell, the use of improved technologies such as fertilizers, varieties, herbicides and others for crop production has been in practice only since the last decade in most parts of the study area.

Crop pest management

Diseases and insects

Western Oromia in general and the study area in particular are known for its high rainfall, relative humidity, and temperature which apparently create favorable conditions for the development of diseases and insect pests. The productivity of many crops is quite low as compared to the national average. This is at least partly due to the prevalence of diseases, insect pests and weeds. Among insect pests, maize stock borer is the most problematic to maize and sorghum production. Shoot fly species are also common on teff and sorghum. Storage insect pests like weevil greatly damage maize, wheat, and sorghum grains in the store. Termites are also important pests of many cereals and other crops and they are often difficult to control. Besides, they may affect the produce in storage too. Nonetheless, farmers have been using chemicals to control the termites, but this has been obviously posing a serious threat to the ecosystem, including soil.

Table 6. Management practice and crop calendar by major crops types

Major activities	Major crop types						
	Maize	Sorghum	Teff	Millet	Wheat	Faba bean	Chickpea
Plowing frequency	3-5 times	4-5 times	4-6 times	3-4 times	4-5 times	1-2 times	2-3 times
Planting date	April- May	April-May	June-July	June-July	June-July	June-July	Sept-Oct
Seed rate:	20-25kg/ha	10-15kg/ha	36-60kg/ha	18-30kg/ha	100-125kg/ha	60-80	50-60
Weeding time	June-July	June-July	Aug-Sept	Aug-Sept	Aug-Sept	July	Nov
Harvesting time	Nov-Dec	Dec-Jan	Dec-Jan	Nov-Jan	Nov-Dec	Nov-Dec	Jan-Feb
Threshing time	Feb-Mar	Feb-Mar	February	February	February	February	April
Rate of fertilizer:	DAP= 100kg/ha UREA=100 kg/ha (split form	DAP= 100kg/ha UREA=100 kg/ha	DAP= 100kg/ha UREA=100 kg/ha (split form	DAP= 100kg/ha UREA=100 kg/ha (split form	DAP= 100kg/ha UREA=100kg/ha (split form	no	No
Time of application:	DAP & half urea at planting & Urea half at knee stage	Both at planting	DAP at planting & urea after emergence	Both at planting by mix each other	Both at planting by mix each other	Both at planting by mix each other	DAP only at planting

Crop losses due to diseases are exacerbated due to continuous use of susceptible local cultivars and inadequate crop management practices. The most common crop pests across the study area are indicated in Table 7. Maize streak virus was found to be the most damaging disease of maize followed by gray leaf spot, head smut and leaf blight. Sorghum head smut, powdery mildew, Anthracnose and leaf blight are also important diseases of sorghum. Rusts of wheat are also common.

Coffee Berry Disease (CBD), Leaf Rust and wilting diseases pose the great threat to coffee production according to the views of the respondents. Some of the coffee-dominated areas in the districts are recently being replaced by cereals and pulses due to deforestation of the natural forest that was used as shade for coffee.

Weed management practices

Farmers use various methods to combat weed infestation. Hand weeding is the most commonly employed method as it usually requires no capital outlay when it is accomplished by family members or done through non-cash labor exchange. Besides, many farmers are aware of the role of tillage in reducing weed population and hence are practicing to increase ploughing frequency-commonly three to six times before planting.

A practice known as *Shilshalo* involves the cultivation of maize and sorghum fields sown either in rows or broad cast using animal-drawn implements to control weeds. A traditional animal-drawn plow is used for inter-row cultivation. This breaks the soil crust, reduces run-off and increases the soil infiltration rate in addition to controlling weeds and ease thinning of seedlings. However, as most farmers do not practice *Shilshalo* at the correct stage of crop development, substantial plant damage (stem breakage and uprooting) is common, leading to reduced yields. Research has been carried out to improve the existing traditional practice by determining the optimum time for ox-cultivation operations to increase sorghum and maize yields. *Shilshalo* was found to be effective when carried out at the six to eight leaf stages for sorghum and the four to six leaf stages for maize.

Manual tools commonly employed to carry out weeding include chopping hoes (pull-and-push type weeders) comprising a steel blade (the soil-working component) fitted to a long wooden handle. These weeders are most useful when weeds are small and the soil is not too hard.

Recently, few farmers have already started using herbicides to control weeds. However, because of the high cost and limited know-how, farmers are not using recommended rate, appropriate type of herbicides at the correct time of application. In addition, these chemicals are sourced from local traders and their quality and efficacy cannot be trusted. In the past, chemicals used to be provided by Agriculture and natural resource office from trusted sources. Acquiring pesticides from illegal and non-licensed traders have its own short and long term adverse impacts-it is better to resort to others possible suppliers such as the cooperative unions who can directly buy from importers and timely supply to the farmers, of course at fair prices and with the necessary pack of information pertaining to safety precautions.

Table.7 .Major pests by crop types and their management options in the study area

Crops	Major weeds				Major insects		Major diseases	
	Weeds	Time of weeding	Control option	Freq. of weeding	Insects	Control option	Diseases	Control option
Teff	*Cynodon dactylon, Snowdenia polystachya*		2-4-D used for control & also hand weeding	2-3	shoofly Aphid	Control option	Yellow rust	
Wheat	*Phalaris minor, Eleusine indica, Snowdenia polystachya*	1st weeding done 2-3 weeks after sowing & before flowering	For broad leaf can use chemical but grass weed no chemical control used Hand weeding	2-3	Shoot fly termite	No control option	yellow rusts stem rust leaf rust frost	No control option
Maize	*Setaria viridis, Snowdenia polystachya*	30-40 1st weeding and 2nd & 3rd a month gap	No chemical control Control manually	2-3	weevil stock borer bird attack Termite	No chemical control method	Gray leaf spot head smut streak virus	No control option
Sorghum	*Cynodon dactylon, Snowdenia polystachya*	1st three weeks after sowing ,2nd & 3rd in three weeks gap	Hand weeding	3	Shoot fly weevil bird attack	bell / ring for bird attack aplitic in powder &liquid form for weevil	head smut Anthracnose powdery mildew leaf blight	remove head smuts leaf blight no obtain used
Coffee	Cyperus, Digitatria spp, etc	Continuous	Mechanical removing/slashing	2-3 per year	Small wheat ant		CBD Leaf rust wilt	No control option

Major constraints to crop production

This PRA report categorizes the crop production constraints into three broad categories: crop production-related (weeds, insects, diseases, input acquisition & soil fertility), post harvest-related (harvesting, threshing, and storage structure), and socioeconomics-related (marketing & credit)

Access, quality and price of inputs

The Government of Ethiopia is trying to ensure the distribution of major crop production inputs to all farmers but focusing on improved seeds and fertilizers while pesticides are also important for diseases, insects and weed management. Most farmers in the study areas, however, could not afford particularly the rising price of fertilizers. And because of this, if at all they use, farmers are not using appropriate amount of fertilizers on their land and so their yield is quite very low. Regarding seeds, there are challenges associated with availability and quality. Often the seeds sold are not uniform in size, broken, full of impurities, have a poor germination. Seeds purchased especially from non-licensed producers and traders need strict regulation by the relevant government offices.

Weeds

Most farmers in the study area do not weed their crops at the right time because of labor shortage. Farmers send their children to school which means there is a shortage of labor to help with farm work. Besides, their capacity to hire labour is limited because of high costs of causal labor. On the other hand, weeds may be favored in a particular season exacerbated by favorable weather and climatic conditions to cause significant losses of crop yield.

Diseases and insects

During the PRA, a serious issue raised repeatedly by the participants was the incidence of crop diseases and insect pests that often cause high yield losses. Much attention has not been given to the area of crop protection either by the government or NGOs to combat yield losses incurred by diseases and insects. Termites are present almost in all farms but are not immediately visible. The sole means of termite management, the use of insecticides, is rightly discouraged by the government but farmers need a way out to save their produce anyway.

Post harvest- related problems

During the focus group discussion, farmers indicated that post harvest issues of crops are also important problems. The yield losses were found to be caused primarily by untimely harvesting, improper shelling methods, and the type of storage structures. On-farm storage structures, such as *dibignit* and *gotera*, can make grains susceptible to different types of damages, including moulds, insects and rodent attacks that cause substantial losses of stored products. Moreover, harvesting and crop management practices are apparently sub-optimal - there are losses resulting from improper handling, threshing and transporting.

Credit services

Available credit sources are not satisfactory for the purchase of inputs for crop production. Although formal credit facilities are available from organizations such as Oromia Micro-finance Institutions, most farmers do not use the services because of lengthy process and fear of legal consequences that they think may result when not timely paid back. Moreover, the credit services provided by the micro-finance institutions are organized on group basis which makes individual farmers accountable for the other group members who may not be able to pay back their loan according to the terms and conditions.

Marketing constraints

Market infrastructures and facilities such as stores, road, weighing/balance scale, as well as market information are limited, resulting in inefficient agricultural marketing system. There are indeed large number of brokers and illegal traders in the market system of some commodities like coffee adversely influencing the gains of producers out of sales of their grains. The market places are unorganized; transaction taking place in an open area without fence and shed.

During focus group discussion, the respondents reported that farmers usually supply grains such as tef, wheat, barley, beans, peas, lentils, etc. during harvest times and selling at lower prices to satisfy their cash needs to repay loans, pay for children's schooling, and meet other financial needs during the first three months after the harvest. Another situation forcing the farmers to sell their produce immediately is the risk associated with longer storage periods due to pest infestations.

Pair-wise ranking of constraints to crop production

To identify and rank the major crop production constraints in the study area, two Kebeles from each of Gidami and Sayo districts and three Kebles from Lalo Asabi district were selected based on their representativeness with regard to agro-climatic zones and socioeconomic aspects. In all Kebeles, focus group discussions as well as KII were held with farmers and experts to identify and rank the key problems to crop production. Pair-wise matrix ranking was used to prioritize these constraints where two problems were compared at a time and farmers were allowed to debate why he/she prioritized one problem over the other.

Gidami district

As can be seen below on the matrix tables 8 and 9, all important problems were uniform across the target Kebeles of the district. The price of fertilizer, access to input and pests were ranked as first, second and third important problems, respectively in Kunbabi Shapi and Wora Koya Kebeles.

Table 8: Matrix ranking of crop related problems Wora Koya Kebele

Major problems	1	2	3	4	5	6	7	8	Scores	Ranking
Pests	X	2	3	1	1	1	1	1	5	3
Access to input		X	3	2	2	2	2	2	6	2
Price of fertilizer			X	3	3	3	3	3	7	1
Marketing constraint				X	4	4	4	4	4	4
Weed problem					X	5	6	6	1	6
Credit access							X	6	3	5
Post harvest problem								X	0	7

Table 9: Matrix ranking of crop related problems in Kunbabi Shapi Kebele

Major problems	1	2	3	4	5	6	7	8	Scores	Ranking
Pests	X	2	3	1	1	1	1	1	5	3
Access to input		X	3	2	2	2	2	2	6	2
Price of fertilizer			X	3	3	3	3	3	7	1
Marketing constraint				X	4	4	4	4	4	4
Weed problem					X	5	6	6	1	6
Credit access							X	6	3	5
.Post harvest problem								X	0	7

Sayo district

In Meta Kebele, access to input, pests and the price of fertilizers were ranked as first, second and third most important constraints, respectively. However, Aleku Bele, price of fertilizer ranked the first, pests, access to inputs and marketing constraints all ranked the second and weed problem ranked the third most important production constraints (Tables 10 & 11).

Table 10: Matrix ranking of crop related problems in Meta Kebele

Major problems	1	2	3	4	5	6	7	8	Scores	Ranking
Pests	X	2	3	1	1	1	1	1	5	2
Access to input		X	2	2	2	2	2	2	7	1
Price of fertilizer			X	3	5	3	3	3	5	2
Marketing constraint				X	4	6	4	4	3	3
Weed problem					X	5	5	6	2	4
Credit access							X	6	3	3
Post harvest problem								X	0	5

Table11.Matrix ranking of crop related problems in Aleku Bele Kebele

Major problems	1	2	3	4	5	6	7	8	Scores	Ranking
Pests	X	2	3	1	1	1	1	1	5	2
Access to input		X	3	3	2	2	2	2	5	2
Price of fertilizer			X	3	3	4	4	3	6	1
Marketing constraint				X	4	4	7	4	5	2
Weed problem					X	5	5	6	2	3
Credit access							X	6	1	4
Post harvest problem								X	0	5

Lalo Asebi district

The major constraints identified in this district were pests, access to input, price of fertilizers, credit access, marketing and post harvest problems. As indicted in the matrix tables shown below, the ranking of the constraints was similar for the two Haroji Sardo and Jarso Damote Kebles where the price of fertilizer, access to input and pests were ranked as the first, second and the third most important constraints, respectively. In Alee Bareda Kebele, however, access to inputs and price of fertilizer both ranked as the first, pests ranked as the second and marketing constraints ranked as the third most important constraints (Tables 12, 13 & 14).

Table 12. Matrix ranking of crop related problems in Haroji Sardo Kebele

Major problems	1	2	3	4	5	6	7	8	Scores	Ranking
Pests	X	2	3	1	1	1	1	1	5	3
Access to input		X	3	2	2	2	2	2	6	2
Price of fertilizer			X	3	3	3	3	3	7	1
Marketing constraint				X	4	4	4	4	4	4
Weed problem					X	5	6	6	1	6
Credit access							X	6	3	5
Post harvest problem								X	0	7

Table 13. Matrix ranking of crop related problems in Alee Bareda Kebele

Major problems	1	2	3	4	5	6	7	8	Scores	Ranking
Pests	X	2	3	1	1	1	1	1	5	2
Access to input		X	3	2	2	2	2	2	6	1
Price of fertilizer			X	4	3	3	3	3	6	1
Marketing constraint				X	4	6	4	4	3	3
Weed problem					X	5	5	6	2	4
Credit access							X	6	1	5
Post harvest problem								X	0	7

Table 14. Matrix ranking of crop related problems in Jarso Damote Kebele

Major problems	1	2	3	4	5	6	7	8	Scores	Ranking
Pests	X	2	3	1	1	1	1	1	5	3
Access to input		X	3	2	2	2	2	2	6	2
Price of fertilizer			X	3	3	3	3	3	7	1
Marketing constraint				X	4	4	4	4	4	4
Weed problem					X	5	6	6	1	6
Credit access							X	6	3	5
Post harvest problem								X	0	7

Summary

The farming system of Gidami, Sayo & Lalo Asabi districts is characterized by mixed crop-livestock production system in which crop production and animal husbandry are mutually interdependent. Crop production system is subsistence-oriented, and is an important component of the mixed farming system. The major crops produced include maize, sorghum, teff, barely, wheat and millet among cereals; faba bean, chickpea, field pea, sesame and linseed among pulses and oil crops; and potato, anchote, garlic, onion, tomato, fenugreek, black cumin and coffee among horticultural, spices and perennial crops. Most of the production system relies up on rainfall and as a result, delays or a lack of rain often adversely affects crop production.

Recommendations for crop production

Based on the PRA discussions and KII results, the following recommendations have been drawn in order to improve crop production and productivity in the West and Kellam Wollega Zones.

- Improved crop varieties that are adaptable, high yielder and disease resistant should be developed and demonstrated to farmers.
- High quality seeds of improved and adapted varieties should be sufficiently multiplied and distributed to farmers at fair and affordable prices.
- Concrete agronomic recommendations such as fertilizer rate, seed rate, cropping system, tillage frequency and others have to be generated as drawn from the results of multi-location and on-farm trials.
- As the zones are highly vulnerable to pests of annual crops and coffee, research should be conducted to know the types, severity, incidence, yield reduction and other aspects of major diseases, insects and weeds; and then further research should be made to devise affordable, safer and effective management options, including IPM. The control of termite and coffee diseases deserve special attention. Pest dynamics needs to be periodically surveyed to watch for some shifts in pest population.
- The safe use of effective pesticides should be demonstrated to farmers in the framework of IPM. Whenever farmers have no options but chemicals to manage specific pests, appropriate chemicals should be provided through their primary cooperatives or cooperative unions.
- The socioeconomics, extension and gender research should be strengthened in order to generate information and sufficiently demonstrate and scale up available technologies to farmers.
- It has been clearly indicated by the matrix ranking process that price of fertilizer and access to input are major bottlenecks in the sample study areas. Therefore, the Oromia Bureau of Agriculture and Natural Resource (OBoANR) should revisit the input distribution scheme in the Zones and devise a mechanism that ensures efficient distribution of major agricultural inputs, of course at fair or reasonable prices.

Livestock production system

Livestock husbandry is one of the major sources of livelihood in West and Kelam Wolega Zones. Livestock production system is semi-intensive and extensive type. Crop and livestock production are highly integrated and mutually interdependent. Livestock production plays an important role in the livelihoods of farmers. Typical to the situation of the country's at large and Oromia's in particular, farmers keep livestock for multiple purposes. Livestock is the dominant source of draught power for farm activities (ploughing, threshing, and transportation), milk, meat, cash and manure for maintaining soil fertility. In the crop-livestock mixed production system, livestock are the main cash source for the purchase of agricultural inputs such as fertilizers and seed. Livestock production also offers saving and insurance mechanisms.

Equines are highly demanded for transportation. Horses and mules are often used for human transportation but occasionally when there is scarcity of donkeys; mules may be used for transportation of goods and produces too. Particularly donkeys are very important for pack transportation of goods and produces from farm to home, home to market and other places. During coffee harvesting period, donkeys play vital role to transport it from farm to home.

Livestock population

The livestock species reared include cattle, sheep, goat, equines (mule, horse and donkey) and poultry. The population of cattle is the highest of all other livestock populations comprising 90.93 29.37 and 47.44 % in Gidami, Sayo and Lalo Asabi districts, respectively. Gidami district has the highest livestock population as compared to the other two districts. Sayo has the highest sheep population which comprises 26.05 % of its total population. Improved breeds are available only for cattle and poultry but their number is not significant. Improved breeds of livestock account for 0.2%, 1.4% and 6.7% of the total livestock population in Gidami, Sayo and Lalo Asabi districts, respectively. Although the number of improved breeds is relatively higher in Lalo Asabi, the major proportion is due to poultry. The population of equines is quite low in all the three districts (Table 15).

Table 15: Livestock population by types in the study districts

District	Type of animals	Number of livestock			Total (%)
		Improved	Local	Total	
Gidami	Cattle	1375	1361667	1363042	90.93
	Sheep	0	42141	42141	2.81
	Goats	0	25193	25193	1.68
	Mules	0	1837	1837	0.12
	Horse	0	612	612	0.04
	Poultry	1643	64075	65718	4.38
	Donkey	0	500	500	0.03
Total		3018	1496025	1499043	100
Sayo	Cattle	1318	64594	65912	29.37
	Sheep	0	58480	58480	26.05
	Goats	0	11188	11188	4.98
	Mules	0	1850	1850	0.82
	Horse	0	3737	3737	1.66
	Poultry	1774	69167	70941	31.58
	Donkey	0	12345	12345	5.50
Total		3092	221361	224453	100
Lalo Asebi	Cattle	0	72,764	72,764	47.44
	Poultry	10311	34,371	44,682	29.13
	Goats	0	20,338	20,338	13.26
	Mules	0	1,500	1,500	0.98
	Horses	0	432	432	0.28
	Donkeys	0	3,500	3,500	2.28
	Sheep		10169	10169	6.63
Total		10311	143,074	153,385	100

Beekeeping

There are three types of beehives in the study districts namely traditional, transitional and modern. However, transitional and modern beehives have not been widely adopted in all the three districts and the bulk of honey is produced by using traditional beehives. The study also indicated that the reason for involvement of farmers in the bee keeping business is mainly to generate income. There are two honey harvesting periods: September to November and April to June. However, the majority of farmers harvest their honey during the period ranging from September to November. The major constraints that limit bee production and productivity are limited availability of bee flora and the occasional use of agrochemicals for crop pest management.

Major livestock feed resources

The main feed resources to livestock in the study districts are natural pasture, crop residues, fallow lands, forest and shrub areas. Among the feed resources, natural pasture and crop residues apparently contribute the largest source of feed to the livestock. There are two types of grazing lands i.e. private and communal. Grazing on either of private grazing land or communal grazing land is a common practice following the onset of rain in most parts of the districts. The study also indicated that the major parts of the natural pastures are privately owned.

The availability and types of crop residues vary across different altitudes of the district. Barley constituted the largest share of crop residues that is used for livestock feeds in the highland areas where as tef straw is the primary source of animal feed in the medium and low altitude areas. Although, crop residues find various uses in the farming community, the bulk of it is used for livestock feeding than any other purpose in the study areas because of the critical shortage of feeds. Crop residues are also used during dry and rainy season to supplement the limited supplies from grazing lands. Feeding of crop residues for livestock mostly begins soon after threshing. The feeding of livestock with crop residues in the morning and evening is a common practice especially in the late dry and early wet seasons because of the low herbage yield obtained from natural grazing land.

Livestock feed production using improved cultivated forage species is not widely adopted in the study area. However, some of the introduced forage species including grass species such as *Phalaris aquatica*, legume species like *Vicia sativa*, Elephant grass, Vetivar grass, *Leaceana pallida*, *Sesbania spps*, cowpea and rhodes grass were occasionally encountered during the study.

Supplemental feeds such as grains are fed to livestock especially when there is shortage of feed from grazing lands and crop residues. Farmers living in the peri-urban and rural areas, often feed grains for draft animals, lactating cows, fattening animals and calves. In this regard, grain of maize and sorghum are mixed with straw and other local supplements such as *atela* (residue from local beer known as *tela*) to feed the cattle. In general, green fodder, followed by crop residues, by-products and hay in that order provide the bulk of livestock feed resources. The availability of livestock feed peaks between September November (fig 1)

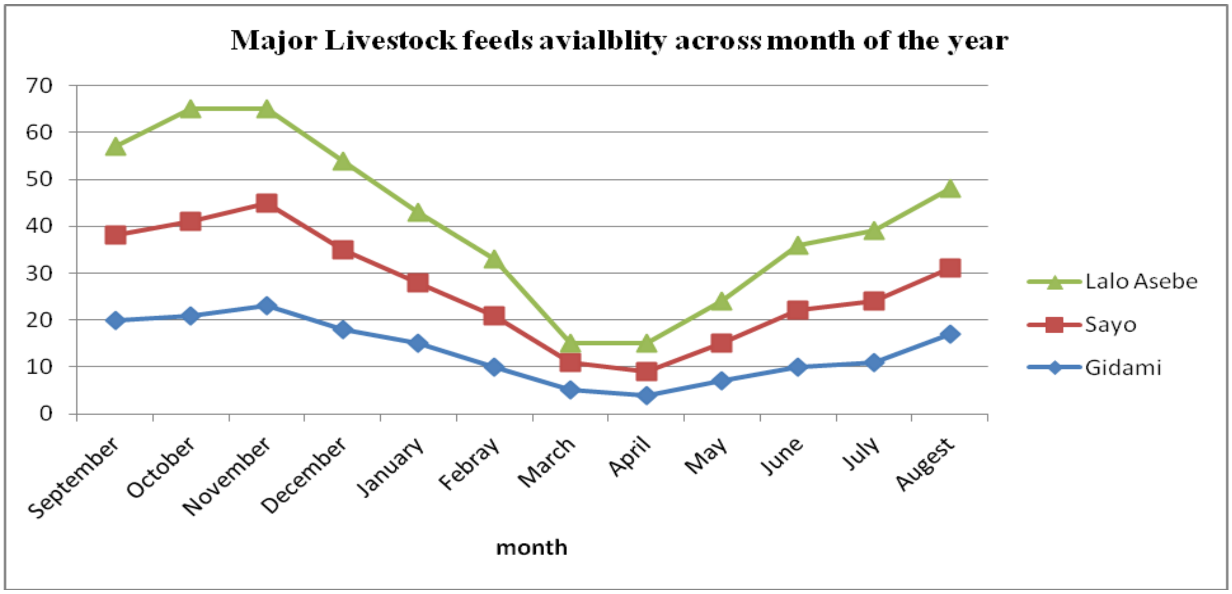

Fig 1.Livestock feed availability across the months of the year

Feed resources during dry and wet seasons

During the dry season, crop residues like straw of maize, sorghum and tef, natural pasture, grain of maize and millet are the most important feed resources for livestock in the study districts. During this season crop residues are the dominant feed resources although, green fodder trees are also used as source of feeding when natural pasture is limited due to very low or no rainfall. Dry maize stover is also used as livestock feed and is often fed to livestock without any treatment/or chopping. On the other hand, the dominant feeding system during the wet season is natural pastures and there is usually an extensive grazing system. Few farmers also practice cut and carry system of feeding during this season.

The contribution of crop aftermath in livestock feeding is significant especially in dry season when feed availability is limited to crop residue, hay and aftermath grazing. These crop aftermaths are majorly obtained from wheat, barley, tef and maize Stover in the upper and mid altitudes whereas teff, wheat, maize and sorghum Stover in lower altitude areas of the study districts.

Animal feeding systems

The feed resources and types fed to different livestock species is governed by different factors among which economic importance of the animals and availability of feed resources are the most important ones (Table 16). Accordingly, oxen and young bulls have better chance of getting crop residues followed by lactating cows and calves. Supplementation of livestock with common salt is a common practice by majority of the farmers to increase its palatability. The respondents also indicated that oil seed by-products (*fagulo*), mainly from noug and linseed cake are purchase from nearby towns and fed to the livestock. However, due to its high cost only few farmers supplement their oxen and milking cows with *fagulo*. Equines entirely depend on natural pasture where as chickens are often fed with grains in addition to natural pasture.

Table 16: Livestock feeding system and priority to access the feed resource in the study districts

Livestock types	Purpose	Feeding system and priority
Lactating cows and calves	Milk production	Natural pastures: grasses, legumes, herbs, shrubs and tree leaves
		Second chance to get crop residues: cereal straws like tef, wheat, barley, maize, and sorghum; grain legume haulms, such as haricot beans, faba bean and field pea
		Supplemental grain like maize sorghum and wheat
		Cut and carry system: green fodder,hay
		By products: such as Atela (residue of local beer); finger millet bread seasoned with Salt
Oxen and bulls	Draft and meat production	First chance to get Crop residues: straw of cereals like tef, wheat, barley, maize, and sorghum; grain legume haulms, such as haricot beans and field pea Natural pastures: grasses, legumes, herbs, shrubs and tree leaves
		By products: such as Atela (residue of local beer); finger millet bread seasoned with Salt
		Noug cake and Molass for fatting purpose
Equines	Transportation	Natural pastures: grazing grass only
Small ruminants	Meat and production purpose	Third chance to get Crop residues: cereal straws like tef, wheat, barley, maize, and sorghum, grain legume haulms, such as haricot beans and field peas, during dry season Natural pastures: grasses, legumes, herbs, shrubs and tree leaves is the best chance for small ruminants (goat and sheep)
Poultry	Egg and meat	Purchased feed like grain and mill is the first chance to get access

Farmers also follow different feeding systems for efficient utilization of the available feeds. In the study districts, most farmers feed their animals in group, let them to graze provide them with cut and carried grasses or fodder. Another feeding practice is tethering which is practiced only by a few farmers who have small number of animals, labor shortage and feed animals for the purpose of fattening. Generally, the study revealed that the majority of the farmers are practicing continuous grazing which may eventually lead to overgrazing and degradation of land.

Breed types and breeding system

The result from focus group discussion revealed that open natural mating with available local bulls is the common breeding system for livestock in the study districts. Crossbreeds or improved breeds species are rarely available for all livestock in the study districts except few for cattle and poultry. However, the respondents expressed their interest towards adopting improved breeds but doubting their adaptability to the environmental conditions especially in relation to the prevalence of diseases and shortage of feeds. Artificial insemination (AI) service for cattle breeding is apparently weak and of poor success rate. The reason might be due to shortage of AI technicians and related technologies and facilities.

Milk production and processing

The results from focus group discussion indicated that milking is done twice a day early in the morning and evenings. It is traditionally operated by using hands. Before starting milking, calves have to suckle their dam for two to three minutes to stimulate the flow of milk. Milk collection is done using traditional containers which is often washed with water and then smoked with olive tree woods and herbs to give a distinct and pleasant flavor to the milk. The average daily milk production often ranges between half and one liter depending on the level of feeding and age of the cows. The low milk yield is apparently associated with low genetic potential of local breeds and poor management of the dairy cows, particularly in terms of feeding.

Housing management of livestock

Making shelter for cattle is not a usual practice in the three study districts. However, majority of farmers were found to separate calves from the flock and provide day and night shelters during dry and rainy seasons. Moreover, small ruminants and equines are separated from the rest of the animals and housed in a different partition in the same home. Lack of awareness and training on livestock housing, fear of theft, predators and disease risks were some of the reasons for not having separate livestock barns.

Water source and watering system

The watering systems in all the study districts were almost similar. The majority of the farmers practiced group watering system and their livestock get water from rivers and ponds. The result from focus group discussion revealed that on average the livestock have to move some miles from home in order to get drinking water from the nearby streams and ponds. The majority of the farmers water their animals twice a day during the wet seasons because water is easily available. However, due to the scarcity of water during dry season, livestock get drinking water only once a day from rivers and streams. In all the study districts there are about 52 water sources which include rivers, streams and springs (Table 17).

Table 17: Water source and watering system

District	Type of water source	Number of water source
Gidami	Rivers	5
	Streams	5
	Pond	4
	Ground water	3
Sayo	Rivers	8
	Streams	5
	Pond	3
	Ground water	2
Lalo Asebi	Rivers	5
	Streams	6
	Pond	2
	Spring	4
	Total	52

Major livestock diseases and parasites

The major livestock diseases that prevail in the study areas include anthrax, blackleg, trypanasomiasis, Contagious Bovine Pleuropneumonia (CBPP), Foot and Mouth Disease (FMD), *Bovine Pasteurolosis,* and Lumpy Skin Disease (LSD). The major internal and external parasites for cattle are tick, crab lice, flea and faciolla, *Ovine pasteurolosis* and Pest des Petits Ruminants (PPR). Sheep pox is the major disease of sheep and goats. Internal and external parasites like custodies, nematodes and liverfluk are the most commonly occurring parasites for goat and sheep. Most common diseases for equines include African Horse Sickness (AHS), lymph skin disease, internal and external parasites. New Castle Disease, fowl typhoid and Coccidiosis are the most widely occurring diseases of poultry. Blackleg followed by anthrax was the most important infectious diseases of cattle, which was responsible for the loss of many animals (Table 18). These diseases are occurring mostly in *Birra* (August to December).

Pasteurollsis was found to be the most economically important bacterial infectious disease of small ruminants. When there is stress, the bacteria multiply rapidly and invade the lower respiratory tract where infection is initiated. Due to its short incubation period, stressed animals become diseased and die immediately even without showing clinical sign. The next most important small ruminant infectious disease is Open Reading Frame (ORF) which is a viral disease that affects mainly younger animals.

Bloat and circling disease are also identified as major health problems of livestock in the area. Circling disease is a major problem of small ruminants in the area and is probably caused by coenerus cerebrals. Bloating is the common gastrointestinal disorder that causes sudden death of ruminants and is caused by feeding on leguminous plants like clover locally known as *siddisaa* just before flowering period and toxicity of wilted sorghum when there is no rain. The wilted sorghum produces a poisonous worm that can cause death when ingested by animals. These problems are seasonal and can be minimized by appropriate feeding management.

The respondents also indicated that parasitic diseases can often be causes for mortality, loss of production, hide and skin rejection and exposure of the animals to many infectious diseases. Among the endoparasits, fasciola ranks first mainly attacking sheep, goats and cattle. It is assumed to be the cause for the damage of organs, particularly liver. It is well understood that ectoparasites are important economical diseases that affect hide and skin quality. The study revealed that equines and camels also suffer from various diseases. Back/sore and colic are the most frequent problems affecting equines in the study area. Back sore may be caused when equines bear huge load frequently without rest and without comfortable harness. Besides, equine owners may be reluctant to treat and give rest to their donkeys and mule suffering from back sore.

Some of these diseases are occasionally happening while others are prevailing throughout the year. Some of the diseases are feed-induced and aggravated during period of feed shortage. As a case in point, oxen were reported to be the most affected classes of cattle by trypanosomosis because of two main reasons: work stress and less time for grazing. Diseases like Anthrax and black leg occur mostly in *Birra* (August to December). Almost all respondents revealed that veterinary services, animal clinics and posts are inadequate and weak. There is shortage of man power, drugs and veterinary equipment. Available drugs are also costly.

Table 18. Major livestock diseases and parasites in the studies districts

Livestock spp	Common Diseases	Parasite
Cattle	Anthrax, blackleg, Trypanasomiasis, CBPP,FMD, Bovine Pasteurolosis, LSD and Mastitis	Tick, Crab lice, Flea, Faciolla, Leech
Sheep & Goat	Diarrhea, Contagious Etyma, Black leg, Septicemia Ovine, Pasteurolosis, PPR, sheep/goat pox, Heart water & Andera	Tick, custodies, nematodes, Liverfluk
Equines	Tryipanomiasis, lymph skin disease and AHS	Tick and other internal and external parasites
Poultry	New Casttle Disease, fowl typhoid, Coccidiosis, Pastroloysis, Salmonella	Flea, Sissi'oo"

Indigenous methods of livestock disease management

In order to reduce livestock losses due to diseases, farmers use different prevention and control measures for the different diseases and livestock species. In all the study districts, similar traditional treatment is practiced for livestock disease management. The reasons for using traditional treatment are lack of adequate veterinary services, long distance to animal clinics and lack of transportation facilities. Some farmers use leaves or roots of certain trees to cure diseases. They also treat their animals with hot irons to cure some diseases particularly when inflammation is apparent on the external body. Bloating is treated by feeding with local liquor (*areke)* and rapeseed as well as by piercing of the ribs. Farmers also treat bloated animals by inserting false banana shoot deep into the stomach to induce the outflow of gas which they think is the cause of the problem. Farmers also commonly treat their sick animals by using mixture of pepper and other plant species locally known as *sootalloo* and *sokokkee in* solution. For treatment of tryps, bark of *odaa* and fruit of *qararo* are used. Plant species locally known as *bordollo* mixed with *atela* (by product of local beer) is used to treat Blackleg disease. Farmers treat their poultry by using water mixed with local *araqe* and lemon for coccidiosis and Newcastle diseases. Some farmers also use drugs purchased from local drug vender or from any other open markets.

Egg production

Egg is an important and cheaper source of protein for rural households who have less access to other sources of protein such as meat. It is also very important in generating income for rural households. In the three study districts, on an average about 80 eggs per hen was produced from indigenous breeds.

Dairy product handling and processing

The dairy products identified in the study districts were milk, yogurt, butter and cheese. Most of these products were used for home consumption. Majority of the women farmers sold butter to the nearest market to cover their home expenditures, particularly for purchasing food items or ingredients and seasonings such as onion, potato, pepper, spices, salt, oil and others. Almost all farmers who keep livestock process their milk by traditional methods. Milk is traditionally processed into butter after fermentation. Butter is produced by churning the fermented milk. One of the major factors affecting the quality of dairy products is related to milking and storage utensils. The type and quality of milking utensils used as well as methods and frequency of cleaning them affect the quality of milk and the products thereof.

Livestock production constraints

To identify and rank the major livestock production constraints in the study districts, two Kebeles from each of Sayo and Gidami districts and three Kebeles from Lalo Asebi district were identified based on their agro climatic zones and socioeconomics representativeness. In the selected Kebeles, focus group discussions as well as KIIs were held with farmers and experts to identify and rank the key problems of livestock production. The key problems are discussed as follows.

Use of low yielding local breeds

Local cattle breeds are small in size and give birth only after long periods of rest. Calves take a longer time to reach maturity. The oxen have less traction power. The cows produce less amount of milk, often less than two liters per day as compared to the hybrids that can produce up to nine liters per day.

Feed shortage in quantity and quality

Natural grazing is the major source of livestock feed and hence livestock production is almost entirely dependent on it. However, grazing lands do not fulfill the nutritional requirements of animals particularly in the dry season, due to poor management and their inherent low productivity and poor nutritional quality. The study showed that the problem is exacerbated by the continuous shrinking grazing land area. Much of the reduction in grazing land is linked to the distribution of some of these lands to young household heads for settlement purposes and for crop production.

Diseases and parasites

The study revealed that various livestock diseases and parasites limit animal production and productivity and cause great reduction in the number of animals. The most important livestock diseases identified are anthrax, blackleg, trypanasomiasis, CBPP, FMD, *Bovine Pasteurolosis*, LSD, bloating, internal and external parasites. *Ovine Pasteurolosis*, PPR, sheep pox, internal and external parasites were the most commonly occurring diseases for sheep and goat. AHS and LSD, internal and external parasites were the most commonly occurring diseases of equines. New Castle Disease, fowl typhoid and Coccidiosis were also among commonly occurring diseases for poultry.

Veterinary service and clinic

Diseases are important cause for the reduction of animal productivity in terms of meat, milk, draft power, hide and dung. Many of the diseases could be controlled by already available vaccines. However, failure to recognize disease symptoms timely followed by lack of acquisition of the pharmaceuticals due to the remoteness of the livestock holder from the service center and lack of infrastructure to support health services delivery were the major problems in the district.

Marketing problems

According to the results from the focus group discussion and KII, lack of infrastructure, limited access to market and lack of market information cause inefficient livestock marketing system in the study area. Moreover, large number of brokers and illegal traders involve in the marketing system of livestock, particularly beef cattle reducing the ultimate gain of farmers out of the sale. .

Pair wise matrix ranking

Based on pair wise ranking, major livestock production problems were prioritized by the respondents during the focus group discussion in order of their importance as discussed below.

Gidami district

In Wora Koyan Kebele, diseases, shortage of improved breeds and shortage of feeds were ranked as the first, second and third most important constraints where as in Kunbabi Shapi Kebele, shortage of improved breeds, diseases and shortage of feeds were prioritized as the first, second and third most important constraints, respectively (Tables 19 & 20).

Table 19: Livestock related problem matrix ranking in Wora Koyan Kebele

Major problems	1	2	3	4	Scores	Ranking
Shortage of improved breeds	X	1	3	1	2	2
Shortage of feeds		X	3	2	1	3
Diseases			X	3	3	1
Market-related problems				X	0	4

Table 20: Livestock related problem matrix ranking in Kunbabi Shapi Kebele

Major problems	1	2	3	4	Scores	Ranking
Shortage of improved breeds	X	1	1	1	3	1
Shortage of feeds		X	3	2	1	3
Diseases			X	3	2	2
Market-related problems				X	0	4

Sayo district

The major problems identified and ranked in the two Kebeles-Meta Tabor and Belle were the same. Lack of improved breeds was ranked as a first major problem while diseases and shortage of feeds were ranked as second and third most important livestock production constraints, respectively (Tables 21 and 22).

Table 21. Livestock related constraints matrix ranking in Meta Tabor Kebele

Major problems	1	2	3	4	Scores	Ranking
Shortage of improved breeds	X	1	1	1	3	1
Shortage of feeds		X	3	2	1	3
Diseases			X	3	2	2
Market-related problems				X	0	4

Table 22. Livestock production related problem pair wise matrix ranking in Belle Kebele

Major problems	1	2	3	4	Scores	Ranking
Shortage of improved breeds	X	1	1	1	3	1
Shortage of feeds		X	3	2	1	3
Diseases			X	3	2	2
Market-related problems				X	0	4

Lalo Asebi district

The major problems identified and prioritized in the two Kebeles- Jarso Damote and Haroji Sardo of this district were found to be the same. Shortage of improved breeds, lack of veterinary services and clinics and diseases prioritized as the first, second and third most important constraints, respectively (Tables 23 and 24). In Ale Bareda Kebele, unavailability of improved breed, lack of veterinary services and clinics, and shortage of animal feeds were ranked as the first, second and third most important constraints where, respectively (Tables 25).

Table 23: livestock related problem matrix ranking in Jarso Damote Kebele

Major problems	1	2	3	4	5	Scores	Ranking
Shortage of improved breeds	X	1	1	1	1	4	1
Shortage of feeds		X	3	2	5	1	4
Diseases			X	3	5	2	3
Market-related problems				X	5	0	5
Lack of veterinary services and clinics					X	3	2

Table 24: Livestock related problem matrix ranking in Harojji Kebele

Major problems	1	2	3	4	5	Scores	Ranking
Shortage of improved breeds	X	1	1	1	1	4	1
Shortage of feeds		X	3	2	5	1	4
Diseases			X	3	5	2	3
Market-related problems				X	5	0	5
Lack of Veterinary services and clinics					X	3	2

Table 25: livestock related problem matrix ranking in Ale Bareda Kebele

Major Constraints	1	2	3	4	5	Score	Rank
Unavailability of improved breed	X	1	1	1	1	4	1
Shortage of animal feeds		X	2	2	5	2	3
Livestock disease and parasites			X	3	5	1	4
Market related problems				X	5	0	5
Lack of veterinary services and clinics					X	3	2

Conclusion of livestock part

The results of this study revealed that the livelihoods of the farm households of the three districts namely Gidami, Lalo Asebi and Sayo highly depend on crop-livestock mixed farming system. Livestock have a number of uses- they serve as draught power, source of food, means of transport, source of manure, source of fuel and cash. Despite those advantages, livestock production is facing a multitude of constraints. Prevalence of major diseases, shortage of improved breeds, shortage of feeds etc are the principal constraints which the livestock production system is currently facing. Consequently, the production and productivity of the livestock has been declining from time to time and needs intervention.

Recommendation for livestock production

Based on the results of the study generated from KIIs, PRA and available secondary data, the following recommendations have been drawn to improve livestock production and productivity in the study districts. There is a need of technological intervention so that farmers adapt the crossbred animals under their conditions either through AI by crossing the indigenous animals with the improved dairy breeds or use of improved dairy bull service. Using available feeds efficiently, improving the nutritional quality of existing feeds by planting legume fodder crops and introducing zero grazing is needed to be encouraged in order to address feed shortage.

Characterization of existing breeds to ascertain the different traits that will give better performance which will help in developing future interventions. With respect to the inadequacy of veterinary services and clinics, the government and other stakeholders who are in charge should give due attention to improve and strengthen animal health care services and infrastructures. Improve the management of existing cattle breeds in terms of feed, housing and watering. Avail improved forage varieties for adaptation and adoption; create a system or seed production thereof for best bet varieties. Create a robust and sustainable research-extension-farmer linkage to enhance the development, adoption and seed production of improved forage crops; train farmers on feed conservation practices, improvement of the quality of crop residues and its conservation, use of agro industrial by-products and pasture and grazing land management practices. Appropriate and timely provision of short term trainings is required for farmers in order to narrow or close knowledge gaps.

Attention should be given for the livestock health from livestock health experts as well as farmers themselves. Hence, keep livestock sheds/stables clean and properly ventilated, keep livestock free of internal and external parasites, timely vaccination and treatment of livestock and provide livestock with sufficient quantity and quality of feed.

Natural resources management

Major trees species in Gidami, Sayo and Lalo Asebi districts

There are different types of naturally growing trees and shrub species in the three districts selected for this study as indicated in table 26. These native species are found either in the natural forest or as remnants of the previous natural forests scattered on farmlands, grazing areas, farm boundaries and around the fences. There are also plantations of many exotic tree species which are found mainly around the homestead, especially in the towns as live fences, source of fruit, timber, shade, and ornamentals.

Table 26. Major indigenous tree and shrub species commonly found in the three districts

Local name	Scientific name	Family name	Habit	Purpose/uses
Abayyii	*Masea lanceolata*	Myrsinace	Tree	Coffee shade and fence
Wadessaa	*Cordia africana*	Boraginaceae	Tree	Charcoal, fence & timber
Bakkanniisa	*Croton marcrostachyus*	Euphorbiaceae	Tree	Fence, agro forestry &charcoal
Mukaarba	*Albizia gummifera*	Legumminaceae	Tree	Coffee shade, fence & charcoal
Qilxuu	*Ficus vasta*	Moraceae	Tree	Coffee shade, agro-forestry, live fence & hive placement
Laaftoo	*Accaia abyssica*	Legumminaeceae	Tree	Charcoal, agro-forestry coffee shade & fence
Eebicha	*Vernonia*	amaygdakina	Tree	Animal feeds, coffee shade, live fence
Badessa	*Syzgium guineense*	Myrtacea	Tree	Charcoal , coffee shade, agro-forestry
Hoomii	*Prunus africana*	Roseaceae	Tree	Timber, construction& charcoal
Bosoqa	*Sapium ellipticum*	Euphorbiaceae	Tree	Charcoal, timber, construction
Somboo	*Ekebergia capensis*	Meliaceae	Tree	Timber, construction& charcoal

Forest products and services

Mankind has been depending on forest for different goods and services for long period of time. Similarly, farmers of the study districts have been driving many products from the existing forest resources. Forest Management and Land Use/cover for the three study districts is indicated in tables 27, 28 and 29 below.

Construction

Farmers commonly use indigenous trees species such as *Baddeessaa, Galanoo, Hoomii and Mukaarba* for construction. However, these tree species are no more adequately available nowadays because of the selective utilization and over exploitation by man as well as the susceptibility of their seedling to termite attack. Consequently, at present time most of the constructions of homes, fences, grain stores, bridges etc. are made by using eucalyptus tree instead. And this is so because eucalyptus tree is more tolerant to termite attack especially if the tree is mature and becomes dry. At the present Eucalyptus tree is relatively more available in the area.

Houses: Eucalyptus tree, *Prunus africana, Syzgium guineense, Galanoo, Akuukuu, Albizia gummifera, Dabaqqaa, Leemana* are most preferred and widely used for the construction of houses.

Fences: similar to house construction, durable species such as eucalyptus tree, *prunus africana* and *Syzgium guineense* are most preferred for this purpose too.

Charcoal: although it is not legally supported, charcoal offers a major energy source for the rural & urban community and many live on charcoal making and selling both in the rural and urban areas. In rural areas, charcoal making is one of the off-farm activities in the study area and it is a means of making livelihood for some poor farmers who have no oxen or those who have no cash to purchase farm inputs. Tree species such as *Syzguim guineense*, *Acacia abyssinica*, *Dabaqqaa*, *Laaftoo and Eucalyptus* are used for this small scale charcoal making.

Livestock fodder: native tree species such as *Cordia*, *Bosoqa*, *Vernonia* and coffee and exotic ones such as *Leucenea*, *Sesbania*, *Acacia decurrens*, and *Gravillea* are commonly used as livestock fodder.

Bee forage: the dominant tree spices suitable and preferred for bee forage include *Mukarbaa*, *Baddeessaa, Eebicha, Croton, B. Lidii, Bosoqa*, mango and coffee.

Table 27: Forest Management and Land Use/cover in Gidami district

Forest management/land use/cover	Items	Kebeles	
		Kunbabi Shapi	Wora Koyan
Land use/cover	Natural forest	108 ha	165ha
	Plantation	16994 ha including coffee	1069.5
	Communal grazing land	475 ha	66 ha
	Area closure/closed areas	64 ha	79 ha
	Cultivated land	1886.5 ha	785.75 ha
	Cultivable land	25 ha	-
Forest Management	Multipurpose trees species	*Tid or Juniperus, Gravilia and Cordia africana croton(makkaniisa) acasia(laaftoo)*	*Casuarina, Acacia Ficus vasta, Croton macrostachyus, Albizia Gerailia(less), Cordia Africana*
	Area of production	In small amounts(less than 5 %)	In small amounts(less than 5 %)
	Management problems of MPTS:	Absence of agro forestry practice Management problem knowledge gap,Institutional gap(seed & seedling provider) Demand for cultivation purpose	Don't know well about the MPTS management
	Current management of multipurpose tree production	For coffee shade Soil erosion protection purpose & fuel	--

Table 28: Forest Management and Land Use/cover in Sayo district

Forest management/land use/cover	Items	Kebeles	
		Meta Tabor	Belle
Land use/cover	Natural forest	10ha	9 ha
	Plantation	60.5ha	57.5ha including coffee
	Communal grazing land	76ha	80 ha
	Area closure/closed areas	12ha	no area closure
	Cultivated land	568 ha	537.5ha
	Cultivable land	Less than 10ha	No
Forest Management	Multipurpose trees species	*Grevillea Robusta,* *Acacia,(laaftoo)* *Jacaranda and* *Cordia africana* *Croton* *Tid(gaattiraa)* *Nim tree*	*Grevillea Robusta,* *Acacia,(laaftoo)* *Jacaranda and* *Cordia africana* *Croton* *Tid(gaattiraa)* *Nim tree*
	Area of production	In small amounts(less than 1%)	-
	Management problems of MPTS:	lack of knowledge on agro forestry practice	Absence of Agro forestry practice Seed costly
	Current management of multipurpose tree production	for coffee shade purpose	More for coffee shade purpose timber &fuel construction purpose

Table 29: Forest Management and Land Use/cover in Lalo Asabi district

Forest management /land use/cover	Items	Kebeles		
		Haroji Serdo	Alee Bareda	Jarso Damote
Land use/cover	Natural forest	9.625 ha	70 ha	1657.5 ha
	Plantation	11.125 ha	174ha (coffee plantation)	12 ha
	Communal grazing land	11.5 ha	130 ha	25 ha
	Area closure/closed areas	17.25 ha	73.2 ha	12.875 ha
	Cultivated land	325 ha	120.98 ha	329.75 ha
	Cultivable land	215 ha	340 ha	28.935 ha
Forest Management	Multipurpose trees species	*Accaia abyssinica* *croton macrostachyus* *Albizia gummifera* *Cordia africana* *juniperus(tid)*	*Casuarina* *Acacia* *Ficus vasta* *Croton macrostachyus* *Albizia* *Gerailia(less)* *Cordia africana*	*Acacia spp* *Croton macrostachyus* *Albizia* *Cordia africana* *Tid*
	Area of production	Unknown	less than 6	unknown
	Management problems of MPTS:	lack of knowledge on agro forestry practice	lack of knowledge on agro forestry practice	lack of knowledge on agro forestry practice
	Current management of multipurpose tree production	for coffee shade purpose & fence	for coffee shading purpose -fertility improvement -timber -construction	for coffee shading purpose -fertility improvement -timber

Natural resource management

In the study area, apparently farmers have not been accomplishing much in the conservation of natural resources although tree plantation, construction of bunds, terraces, agro-forestry practices particularly in coffee growing Kebeles can be mentioned as good measures to control soil erosion. Besides, addition of farmyard manures, composts and home wastes are identified as good farmers' practices that can significantly contribute to the improvement of soil fertility though it has not been applied on wider scale.

Soil erosion and soil and water conservation practices

Soil and water conservation in the study area is similarly marked by the combination of physical and biological conservation measures to minimize soil erosion. There are different types of soil erosion like sheet erosion, rill erosion, gully erosion and rain drop /splash erosion. The physical soil conservation structures practiced include soil bound with forage tree/crops, stone terraces, tied-ridges, area enclosure and thrash lines. Agro-forestry, intercropping, minimum tillage, crop rotation, mixed cropping and maintaining crops' residues are the major biological soil conservation structures practiced by the farmers in the study area.

Farmers practice intercropping of different crops in order to increase the availability of food from different types of crops and to obtain feed for their livestock by thinning on continuous basis. Companion crops also offer different advantages; some crops are drought tolerant (eg sorghum) while others (e.g haricot bean) are early-maturing. Intercropping also helps farmers make better use of their limited land and scarce labor. Farmers who have small farm can grow the major crops they need for their home consumption, though this hardly ensures family food security.

Some farmers practice early land cultivation and crop rotation. Cultivating the land soon after harvesting enhances productivity and reduces the amount of fertilizer applied, thereby decreasing the expenditure on inputs. Some farmers suggest that after the emergence of this practice, they are not worried much to prepare their land well before the onset of rainfall.

Major causes for soil erosion

Farmers in the districts perceived the existence and significance of soil erosion due to the apparent negative impacts that has resulted after long time. They are of the view that the proportion of the different soil types has been changing over time. High erosion is caused mainly due to deforestation, over grazing and intensive tillage. Some of farmers' indicators for soil erosion include exposure of the sub-soil, reduced soil depth, reduced yield, high input requirement, changes in stream water quality and quantity as well as the climate change. Farmers elucidated this by taking a case-in-point that the use of fertilizers was not common in the past, but yield was yet pretty good since the soil was naturally intact. Recently, however, most crops give very low yield, without the use of fertilizers.

According to the respondents' views, when the steep slopes and mountains were covered by vegetation, clean water could be obtained from streams during the rainy seasons and good quantity of water in the springs during the dry seasons. Recently, however, the color of water in streams and rivers has turned brown due to the high sediment load. During the dry season some springs dry out or the volume of water is significantly reduced. This indicates that surface runoff and soil erosion is increased, reducing the annual recharge to the ground water, and hence reduced water yield of springs.

Erosion control measures practiced by farmers

In an attempt to tackle the problem of soil erosion, farmers have developed several indigenous technologies and practices since antiquity. Among these are cut-off-drains locally called soil bund and drainage furrows called water channel. Both structures are constructed mainly by oxen drawn plough, but depending on the runoff expected, which in turn depends on the slope length and gradient, intensity of rainfall and the type of crops planted upstream of the field, re-enforcement by hoeing may be necessary. If tef is planted upstream, the cut of drain (soil bund), which is constructed at the upper most end of the field to divert all the runoff before it enters into the field should be reinforced by stones, wood, blocks of soils and grass especially across depressions.

The type of crop planted is also an important factor determining the type and intensity of the structures. In fields planted to small cereals, since the seedbeds are fine and even packed for tef, higher runoff rates are expected. Thus to prevent the seed, fertilizers and soil loss due to runoff, semi-parallel drainage furrows are constructed at relatively closer interval depending on the slope. The spacing and gradient of furrow depends on several factors like slope gradient and length, and land use or crop type of the upstream area. When the slope is steep and long, or when the upstream field is planted to tef and the crop to be planted on the field to be protected is also tef, the furrows spacing should be narrow and sometimes needs to be intercepted by perpendicular furrows such that a net of furrows be formed.

The quality of these measures indicates the level of knowledge and awareness of the farmers about the consequences and control of. An active farmer monitors what happens at the upstream or neighborhood of his field. He should follow what crops are sown and the direction of furrow and soil bund of the neighboring farmers and up stream of the field in order to implement necessary measures. If his neighbor is directing the runoff to his field, he should receive and rely it to the next or send it to main drains. It is also customary to alert neighbors about the direction of the drainage furrows, so that he may take necessary measures for his own. It is thus apparent that in the traditional soil and water management system in this area, watershed approach is prevalent and hence, any external intervention should make use of the advantage.

Soil physical and chemical characteristics

Characteristics and limitations of the soil types

The texture of the surface layer has some influence on many other soil properties, and gives farmers a clear indication as to whether a particular soil type can be cultivated after the first rains of the season Soil color, texture and its position in the landscape are quite important criteria for farmers to evaluate their soils (Table 30).

Black soil (Mollisol)

Black soil refers to dark topsoil with high organic matter content. It is suitable for all crops grown in those districts even without the use of fertilizers, but tef suffers from lodging, sometimes even under no fertilization indicating high level of nitrogen content of these soils.

Red soil (Nitosol)

These are soils with low organic matter content, low fertility and in extreme cases whose sub-soil is exposed due to soil erosion and intensive tillage. They are commonly found on steep slope areas where cultivation practices are easier due to the light texture and sufficient drainage. Only Noug (*Guizotia abyssinica*) and Linseed (*Linum usitatissimum*) can grow on these soils well without fertilizers, while other crops like tef, wheat and maize grow only with fertilizers. Poor soil fertility and erosion are the major limitations of these types of soils.

Loam (Vertisol)

This is a black clay soil occurring in the bottoms of valleys. Moisture content is often considered as the major problem since it becomes too hard when dry and too heavy when wet. Only tef and noug can grow well on this type of soil without drainage while other crops like barley, wheat and maize can grow better only on well drained beds. On these soils, according to the explanations of farmers, crops also poorly respond to fertilizers due to the standing water that washes it away before it joins the root zone. It could also be due to the poor aeration and de-nitrification induced by the standing water, since the flat topography rarely allows runoff to wash the nutrients away.

Sandy soil

This occurs on the summit where there is usually high rate of erosion. It is exposed after the removal of the red soil (sub soil) due to erosion and extensive tillage for a long time. In this case, it is likely that the parent materials could be exposed.

Table 30. Soil characteristics, management and use of fertilizer across the district

District	Soil characteristics	Soil management			Use of fertilizers
		Physical	Biological	Organic	
Gidami	Sandy loam, black soil, red soil	Tillage frequency, crop residue/manure /Farm yard manure	Bio fertilizer (Rhizobium)	Compost/farm yard manure	DAP and Urea
Sayo	Sandy loam, black Soil, red soil				
Lalo Asabi	Black soil (in less coverage), red soil (in large coverage)				

Soil fertility maintenance practices

In addition to the commercial fertilizers, several traditional soil fertility maintenance techniques have been in use in the study area. These include manuring, crop rotation and use of compost. In the past since farmers used to keep a larger number of herds and area of land, manure and fallowing were the major practices for soil fertility maintenance. However, due to population pressure, which resulted in reduced land holding and also limited grazing land, keeping a large herd and fallowing have gradually been abandoned.

Manuring: in the context of the study area, manuring refers to the process of kraaling cattle at night and rotates the position of the barn regularly in order to uniformly distribute manure on the crop fields. In this case, not only manure but also urine that is rich in nitrogen is added to the soil. Farmers want to practice manure either alone or in combination with inorganic fertilizers. However, herd size is a necessary condition to practice it. In this region cattle spend the nights in the barn where they drop their dung and urinate in the barn that will be shifted to new spot after few days, depending on the season, crops to be planted and size of the herd. Longer kraaling is exercised during the dry seasons and for heavy feeder crops such as maize, sorghum and potato where as shorter kraaling is often exercised during the rainy season for tef and other small cereals. Since grazing lands including crop stubbles are communal, farmers with larger herd size benefit more for manure. As a consequence, farmers still tend to keep a larger herd of their own or relatives. The other advantage of this practice is that crop residues and other herbs can easily be incorporated into the soil. In addition to soil fertility improvement, weeds are also controlled to some extent.

Crop rotation: cereals are cropped in rotation with legumes or oil crops mainly for soil fertility restoration and diseases, insects and weed control. Farmers are of the view that faba bean, field pea, linseed and barely improve soil fertility while tef and wheat tend to exhaust soil nutrients.

Fallowing: is a practice of abandoning land for rejuvenation when the nutrients are exhausted. Fallow land is commonly used as a grazing ground for five to seven years depending on land holding of the farmers and the nature of the land to recover. Nevertheless, this practice is being abandoned as land holding is on the course of shrinking. Compost/farm yard manure: is a practice of spreading households' wastes to the field for soil fertility maintenance. Farm yard manure, which literally means waste, consist all kinds of human and livestock residues/leftovers in and around the residence. In the farm household, cleaning grains before grinding is among the daily practices. This leaves weed seeds as a residue to be cleaned away as any waste and distributed to the field as farm yard manure. Consequently, the practice is criticized for enhancing weed infestation on crop lands.

Water harvesting techniques, irrigation access and moisture management

Farmers in the study area are not aware of water harvesting techniques as the area is rich in ground water and rivers. Moreover, low moisture stress is also not a common phenomenon. One prominent and perhaps the only means of water harvesting technique used in this area is from the roofs to use for washing, cooking and sanitation. Nevertheless, increasing agricultural productivity in both rain-fed and irrigated agriculture by using water harvesting and other means is a viable option. Water resources and its purposes in the three study districts are indicated in tables 31, 32 and 33 below.

Table 31. Water / River resource and its purpose in Gidami district

Items	Kebeles	
	Kunbabi Shapi	Wora koya
Available water resources River/Surface water:	*Gambari, Gambaa, Cokorsa*	*Mooraa, Daamii, Faxafii, Tooboo*
Irrigation Access	Yes (traditionally)	
Modern irrigation scheme	No	
Traditional Irrigation Scheme	*Gambarri*	*Dhiibuu*
Irrigation water management	Surface irrigation method used No fixed schedule but depend up on consensus of the community 2 times per week	Surface irrigation method used No fixed schedule but depend up on consensus of the community 1 times per week
Water harvesting techniques	Water harvesting unknown in the village	No

Table 32. Water / River resource and its purpose in Sayo district

Items	Kebeles	
	Meta	A/Bele
Available water resources River/Surface water:	*Kerebicho, Mexi, Faxani*	*Shuushee, Galli, Abba jimaaloo, Dallo*
Irrigation Access	Yes	Yes
Modern irrigation scheme	No	No
Traditional Irrigation Scheme	*Kerebicho, Mexi, Faxani*	*Galli belle and Michael*
Irrigation water management	Surface irrigation method used No fixed schedule but depend up on consensus of the community	Surface irrigation method used No fixed schedule but depend up on consensus of the community 1 times per week
Water harvesting techniques	No	No

Table 33. Water / River resource and its purpose in Lalo Asabi district

Items	Kebeles		
	Haroji Serdo	Alee Bareda	Jarso Damote
Available water resources River/Surface water:	*Laga warjilo, Laga qararo, Laga budo*	*Laga qarsaa Bareedaa Hursaa*	*Ankorii, Laga qarsaa, Laga baddeessaa, Baantuu , Laga birbir, Laga uwwaa, Suphee, Nooraa baantuu, Kumbiyyaa, Huursaa*
Irrigation Access	No	No	Yes (Traditionally)
Modern irrigation scheme	No	No	No
Traditional Irrigation Scheme	No	No	*Baantuu nooraa, Baantuu bandii, Kumbiyyaa, Maatii bultum, Migiroo jabaa, Nabboo, Huursaa*
Irrigation water management	No	No	Traditional (surface irrigation) method used No Irrigation Scheduling There is no amount based on water requirement
Water harvesting techniques	No	No	Water harvesting unknown in the village

Matrix ranking of natural resource related problems in Sayo district

As in previous sections, matrix ranking was used to prioritize constraints related to natural resources where two problems were compared at a time and farmers were allowed to debate why they prioritized one problem over the other. After systematic discussion with the focused group, the major constraints identified for matrix ranking were soil erosion, deforestation, temperature increase, decline in soil fertility and termites.

As indicated in the table below, the constraints varied across the target Kebeles. Soil erosion and deforestation both ranked first, temperature increase ranked second and decline in soil fertility and termite problem both ranked third most important constraints in Meta Kebele (Table 34) where as in Alaku Bele Kebele, deforestation ranked the first most important constraint and others like soil erosion, temperature increase, decline in soil fertility and termite problem all ranked as the second most important natural related constraints (Table 35).

Table 34: Matrix ranking of natural resource related problems of Meta Kebele

Major problems	1	2	3	4	5	Scores	Ranking
Soil erosion		1	1	1	5	3	1
Deforestation			2	2	2	3	1
Temperature increase				3	3	2	2
Decline in soil fertility					4	1	3
Termite problem						1	3

Table 35: Matrix ranking of natural resource related problems of Aleku Bele kebele

Major problems	1	2	3	4	5	Scores	Ranking
Soil erosion		1	3	1	5	2	2
Deforestation			2	2	2	3	1
Temperature increase				4	3	2	2
Decline in soil fertility					4	2	2
Termite problem					5	2	2

Matrix ranking of natural resource related problems in Gidami district

The same procedures were followed to rank the same major natural related constraints i.e soil erosion, deforestation, temperature increase, decline in soil fertility and termites across the Kebeles in this district too. Two Kebeles namely Wora Koya and Kunbabi Shapi were selected. As indicated in the tables below, the ranking of the constraints varied across the target Kebeles. In Kunbabi Shapi Kebele, decline in soil fertility ranked the first; soil erosion, temperature increase and termite problem all ranked second and deforestation ranked the third most important constraints of the area (Table 36). In Wora Koya Kebele, both soil erosion & deforestation ranked as the first most important, temperature increase ranked the second most important constraints where as decline in soil fertility and termite problem both ranked the third most important constraints of natural resources (Table 37).

Table 36: Matrix ranking of natural related problems of Kunbabi Shapi Kebele

Major problems	1	2	3	4	5	Scores	Ranking
Soil erosion		1	1	4	5	2	2
Deforestation			2	4	5	1	3
Temperature increase				3	3	2	2
Decline in soil fertility					4	3	1
Termite problem						2	2

Table 37: Matrix ranking of natural related problems of Wora Koya Kebele

Major problems	1	2	3	4	5	Scores	Ranking
Soil erosion		1	1	1	5	3	1
Deforestation			2	2	2	3	1
Temperature increase				3	3	2	2
Decline in soil fertility					4	1	3
Termite problem						1	3

Matrix ranking of natural related problems in Lalo Asebi district

In this district, three Kebeles namely Alee Bareda, Haroji Sardo and Jarso Damote were selected for the matrix ranking of major natural related constraints based on procedures and criteria that have been discussed with respect to the other districts in the previous sections. Similar natural related constraints i.e soil erosion, deforestation, temperature increase, and decline in soil fertility and termites were identified through the systematic discussion and were ranked.

In Alee Bareda, termite problem ranked the first, soil erosion the second and decline in soil fertility ranked as third most important natural resource constraints (Table 38). In Haroji Serdo kebele, soil erosion and deforestation both ranked the first, temperature increase the second and decline in soil fertility and termite problem both ranked the third most important natural resource constraints (Table 39). In Jarso Damote Kebele, soil erosion ranked the first, temperature increase and deforestation both ranked the second and decline in soil fertility and termite problem both ranked the third most important natural resource constraint (Table 40).

Table 38: Matrix ranking of natural related problems of Alee Bareda Kebele

Major problems	1	2	3	4	5	Scores	Ranking
Soil erosion		1	1	1	5	3	2
Deforestation			2	4	5	1	4
Temperature increase				4	5	0	5
Decline in soil fertility					5	2	3
Termite problem						4	1

Table 39: Matrix ranking of natural related problems of Haroji Serdo kebele

Major problems	1	2	3	4	5	Scores	Ranking
Soil erosion		1	1	1	5	3	1
Deforestation			2	2	2	3	1
Temperature increase				3	3	2	2
Decline in soil fertility					4	1	3
Termite problem						1	3

Table 40: Matrix ranking of natural related problems of Jarso Damote Kebele

Major problems	1	2	3	4	5	Scores	Ranking
Soil erosion		1	1	1	5	3	1
Deforestation			2	3	2	2	2
Temperature increase				3	3	2	2
Decline in soil fertility					4	1	3
Termite problem						1	3

Conclusion for natural resource management

The natural resource of the study district is under serious threat due to deforestation, soil erosion and shortage of water for both human and the livestock. The magnitude of these problems is becoming even worse and worse from time to time as situations in the surveyed areas of the west and Kellem Wollega AGP- II beneficiary districts indicated.

Recommendation for Natural Resource Management

The following recommendations are drawn from the study results:

Tree plantation and afforestation are quite important to save the fast diminishing natural vegetation. Forestry research program should focus on developing tree species that are well adapted to the agro-ecologies of the area. Tree species suitable for coffee shade must also receive great attention as the district is one of the most important coffee growing areas in the country. Agro-forestry is practiced in coffee growing areas of the district. Research should augment these indigenous practices of farmers of the district focusing on development and demonstrations of suitable agro-forestry practices.

Soil and water conservation researches should be launched to respond to the problem of soil erosion of the zone, as the zone is characterized by rouge, up and down topographies that make it highly prone to soil erosion. The high rain fall in the zone is also contributing much to soil erosion. Different soil and water conservation measures, therefore, must be set as researchable priority issues in those districts. Soil fertility management researches based on soil test recommendations must be soon launched with the integration of organic and inorganic soil fertility improvement strategies.

Agricultural engineering technologies

The West and Kellem wollega agricultural system is predominantly subsistence, characterized by the use of traditional farming implements and practices. Almost all farmers in the study areas use hand-tools and traditional tillage equipment. These implements are either simple hand tools or are operated using animal power, mainly oxen. Similarly farmstead operations in crop production, animal husbandry and forestry are performed with bare hands or very traditional farm tools.

Farm power sources

Farm power is an essential input in agriculture for timely field preparations and for permanent jobs and for making livelihoods through rental of semi-mechanized post harvest equipment like operating irrigation equipment, threshers, shellers, cleaners, graders and others . Obviously, the first kind of power used in agriculture was human power and all operations from land preparation through cultivation, harvesting, and processing of final product were performed more or less by hand in the study districts. Draft animals provided a large part of the power requirements of agricultural production. The major sources of farm power used for tillage, cultivation, harvesting, threshing, cleaning and transportation in the study districts were women, men and children and draft animal tramping.

Tillage implements: soil tillage is one of the fundamental field operations in agriculture because of its influence on soil properties, environment, and crop production. To ensure normal plant growth, the soil must be prepared in such conditions that roots can have enough air, water, and nutrients. The study indicated that these implements are all traditional ones.

Traditional implements: traditional implements used by farmers for land tilling was only local 'maresha' and small hand tools for hoeing and cultivation, particularly to enhance weeding operations. All primary, secondary and tertiary tillage was done through these traditional implements in the study districts.

Improved implements: the only improved implement used for land tillage purpose by some farmers was four-wheel tractor. There were no improved implements used for primary, secondary and tertiary land tillage like, ARDU plough, AIRIC plough, spike tooth harrow, row cultivator, and power tiller in the study districts.

Traditional row planting equipment: some farmers have been using traditional row planting/sowing which includes hand dropping and the use of drilled containers that are used for tef, wheat, maize and fertilizer application. This consumes time and labor; moreover seeds and fertilizers may not be evenly dropped. Generally traditional row sowing methods have the following limitations:

In manual seeding, it is not possible to achieve uniformity in distribution of seeds and fertilizers.

Poor control over depth of seed placement.

Labor requirement is high because two persons are required for dropping seed and fertilizer. The effect of inaccuracies in seed placement on plant stand is greater particularly in the case of crops sown under dry farming conditions. Improved row planting technologies: there were no tractor-mounted planters and fertilizer applicators for the major crops like maize, wheat, barley and others. Animal-drawn planters are not available either.

Pesticide application equipment: in the study area, the only available pesticide spraying equipment was Knapsack sprayer for all crops and pests that need chemical spraying. Other advanced technologies like semi-mechanized/motorized and tractor-mounted pesticide sprayers were not encountered.

Water management technologies: water is generally a vital component of agricultural production in order to maximize the volume and quality of production. The study revealed that there were no mechanized water management technologies for conservation and irrigation.

Moisture management: farmers managed their farm land moisture through frequent tillage that makes the soil structure loose, aerated and increased its water holding capacity but all tillage implements used for this purpose are traditional ones which are not effective as compared to improved ones. In some areas with water logging problems associated with high rainfall and vertisol, some farmers use Broad Bed Maker (BBM) for draining the excess water. Other mechanized or semi-mechanized moisture management technologies were not encountered.

Irrigation systems and facilities: in the study area, all irrigation activities are traditionally practiced by using river water diverted through furrows; modern irrigation schemes like irrigation pumps, drip irrigation system, sprinkler irrigation, surface and spate irrigation methods and their associated technologies have not been adopted and were not encountered, particularly in the case of smallholders.

Water lifting devices: water-lifting devices are used to lift water to a height that allows users to easily access water. Water lifting devices can be used to raise groundwater, rainwater stored in underground reservoir and river water. In this regard, no farmer used treadle pump for irrigation purposes. Only some farmers used gravity system for irrigating their farm land.

Harvesting technologies: all types of crops belonging to cereals, pulses, and horticultural as well as perennial ones such as coffee, banana and mango are harvested either by using sickles, uprooting or hand-picking. Mechanized or semi-mechanized harvesting equipment and technologies were not encountered in the study area.

Post harvest management technologies

Thresher/sheller: majority of the farmers thresh and shell wheat, teff, barley, faba bean, chickpea, maize and others by animal trampling on a flat surface. Some of them also detach grain from the hay manually by beating with stick on an open floor. Due to the absence of engine operated crop thresher, shellers and de-hullers, the following problems were identified through this study.

Much human and animal labor is spent for threshing

Those farmers who have no animals wait for long time until they get or rent animals from other farmers and this leads to significant loss of their produce.Since traditional crop threshing methods take longer time as compared to engine operated threshing machines and combine harvester, post harvest losses were high because of rain, pests, animals, etc. Grain quality is highly affected due to mixtures/impurities, animal dung and others.

Grain cleaning technologies: up on threshing, grain cleaning is done traditionally by winnowing using local materials like *Qorbi/mensh*, *Gundo*, *Darba* and gingilcha to separate grain from the residues and other impurities. Sometimes air stream may not be available or may not be stronger enough to separate grain from these materials by winnowing. Therefore, farmers have to wait days or weeks until they get wind stream that is strong enough to separate grains from impurities. Sometimes this may be the cause to loss of grain quality due to rainfall. The amount of labor required for grain cleaning is also high. In a nutshell, mechanized or semi mechanized grain cleaning technologies are not available in the study area.

Processing technologies: the study districts were dominated by coffee growing and crop-livestock production system. However, they were not using mechanized equipment like coffee de-huller and de-mucilater, milk churner, honey extractor, wax stumper, animal feed chopper and animal feed mixer. All of the farmers rather use traditional method for processing their agricultural products.

Transportation technologies: for transporting agricultural inputs, products and others from one place to the other, including marketing place, farmers use manual and traditional means of transportation largely by employing human and animal power. Most often, farmers use donkeys and occasionally mules for pack transportation of goods. Some farmers also use donkey-drawn carts for transportation but other animal-drawn carts were not encountered.

Storage technologies: traditional storages known as *Gumbi* (made of mud) and *Gotera* (made of grass, wood and mud) are widely used to store grain in the study area. Occasionally small sacks and warehouses are also used for grain storage. The traditional storages systems often expose grain to pests like insects, rodents and birds leading to significant grain loss in the storage. These problems, in turn, force some farmers to sell their produce immediately after harvest at lower prices only to buy it back later at an expensive price, leading them to fall into food shortage crisis. None of the farmers in the study areas used modern and semi-modern facilities like metal silo for grain storage system. They have no storage system for vegetables and fruits too.

Livelihoods system

The livelihood system of the study districts is quite diversified. The crop-livestock farming system is perhaps the most dominant and provides a reliable means of livelihood for majority of farm households. Crop production, specifically coffee is the major source of income for the majority of the rural households while livestock production is the second major means of income generation in all of the study districts. The third major livelihood sources for the farm households are none-farm and off-farm activities from which farmers earn cash like petty trade, selling of charcoal and gold mining. Income generated from activities which might have negative impact on climate and natural resources such as sales of firewood and forest products was also found to be source of livelihood for some farm households. Table 41 summarizes major livelihood source of farm households across the three study districts

Table 41: The major livelihood sources of farm households in the study districts

Source of livelihood	Rank in the districts		
Agriculture(farm)	Lalo Asebi	Gidami	Seyo
Crop production	First	First	First
Livestock production	Second	Second	Second
Non and off farm activities			
Wage and salary	Third	Third	Third
Remittances	Fourth	Fourth	Fourth

Gender role in different agricultural activities

Participation in crop production

Many labor-intensive agricultural activities such as land preparation, weeding, harvesting and transporting require active involvement of both women and men. Analysis of the gender division of labor in different farm tasks has revealed that women across the three study districts take part in almost all farming activities most notably on weeding. The only exception is ploughing with oxen, which is exclusively done by men. However, hand cultivation or hoeing and hand weeding is often done by both men and women. Besides, children are also engaged in most of the activities to help their parents despite their enrollment in school. Those children who are not enrolled in school help their parents especially in poultry and livestock rearing.

Participation in livestock production

Besides crop production, both men and women play a significant role in related tasks including livestock production and apiculture. The study indicated that men are more involved in beekeeping activities while women are more involved in home-gardening, poultry and taking care of lactating cows, calves and small ruminants. Taking care of the cattle is done equally by men and women, while managing dairy products is more often done by women. Besides managing these resources, women are responsible in other important domestic chores such as taking care of children, fetching water, cooking and collecting firewood. Despite women's active participation in the entire agricultural production system, their role does not appear to get much recognition by the society. For instance, majority of the male respondents considered only the productive work as most important work, while they tended to ignore the importance of reproductive works, often accomplished by women, such as fetching water, cooking, taking care children and collection of firewood, etc.

Decision making over resources

The study also examined the gendered differences in decision-making over productive resources, focusing on decisions in the use of end-products like dairy, honey, grains etc. The respondents indicated that the whole family has access to different resources such as land and water. However, the power to make various decisions on the use of resources is traditionally owned by men. Women are usually under-represented in the decision-making process. While men tend to dominate decisions regarding the use of crops, cattle and apiculture products, women are relatively better empowered to make decisions regarding small ruminants, poultry and livestock products such as milk and butter. On the other hand, men appear to have absolute control over high value crops and cattle. In line with this, the study indicated that small products such as poultry and livestock products are primarily used for household consumption but are sold when they are surplus. In this case, women have full control over the money obtained from the sale of these products in all the three study districts. The money which is generated from the sale of high value crops and cattle is usually used to buy fertilizer, land, oxen and improved animal breeds. Moreover, it may be used for construction of houses, cover children schooling expenses, family medication, and veterinary services and for some social events like wedding and funeral services of neighbors in the framework of social structure known as *Edir*.

Soil Acidity: Threat to Crop and Land Productivity in the Cereal Based Mono cropping System of Western Ethiopia. A Review

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Abstract

The acidity of soil and water solution is determined by its content of hydrogen ions when the solution breaks and ionizes into H^+ and OH^-. Hence, if there are more hydrogen ions than hydroxyl ions, the solution is said to be acidic. Soil acidity is characterized by low pH, Al toxicity, Mn toxicity P deficiency and P unavailability to the plants. At low pH, Al becomes soluble in soil solutions and Al^{3+} activity is high. It reacts with basic solutions to form insoluble oxides and hydroxides and occurs as replicable cations. Soils become acid when hydrogen ions are carried by downward percolating waters and replace the calcium and magnesium ions. Soil pH has direct effect on plant growth and on microorganisms at very low pH (less than 5) and also has indirect effect at pH between 5 and 5.5. At this level, Al and metals like Mn, Zn and Cu could be toxic to plants and microorganisms. At low pH and high acidity levels, availability of macronutrients (calcium, magnesium, potassium, phosphorus, nitrogen and sulfur) is limited. Some of these nutrients are replaced through soil erosion, leaching and crop removal. In addition, the use of acid forming inorganic fertilizers greatly enhances acid levels of the soil. The conversion of (NH_4^+) nitrogen to nitrate (NO_3^-) in the soil produces significant amount of acid forming H^+ whereby acid sulfide soils are formed in areas with subsurface drainage. The western, south western, north western and central highlands of Ethiopia are affected by soil acidity that could be attributed due to removal of base by high yielding crops, loss of bases by leaching, replacement of bases by H^+ and fast dawn ward movement of water due to high and torrential rains. Production of Al tolerant and P efficient crops and crop verities were less expensive mitigation strategy of soil acidity. Liming is the most commonly used to reduce soil acidity and improves yields of food and feed crops. It is also used to improve and retain land productivity potential in the world and in Ethiopia as well. Now days, single technologies are reported inefficient for acid soil reclamation. However, integrated use of organic manures, cropping system arrangements and liming are used and reported to reduce soil acidity, increase crop yields and improve land productivity.

Key words: Aluminium toxicity, anion, cataion, soil acidity

Introduction

Soil pH and soil acidity

Soil is made up of various components which determine its properties. These include mineral particles (sand, silt and clay) which give soil its texture, organic matter (living and dead), air and water. Parent material from which soils developed, organic matter decay, harvest of high yielding crops, acid forming inorganic sources of nitrogen fertilizers, excessive rainfall, climate and land management practices are causes of soil acidity. The water component is where pH is measured, where specific dissolved chemicals cause the soil to be acidic; hence it is the concentration of H^+ ion in the solution that influences acidity (Belinda, 2000). Soil and plant performance affected due to soil acidity can be identified by soil and plant tissue analysis whereby the land structure representing acid soil is presented in (Fig 1).

Nutrient availability is reduced, toxic elements Al and Mn become more soluble blocking site of uptake of roots and binds with P and H^+. Water dissociates into H^+ and OH^- whereby the hydrogen ion concentration increases, pH decreases and acidity increases. Soluble Aluminum and manganese become available and may reach toxic level to reduce plant growth when soil pH is low. At or below pH of 4.8, aluminum will reduce root growth while manganese disrupts photosynthesis and other functions of growth. Activities of biological nitrogen fixing bacteria associated with roots of legumes will be reduced in strongly acidic soils (Yost, 2000).

Fig. 1 Acidic soils (Left: Nedjo, western Ethiopia, Right: https://www.google.com/images)

Soil acidity and P availability

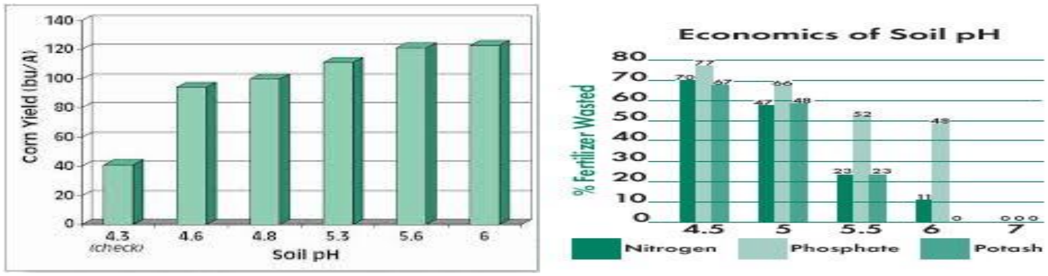
Phosphorus is classified as one of the most important element for crop production. It is known to be involved in many physiological and biological processes of plants. Plants must have phosphorus for normal growth and maturity. It plays role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other processes in plants. Phosphorus deficiency affects the major functions in energy storage and transfer of plants. Specifically, it affects tillering, root development, early flowering and ripening, reduces quality of forage, fruit, vegetable and grain crops and decreases disease resistance (Tisdale *et al.*, 2002). Phosphorus in acid soils can be affected by precipitation whereby high levels of extractable Al in acid soils causes P deficiency and formation of Al-phosphate complexes in acid soil solutions (Sanchez, *et al.*, 1997). The P fixation with Al is more commonly seen from pH 4.5 to 6 and results in substantial lock-up of P, while in less acid to neutral pH soils, Calcium (Ca) phosphate is the more commonly encountering inorganic form of P. Above pH level 7.0, Ca is the dominant ion and fixation is less permanent whereby in acid soils, P is concentrated at the surface of the soil while a high phytotoxic Al is found in the sub soils. Crops grown in such soils are exposed to various concentrations of P and Al at different depths in the soil profile (Iqbal, 2012).

Ethiopian Nitosols and other acid soils are reported to have low P contents not only due to the inherent low available P but due to the high P fixation capacity of the soils (Yihenew, 2002). Indeed, the highest concentrations of available P were recorded on the surface soil of intensively cultivated soils of research sites compared to the soils of farmers' field and virgin land (Wakene and Heluf, 2003), presumably due to the continuous application of inorganic P fertilizers. Soils of central highlands of West Shewa (Jeldu, Cheliya, Tikur Inchini, Jibat, Welmera and Ejere) were analyzed for soil acidity and Available P. Among the test samples, 80.5% were grouped under strongly acidic and 70% of the analyzed samples were P deficient, rated as low, very low and extremely low Available P (Tesfaye *et al.*, 2015). Use of lime, application of organic fertilizers, and crop rotation in the cultivated lands may alleviate P fixation and low crop productivity problems (Achalu, 2012). Similar report by Chandrasekaran *et al.,* (2010), emphasized application of manures, sewage sludge, and/or green manure and conservation tillage (crop residue management), compost, vermi-compost and poultry compost enhances the availability of P and other nutrients.

Soil Acidity and Plant growth

Many soluble and insoluble forms of Aluminum exist in acid soils. Not all of these exist in insoluble and soluble forms of Al are harmful to plants. For example, Al exists in the form of insoluble alumino-silicate or oxides in acid soils are non-toxic for plants. The toxic $Al^{3+}$is usually exchangeable and bound closely with the cation exchange complexes because of its higher adsorption strength to soil particles (Kochain, 1995). The author also emphasized that Al toxicity is most common severe problem associated with acid soils. It affects majorly bacteria population inhibiting root nodulation in legumes. Calcium entrance to plants is blocked, binds with P in ATP which inhibits energy transfer and genetic coding and restricts cell wall expansion. It is pH dependent and rarely a problem above a pH of 5.2. Study in Cornell University indicated that maize yield can be decreased on average by 45% when grown on soils with pH ranging from 4.3 to 4.5 compared to that grown on soil pH of 6.0 (Fig. 2). Similarly, loss of 77% P, 70%N and 67% K were recorded while applying inorganic fertilizer sources on acidic soil with pH of 4.5 (Fig. 2).

Most plant species grow optimally in a soil pH environment that is between 5.0 and 6.5; with pH values below this range, causing a significant reduction in plant viability, growth and reproduction. Weed invasion in low pH is common because introduced species are unable to cope with poor fertility and Al toxicity in strongly acid soils. Plantation forestry involves the bulk removal of vast quantities of biomass, which has the potential to acidify the soil over a short time period. Large amounts of cations are contained in forest thinning and the leaves of some species (Prosser *et al.,* 1993). Therefore, it is likely that the removal of all these components from the plantation will result in lowering pH. Failure to add sufficient lime during plantation establishment or after pruning operations resulted in the lowering of soil pH and raising Al to the toxic levels.



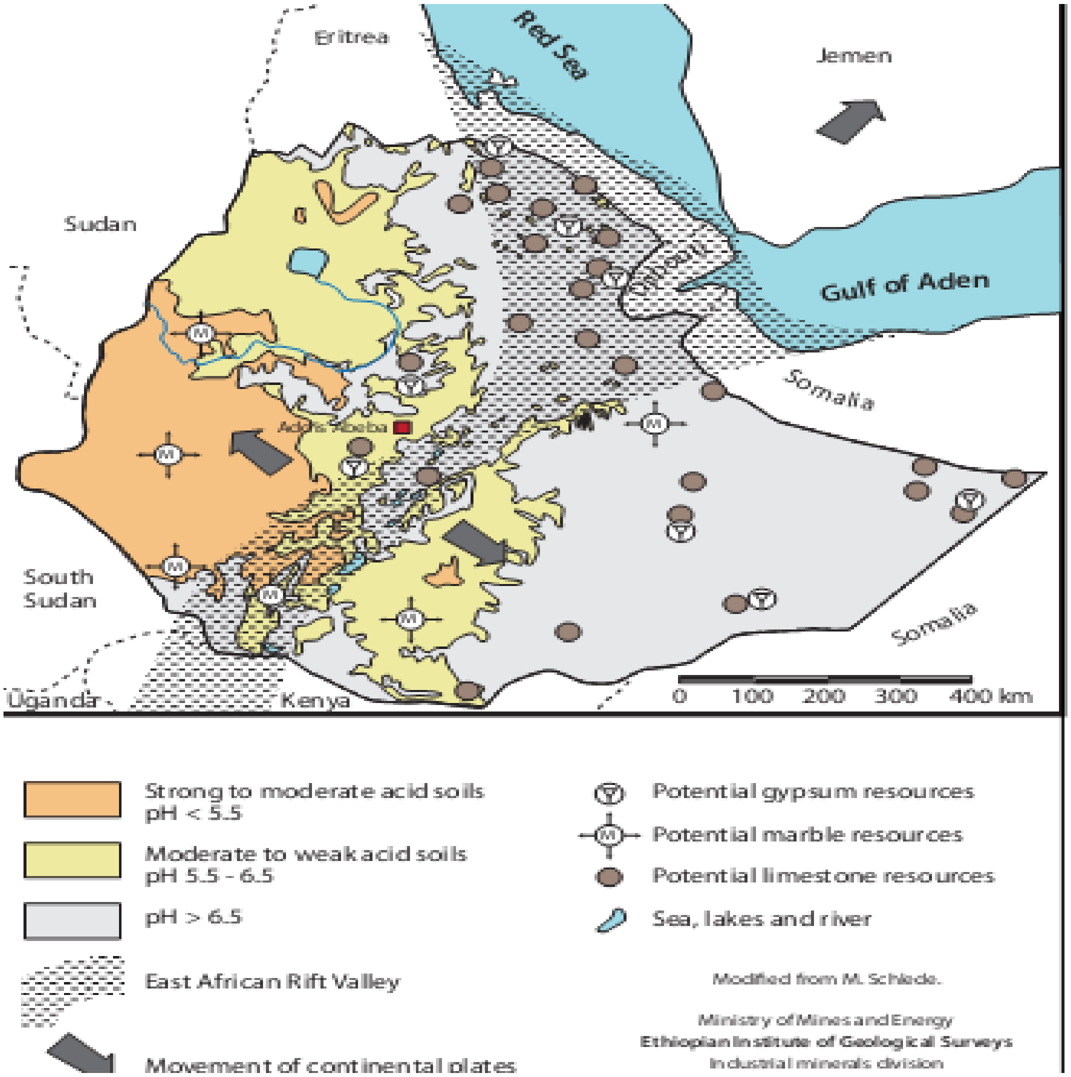
Source: Cornell University, USA

Fig. 2 Left: maize yield loss and right: NPK loss on acid soils

Soil acidity in Ethiopia

About 43% of Ethiopian agricultural land in the three high potential regions is acid affected of which 28.1% of the entire country is rated as affected by strong soil acidity (Tegbaru, 2016). These acidic areas are concentrated to the western, south western, north western and central highlands of the country (Fig. 3). The areas of central highlands of Shewa, Wellega, Jimma, Illubabor and Gojjam are cereal based farming system where maize, wheat and teff growing areas are characterized as acidic, pH ranging from 5 to 6. These areas are conducive for crop growth, fragile and could gradually becomes strong acidic if they are not managed properly (CIAT, 2017). Extremely acidic or very strongly acidic records were obtained for soils of the central highlands of west Shewa; Jeldu, Tikur Inchini, Jibat, Chaliya, Welmera and Ejere districts with the lowest pH of 4.2 recorded for Chaliya (Tesfaye *et al.,* 2015). Soil pH of all 36 samples from Bako Tibe District of West Shewa by Tolera *et al.,* (2015), ranged between 4.63 and 5.92. This could be due to the depletion of basic cations in crop harvest and due to its highest microbial oxidation that produces organic acids providing H ion to the soil which lowers pH value. Similar work by Abebe and Endalkachew, (2012), in southwestern Ethiopia resulted in pH ranged between 5.23 and 5.60 with medium level of available P. Soils become acid through continual, inappropriate and prolonged use of acid forming inorganic fertilizers. Increasing level of N use from 120 kg/ha to 160 and 180 kg/ha reduced pH from 6.0 to 5.8 and 5.7, respectively. The pH values fall more rapidly when ammonium sulfate is used in fertilizer blends for its sulfur (S) content which has about twice the acidifying values of N source, UREA. (USDA, 1999).

Calcium and magnesium are among important base cations removed by crops, lost by leaching and replaced by H^+ and these bases are carried away by drainage water. High and torrential rains also cause acidity while the more water moving down the soil, the faster is the leaching process (Abreha, 2013). Soils of humid regions are more prone to acidity due to torrential rains which have mean rainfall that exceeds evapo-transpiration. High termite abundance in the region affects crop growth and feed on crop residues that contained base nutrients like Ca and Mg. Unavailability of these base cations associated with soil erosion and down ward movement of water enhances soil acidity in the region.



Source ATA (Agricultural transformation Agency, Ethiopia)
Fig.3 Soil acidity distribution and coverage in Ethiopia

Soil pH, Total P and Exchangeable Ca were higher for forest land followed by grazing land and lowest for cultivated land (Achalu *et al.*, 2012). The reasons reported by Alemayehu and Assefa, (2016), were intensive farming over a number of years with nitrogen fertilizers application on cultivated land. Soil acidity is also consequence of the leaching of basic cations due to high rainfall which resulted in rapid erosion, acidifying effects of acid forming nitrogen fertilizers, poor nutrient cycling and the mining of basic cations through harvested crops. With similar consequences, Birhanu *et al.*, (2016), reported pH values of 4.8 and 5.8 for arable and forest lands, respectively at Komto, West Wellega. Low mean OM % of 2.23 and Mean AVP of 1.95 ppm were recorded for arable land against OM of 7.7 and AVP of 4.04 for forest land. Out of 2632 soil samples tested at Nekemte soil laboratory, 63% of the samples were below pH of 5.5 while the samples collected from Mida Kegn, West Shewa were very strongly acidic, pH < 4.5 (unpublished report).

Soil Acidity Mitigation

Reclamation of acid soils

No other single chemical soil characteristic is more important in determining the chemical environment of higher plants and soil nutrients than the pH. Lime is truly a foundation for much of humid region agriculture. Knowing how pH is controlled and how it influences the supply and availability of essential plant nutrients as well as toxic elements is essential for the conservation and sustainable management of soils throughout the world (Brady and Weil, 1999). No matter how it is expensive, to improve the condition on acid farmlands, intensive-abundant liming and controlled-efficient subsurface drainage of the tillage has been recommended because liming of top soil does not reduce acidity which drives from below the tillage layer (Kannen *et al.,* 2012). The authors with similar opinion addressed that more than single reclamation is required for complex soil acidification.

Long-term field experiments and agricultural practices have demonstrated that soils have been constantly acidified and depleted of calcium and magnesium. This occurs through the leaching of chemical elements from the upper layers by infiltrating water as well as by the uptake and consequent removal of these elements in crops. Acidification of soils is intensified by the application of mineral fertilizers primarily nitrates as well as by acid rains. The process of acidification affects not only cultivated soils but also forest and water resources (Anatolij and Vladislav, 1997). If only the top 10cm of the soil profile is acidic, it can be readily corrected by applying and incorporating finely ground limestone. However, if the acidification of the soil continues and the surface pH drops below 5.0, the acidity will leach into the subsurface soil. The further the acidity has moved down the profile the greater the effect on plant growth and the more is difficult to correct. The pH of a soil rarely falls below 3.8, if the soil is further acidified, it causes a breakdown of the clay minerals and is a permanent change to the soil so cannot be reversed (Upjohn *et al,.* 2005).

Several research works of acid soil reclamation were related to intensification of crop yields and improvement of land productivity. The work by Surachai (1999) had shown soil and water conservation as acid soil reclamation. The author reported vetivar grass retained the land to full production by reducing the runoff as a means of moisture conservation. Retaining 60% of the rainfall was considered best way of refilling groundwater. Accordingly, enhancement of moisture content of acid sulphate soils by improving water holding capacity and by decreasing toxic substances are its inexpensive, effective management and conservation tool to address acidity problems caused by runoff and leaching. Besides the soil and water conservation as a tool for soil acidity reclamations, many other works elsewhere and in Ethiopia were dealing with integrated soil acidity management with the emphasis to improve the quantity and quality of food and feed crops. This integrated approach contributes to improved nutrient use efficiency, reduces fertilizer needs, deeper root growth resulting in more efficient uptake of nutrients from the sub-soil and less leaching. More biomass production also contributes to reduce seepage and leaching, with more intensive nutrient recycling, maintenance of high organic matter and consequently less erosion that protect soil by vegetation and mulch cover.

Soybean

Reduced microbial activity due to soil acidity affects root nodulation and biological nitrogen fixation of most legumes. Rhizobium associated with most of the legumes is effective and fix nitrogen at pH range from 6 to 7, but the species associated with lupin is effective at pH 4 (Yost, 2010). Performance evaluation of ten acid tolerant soybean lines was tested for Genetic x Environment interaction on a pH of 4.3 in Indonesia. The result has shown G x E for characters like days to flowering, days to maturity, pods per plant and plant height was significant. The yield difference between genotypes were observed but not significant for G x E (Kuswantoro and Zen, 2013).

Research on investigating the revival of soil acidity and yield of soybean due to lime reclamation at Bako and Gute, western Ethiopia indicated that application of lime following exchangeable acidity based (4.6 ton ha^{-1}) increased soil pH and yields of soybean during the 1st, 2nd and 3rd years of application (Table 1). Similar report by Workneh, 2013 at Jima, identified application of lime at the rate of 2.6 t ha^{-1} and rhizobium inoculation increased pods per plant by 30%, seed yield by 29% and biomass yield by 14%. Split application of lime on soybean at Hurumu, western Ethiopia resulted in grain and biomass yields were affected by split application of lime over four years' experiment (Jafer and Gebresilassie, 2017). During year 1, lime splitting into four, three, two and full dose resulted in non-significant yield differences whereas all splitting and full dose of lime application in the consecutive years were significantly higher than the control (Table 2).

Table 1 Soil pH changes and yields of soybean through lime reclamation of acid soils at Bako and Gute, western Ethiopia

Initial pH		Year	pH change		Biomass weight kg ha^{-1}		Grain yield Kg ha^{-1}	
Bako	Gute		Bako	Gute	Bako	Gute	Bako	Gute
4.86	4.98	1	5.57	4.97	4431	1883	2355	1010
		2	5.54	5.17	5393	2616	2280	2341
		3	5.54	5.05	2850	1530	1338	645
		4	5.49	5.09	2703	1986	1269	619
LSD (5%)			NS	0.15	252.94	212.74	122.53	105.53

Source: BARC Progress Report (2013)

Table 2 Effect of lime application on soybean yields at Hurumu, Illubabor

Treatments	Biomass weight kg ha^{-1}				Seed yield kg ha^{-1}			
	2010	2011	2012	2013	2010	2011	2012	2013
Control	4800	2594	1878	6000	1690	1344	1436	1973
25 % every year	4833	3147	2332	6683	1510	1953	1753	2390
33% every year	4983	3204	2686	6483	1750	2024	1739	2307
50% every year	5033	3292	2420	6517	1738	2004	1858	2327
Full dose	5067	3242	2388	6200	1789	2050	1766	2088
LSD (5%)	NS	NS	395.63	642.19	NS	470	360.91	288.35

Wheat

Aluminum tolerant wheat varieties have the capacity to excrete 5-10 folds more malic acid than aluminum sensitive genotypes. Malic acid added to nutrient solutions was able to protect Al-sensitive seedlings from normally phytotoxic aluminum concentrations. Hence, Al-tolerant wheat species excreted about 4 times the total amount of malic acid initially present within the root apices; these wheat species encodes an Al-tolerance mechanism based on aluminum-stimulated excretion of malic acid (Delhaize, *et al.*, 1993).

Soil acidity management by Asmare *et al.*, (2015), at northern highlands of Ethiopia identified application of lime ($CaCO_3$) at the rate of 11.2 ton ha^{-1} increased soil pH from 4.89 to 6.03 and reduced exchangeable Al from 1.28 to 0.07. However, wood application gave a better yield than the lime application because of the additive nutrients such as P, K, Mg and micronutrients essential to plant growth. The experiment proposes combined application of wood ash, lime and P fertilizers for input minimization. Integrated use of lime, manure and mineral P fertilizer on bread wheat in Gozamin district, north western Ethiopia by Mekonnen *et al.,* (2014), resulted in integrated lime, manure and P fertilizer management improved P availability and produced more grain yield than their respective main effects. Hence, significantly high grain yield was obtained from combinations of 5 t ha^{-1} manure and 2.2 t ha^{-1} lime, which was ranging from 0.26 to 0.85 t ha^{-1} more grain yield than the respective individual effects. Integrated lime and NP fertilizer application increased biomass by 173% and grain yield by 236% over control at Tsegede highlands of northern Ethiopia (Abraha *et al.,* 2013). Hence, the research works identified that integrated use of lime with organic and inorganic fertilizers have been paramount effective than the main effects of each input.

Barley

The productivity of barley decreases as pH decreases due to the sensitivity of barley to low soil pH and its sensitivity to Al which becomes more soluble in solution as soil pH decreases. The target surface soil pH (0-10cm) for healthy growth of barley is $\geq$ 5.5 and sub-surface soil (20-

30cm) pH is ≥ 4.8. The solution to improving barley productivity on acid soils is to apply lime. Improving the genetic tolerance of barley in low pH and high Al-toxicity does not replace the need for lime (Gazey and Davis, 2009). Research result in Croatia by Kovacevic and Rastija, (2010), revealed that liming considerably affected the soil pH and plant available P status. Barley grain yield was higher at higher rate of dolomite (15 t ha^{-1}) four years after application where yield increase of 20% was achieved.

Study by Achalu *et al.*, (2013), demonstrated soil incubated with 10 t ha^{-1} lime increased soil pH from 4.7 to 5.7. In this study, application of lime increased P uptake which could be attributed to increase in soil pH, reduction of the ion toxicity of H^+, Al^{3+} Mn^{2+} and reduction in nutrient deficiency (Ca, P and Mo). Exchangeable acidity was also reduced and grain yield was increased with respect to land use system, being highest for forest land lowest for cultivated land of soils of East Wellega zone. Research by Shiferaw and Anteneh, (2014), resulted in half dose application of lime produced the highest barley mean grain yield during initial year of the experiment. However, during the second and third years of the experiments, the highest yields were obtained from full dose of lime application. The authors justified the obtained results; applied lime has residual effects but full dose lime had more efficient residual effect in the second year. Application of 8 and 10 t ha^{-1} lime significantly increased barley biomass yield, grain yield and P uptake compared to lower lime rates and a control. This study proofed barley biomass yield was also higher with the interaction of 6, 8 and 10 t ha^{-1}lime x forest soil x larger particle size of lime (Achalu *et al.,* 2012).

Teff

Al-sensitive and Al-tolerant genotypes were identified through root growth measurement and haematoxilyne staining methods. From the tested 28 teff genotypes, some of them have tolerated Al toxicity (Ermias, 2015). The author justified exclusion of Al from roots by organic acids may operate as a tolerance mechanism by teff. Application of 12 t ha^{-1} biochar and 2 t ha^{-1} lime reduced exchangeable acidity, increased CEC, increased soil OC, TN and also raised soil pH from 5.38 to 6.17 and 5.9; available P from 12.75 ppm to 18,92 ppm and 17.50 ppm, respectively. Teff biomass yield was increased by 35% and 23% while grain yield was increased by 46% and 41% by application of 12 t ha^{-1} and 2 ton ha^{-1} lime, respectively (Anteneh, *et al.*, 2014).

Maize

Varietal screening of maize for Al-tolerant and P efficient, was successful, obtaining genotypes that restrict Al uptake in the transition zone near the apex. Induction callose formation is a sensitive injury from Al while genotypes resisted Al-toxicity excluded its uptake into the root apex by sequestration with exuded citrates. Lime application to acid soil in Brazil have been used to decrease toxic effects of Al to the roots, but practical mechanical methods for deep lime incorporation have not been developed (Horst, 2000,). Therefore, the combination of liming practices for neutralization of soil acidity at the surface together with selection of more tolerant plant species to Al toxicity has been more economic approach. A research started with selection of Al tolerant inbred lines from 369 end up with 30 Al tolerant lines. Progressively, through diallel crosses and recurrent selections, two populations were found having high frequency of gene for Al tolerance whereby both are being used in tropical areas of the world as a source of gene for tolerance toxic levels of Al saturation (Magnavaca, *et al.*, 1987). Results from a 4 years experiment to assess the effectiveness of fallow, slush burn and legume rotation farming system on acid soils in Cameroon identified that acid tolerant maize variety out yielded acid sensitive variety and farmers' variety by 43% and 16%, respectively. Except for the first year of liming, the grain yield of acid tolerant variety increased over the acid sensitive variety with years of cultivation up to 27% in the second year, 33% in the third year and 53 % in the fourth year (The *et al.*, 2012). Besides the increase of soil pH from 4.5 to 6.86, application of 5 t ha^{-1} dolomite on acid soil in Croatia for five years resulted in higher maize grain yield but not significantly different from application of 10 and 15 t ha^{-1}. Highest maize grain yields were obtained during the second and third years of application while yields for initial and fifth years of application were lower for all rates of dolomite applications (Kovacevic and Rastija, 2010). Lime application at the rate of 5.75 t ha^{-1} has increased soil pH from 4.86 to 5.67 and 6.12 during the second and third year of applications, respectively. Application of lime resulted in 90% yields advantages over non-limed but applied recommended NP fertilizers. Mean while, yield increase of 13% was reported during the second and the third years of lime application (BARC, 2013).

Acid Tolerant crops

Crop tolerance of low soil pH has become extremely important in the agricultural development of humid tropics because so many of those soils have low pH while some plants are more able than other to grow on soils with low pH (Maranville, *et al.,* 1994). These crop plants have their specific characters tolerating acid soils with low pH. Considerable tolerance of low Ca and high Al, requirement of low pH, high levels of toxic Al and Mn has the components of both tolerance (of the presence of toxic elements within the plant) and of avoidance (prevention of the toxic element from entering the plant) were tolerance mechanisms discussed (Marschner, 1991).

High concentrations of Al are found in various plants including tea, rye, Bermuda grass, star grass, buck wheat and peanut. Other plants with known ability to tolerate soils with high Al concentration (called Al saturation) include rubber and blue berry (Kamprath and Foy, 1985). The authors' findings also pointed out that varietal differences in tolerance of aluminum have been identified in rice, alfalfa, tomato, soybean, cotton, maize, sunflower, pea and sweet potato. Besides the high Al tolerance crops, forage and forest species, maize and rice were found more tolerant of high soil Mn than soybean and barley while clover and oats are more tolerant than cowpea and sweet clover.

Vegetables/crops were ranked in tolerance from most tolerance to sensitive as tomato > lettuce > barley and bean > clover > potato. As the case of Al tolerance, there also appears to be differences in Mn tolerance within plant species. Varietal tolerance has been reported in soybean wheat apple and cotton. Tolerance of Mn in forage legumes appears to be a combination of prevention of Mn entry into the plant and greater internal tolerance. Rhizobia associated with most of the legumes fix N at pH of 6.3 to 7, while that associated with lupin function well at pH 4.0. Superior Mn tolerance in maize compared to peanut is believed to be due to reduced transport of Mn to the leaves (Yost, 2000). The author also described that the ability to grow well with low levels of Ca, Mg and P is therefore another type of tolerance or ability to grow in soils with low pH. Tropical biodiversity has contributed to the development of crop management alternative by contributing many of the tolerant species and cultivars with different critical pH range (Fig 4).

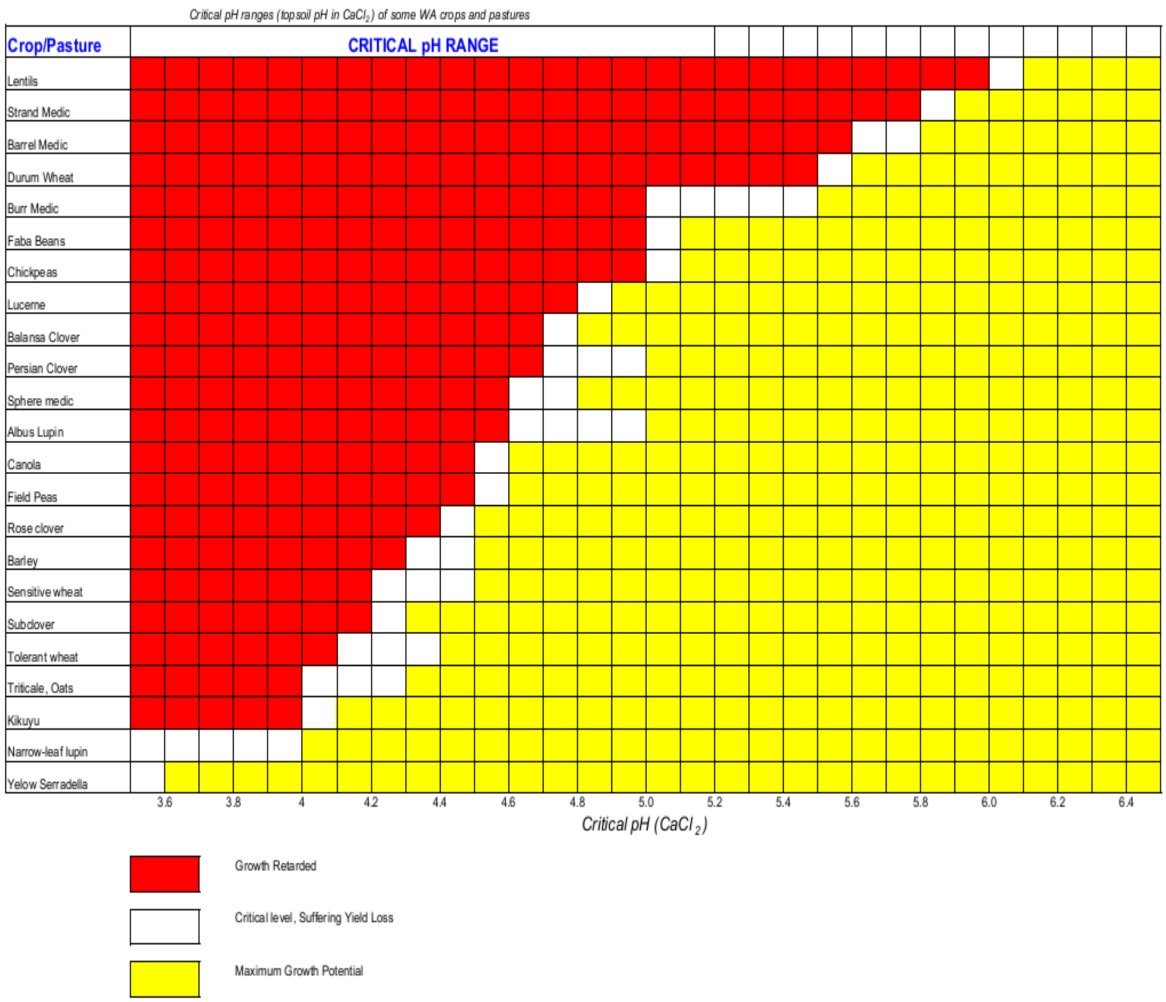


Fig. 4 Critical pH ranges for different crops

Challenges

Open livestock grazing

Soil organic matter serves multiple functions in the soil including nutrient retention, water holding capacity and soil aggregation. As a result of open livestock grazing in many parts of the country, soil organic matter levels have declined, led to establishment of grazing-tolerant herbaceous plant species which also are tolerant to decomposition. These plant species are growing aggressively and are noxious weeds to major crops. Extensive and conventional method of livestock production which is said specific to Ethiopia affects biomass retention, affects seedling growth, influences soil erosion and is a major cause for destruction of soil and water conservation structures.

Limited access to lime

Liming has been identified as the most effective but costly acid soil reclamation strategy. It is required in large quantities depending on the application method. Target pH lime application is effective in increasing pH but requires larger amount compared to exchangeable acidity lime application method. However, the capacity of Guder lime crusher located at 120 km west of Addis Ababa is not accessible to extreme western Ethiopia and could not satisfy the demand for reclaiming larger area of acid prone soils. Manual limestone transportation (Fig 4) to the crusher unit and manual breakage of limestone to smaller particles so as to suit to the crusher machine and manual lime application to the field (Fig 5) are some the challenges related to lime production and management.

Fig 4 Lime crushing units, left (Guder, Ethiopia) and right (Finland)

Fig. 5 Lime application method, left (Ethiopia), right (Finland)

Opportunities and future research directions

Availability of land use policy and local bylaws related to protection of open livestock grazing could restrict vegetation damages by cattle. Strong livestock breeding research program that releases improved breed and improved feed regime (cut and carry system) could reduce the number of cattle practicing open grazing. Besides obtaining improved breeds, there are also recommended management technologies that are environmentally friendly and economically feasible. Livestock production under controlled padlock provides manures and sludge from biogas sulary with no or limited loss that would otherwise lost if open grazing system is used.

Availability of carbonate and phosphate rock in the central Ethiopia and western Ethiopia could improve the accessibility to lime and P source fertilizers. The requirement of limestone industry in the area of limestone source, western Ethiopia is necessary to bind industry and agriculture. The by-product from marble production is a high quality agricultural lime but the industry was established in the eastern Ethiopia that would otherwise require double transportation cost to the acid affected areas. Strong multi-disciplinary researcher team consisted of soil scientists, agronomists, plant breeders and natural resource specialists that can identify the root causes of soil acidity and develop standard and comprehensive project of integrated approach tackling the threats due to soil acidity. Hence, future directions of the researchers should emphasize on identification of acid tolerant crops and crop species, cropping system that increases biomass on the field, soil test crop response based NPKS requirement and integrated use of organic, inorganic fertilizers and liming.

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Participatory Identification of Agricultural Production Constraints in Bale and West Arsi Zones, Oromia

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Abstract

Ethiopia has launched the second Agricultural Growth Program (AGP-II) in the period of GTP-II to enhance agricultural productivity and production of farming/pastoral communities the country. Accordingly Oromia region is also implementing AGP-II program in different project zones. Bale and West Arsi zones are one of the beneficiaries of this program. In order identify agricultural production constraints; AGP-II program has conducted constraint identification survey in both zones in representative districts. As a result, the AGP-II assessment has identified priority crops, livestock and natural resources that need attention in research by the program to further transform agricultural productivity and production in the target districts. According to the survey results, the major crop production constraints were lack or limited access to improved crop seeds, agricultural chemicals, poor crop management practices, poor marketing, low institutional support and lack of value chain development approach to ensure participation and to benefit farmers in the study area. Livestock production are also constrained by feed shortage, shortage of improved breed, disease and shortage of water in the studied areas. The major natural resource management constraints in the study areas were deforestation, shortage of water, knowledge gap, salinity problem, soil erosion, water logging and tree pests (disease and insects). Most parts of Bale and West Arsi zones are mechanized areas. Agricultural mechanization, along with other farm inputs such as fertilizers, improved seeds and pesticides, can significantly improve agricultural productivity. According to the survey results, the major sources of farm power used for tillage, cultivation, harvesting, threshing, cleaning and transportation are human (women, men and children) and draft animals (bullocks, camels, horses, mules and donkeys). Few farmers in the studied districts have used tractors and combine harvesters as farm power sources for tillage, and wheat and barley harvesting, respectively. Some farmers of the study area use tractor mounted wheat and fertilizer row planter. In general, the results of this survey identified agricultural production constraints in the studied districts and prioritized them in terms of their importance. Thus, this results help research institutes and other development entities to target their intervention to address the problems of farmers in the areas.

Introduction

Agriculture is the base of livelihood of the majority of people in Ethiopia. It is the source of food and cash for farming/pastoral communities and others. Economic growth of the country is highly dependent on the success of the agricultural sector. Agriculture accounts for about 45% of the Gross Domestic Product (GDP), and more than 85% of the total population employment that is directly or indirectly engaged in agriculture; generates about 80% of the foreign exchange earnings of the country; provides raw materials for 70% of the industries in the country (Dawit *et al*., 2010). Since agriculture plays significant role in food security, industrial raw materials and foreign exchange earnings, the government allocates bout 15-17 % of budget to the sector per annum.

In view of transforming agricultural sector, the government has designed different agricultural development strategies such as Agricultural Development Led Industrialization (ADLI) (2006), Growth and Transformation Plan I (GTP-I) (2010), and Growth and Transformation Plan II (2016). These strategies are implemented to improve productivity and production of agriculture by the support of establishing Agricultural Transformation Agency (ATA) 2010, and Agricultural Growth Program-I (AGP-I) (2010) and currently AGP-II (2016).

To further enhance agricultural productivity and production of farming/pastoral communities, the country launched the second Agricultural Growth Program (AGP-II) in the period of GTP-II. The AGP-II assessment has identified priority crops, livestock natural resources and agricultural engineering to be addressed by research that need special attention by the program to further transform agricultural productivity and production to benefit more communities. Before starting research work in the identified thematic areas, conducting survey for identifying agricultural production constraints that serves as base line information on those thematic areas identified is essential. Therefore, the objective of this survey was to identify agricultural production constraints through participatory approach on the mentioned thematic areas in AGP 2 districts of the zones to understand the present agricultural production constraints.

Methodology

This survey was carried out in 2016/17 cropping season in three representative districts of Bale and West Arsi Zone of AGP II project.

Description of the studied districts

Agarfa

Agarfa District is located in the north western of Bale Zone. The district has 19 kebeles of these seven (37%), nine (47%), and three (16%) are located in the highlands, midlands and lowland agro-climatic zones, respectively. Besides, there are three towns in the district having four urban kebeles. The altitude of the district ranges from 1256 to 3750 masl. Topographic coverage of the district is 25% plain, 10% hills, 5% mountains and 60% undulated areas. The mean annual temperature is 16.5^{o}C, whereas the mean minimum and maximum temperature is 8 and 25^{o}C, respectively. The average annual rainfall is 850 mm and the range is 600 to 1100mm. Rainfall pattern of the district is characterized as bi-modal, i.e two distinct seasons, *Belg*, March to July and *Meher*, August to December. Production system practiced in the district is mixed farming (crop and livestock) (District Agriculture and Natural Resource Development Office).

Adaba

Adaba district is located in the eastern part of West Arsi Zone. The total estimated area of the district is about 2,166.41 km^2. It has 22 kebeles of which four (18.2%) kebeles located in highland while 18 (81.8%) are in midland agro-climatic zone. There are also three towns and two urban kebeles in the district. The altitude of the district ranges from 1840 to 3800 masl. Topographically, the district has about 60% is undulated lands, 25% plain, 10% hilly and 5% mountains. The mean annual temperature is 16.5^{o}C whereas the mean minimum and maximum temperatures are 8^{o}C and 25^{o}C respectively. The average annual rainfall is 850mm while the range is 600 to 1100mm.The rainfall pattern of the district is uni-modal. Production system practiced in the district is crop-livestock mixed farming system. Additionally, in some kebeles of the district, community based forest management and utilization is practiced. In this practice, communities manage and conserve forest biodiversity, share benefit from revenues generated from this forest resource. This helps to increase income of the surrounding communities which in turn improves rural livelihoods and ecosystem of natural forest in the district.

Ginnir

Ginnir District is located in Bale Zone south eastern Oromia,. Its total area is estimated to about 2351 km^2. The district has 40 kebeles, three towns and four urban kebeles. The altitude ranges from 1200 to 2406 masl. From the total area of the district about 85 % is plain land, 3% is mountains, and 12 % is rugged and gorge. The annual average temperature is 25.45 where as the minimum and maximum temperature is 23.2^{o}c and 27.7^{o}c respectively. The annual average rainfall is 700mm where as the minimum and maximum rainfall is 200 and 1200mm respectively. Rainfall pattern of the district is bi-modal, i.e. two distinct seasons, *Belg* from March to July and *Meher* from August to December. Mixed farming system of crop and livestock production is the common farming practice of the district.

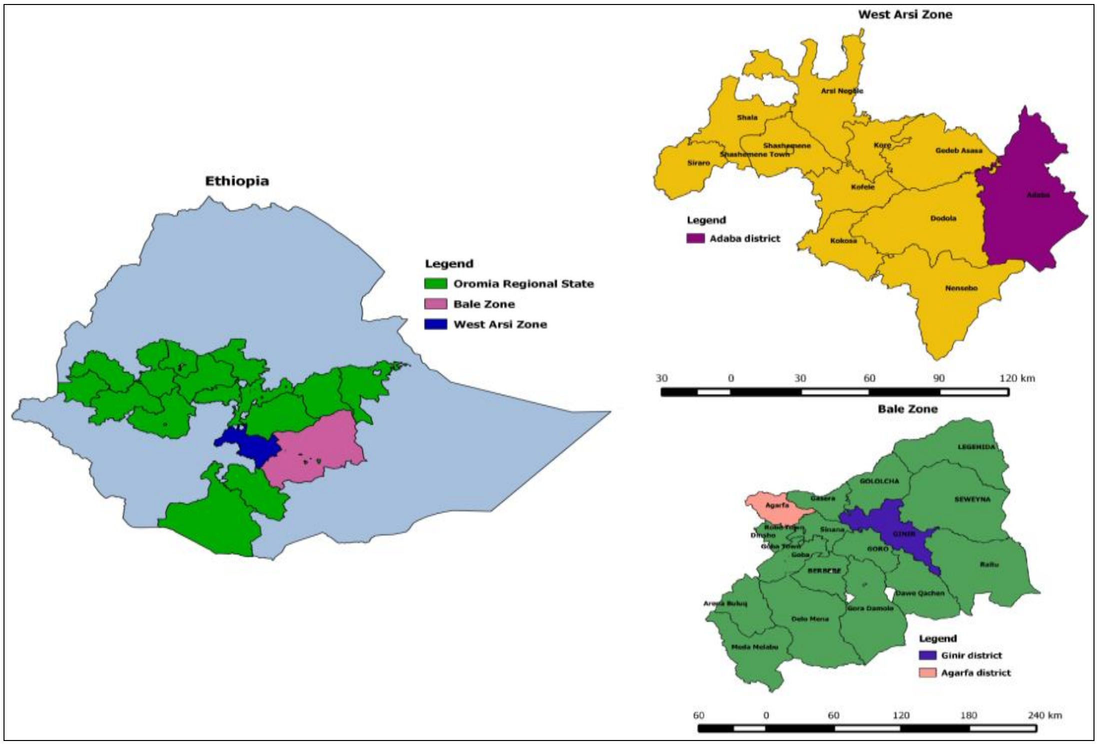

Fig.1. Study locations -Agarfa and Ginnir districts from Bale Zone and Adaba District from West Arsi Zone.

Sampling techniques and data collections

AGP-II program has six districts (four from Bale and two from west Arsi zones) which are under Sinana Agricultural Research Centre. Out of six districts, survey for identification of agricultural production constraints was conducted in three representative districts; i.e Agarfa and Ginnir in Bale and Adaba in West Arsi were purposely selected based on agro-climatic zones. Then from each district, three representative kebeles totally nine kebeles were selected based on their agro-climatic condition, location of kebeles in the districts, types of dominant commodities produced and distance from capital town of the district . Participating farmers included in group discussion were selected based on their age, wealth status and sex of household heads. Data were collected both from primary and secondary sources. Specifically primary data were collected from farmers through structured questionnaires using Focus Group Discussion (FGD); whereas the secondary data were collected from different sources such as published and unpublished documents, from District Agriculture and Natural Resource Development Offices, Farmers' Organizations (unions/cooperatives), input suppliers, and Livestock Resource and Fishery Development Office.

Data analysis

Primary data collected from representative groups of each agro-climatic zone using Participatory Rural Appraisal (PRA) techniques were summarized by qualitative assessment tools such as tabulation, percentage, conceptualization and other relevant descriptive statistics. Moreover, percentages and tabulations were used to summarize quantitative data collected from secondary sources.

Results and Discussion

Analysis of secondary information source in the studied districts

Demography

The variables used to describe demographic characteristics of the study districts are sex and residential areas. The total population in Agarfa district was 123090 (63598 male and 59492 female). From this total population, 100399 (82%) and 22691(18) in the district lived in rural and urban areas respectively (Table 1). For Adaba district, the total population was 189279 (97792 male and 91487 female). From this, 166595 (88%) population lived in rural while 22684 (12%) lived in urban areas (Table 2). Similarly, the total population of Ginnir district is 371977 (282557 male and 89420 female). From this, 141967 (38%) and 230010 (62%) of the population in the district lived in rural and urban areas respectively (Table 3).

Table 1. Population distribution by sex and residential areas in Agarfa District

No.	Category	Male	Female	Total
1	Rural population	52153	48246	100399
2	Urban population	11445	11246	22691
	Total	63598	59492	123090

Source: Agarfa District Agriculture and Natural Development Office (2016)

Table 2. Population distribution by sex and residential areas in Adaba District

No.	Category	Male	Female	Total
1	Rural population	86440	80155	166595
2	Urban population	11352	11332	22684
	Total	97792	91487	189279

Source: Adaba District Agriculture and Natural Resource Office (2016)

Table 3. Population distribution by sex and residential areas in Ginnir District

No.	Category	Male	Female	Total
1	Rural population	72450	69479	141929
2	Urban population	14268	14021	28289
	Total	86718	83500	170218

Source: Population projection of Ethiopia for all regions, CSA (2013)

Agricultural landholding

Most farmers living in Agarfa District owned 2-5 hectares of land for agricultural production, however, the number of farmers owning land greater than 5ha is few (Table 4). In Adaba district, the majority of farmers (90%) owned 1-2 hectares of land for agricultural production, however, the number of farmers owning land greater than 2ha is few as indicated in table 5.This indicates that shortage of land is a serious problem in agricultural production in the district. More than 53% of farmers in Ginnir District owned 1-2 hectares of land for agricultural production, however, the number of farmers owning land greater than 2ha is 20% (Table 6).This district has relatively better land holding as compared to Agarfa and Adaba.

Table 4: Agricultural landholding of farmers in Agarfa District

No.	Land holding (ha)	Number of farmers
1	≤ 0.5	876
2	0.5-1	1040
3	1-2	2701
4	2-5	8600
5	≥ 5	292

Source: Agarfa District Agriculture and Natural Resource Development Office (2016)

Table 5: Farmers landholding categories of Adaba District.

No.	Land holding (ha)	Number of farmers
1	≤ 0.5	243
2	0.5-1	440
3	1-2	8361
4	2-5	242
5	≥ 5	0

Source: Adaba District Agriculture Office (2016)

Table 6: Farmers landholding categories of Ginnir District

No.	Land holding (ha)	Number of farmers
1	≤ 0.5	882
2	0.5-1	5466
3	1-2	12733
4	2-5	4266
5	≥ 5	504

Source: District Agriculture and Natural Resource Development Office, (2016)

Land use types

Land is perhaps the single most important production factor and measure of wealth in the studied districts. It is the main source of income and increases the prestige of people in the community. In Agarfa district, the land use types were arable land, cultivated land, forest land, grazing land, land used for construction, area closure and others. The detail of the land use categories in district is indicated in Table 7. Of the total land in Adaba District, 36% covered by forest land, 31% cultivated land and 9% grazing land (Table 8). From the total areas of Ginnir District, 29%, 16%, and 10% were cultivated, forest and grazing land respectively (Table 9).

Table 7: Land use types of Agarfa District

No	Category	Area (ha)
1	Arable land	27919.8
2	Cultivated land	37202.8
3	Forest land	14163.7
4	Grazing land	6086.4
	4.1 Communal	-
	4.2 Private	6086.4
5	Land used for construction	26764
6	Area closures	1135
	Total	114084

Source: Agarfa District Agriculture and Natural Resource Office, (2015)

Table 8: Land use types of Adaba District

No.	Land use type	Area (ha)	Percent
1	Arable land	2187	1.6
2	Cultivated land	43255	30.96
3	Forest land	50517	36.15
4	Grazing land	11992	8.58
	4.1 Communal	8564	6.13
	4.2 Private	3428	2.45
5	Land used for construction	4660	3.33
6	Area closures	3128	2.24
7	Others	12002	8.59
8	Total	139733	100

Source: Adaba District Agriculture and Natural Resource Development Office (2016)

Table 9. Land use types of Ginnir District

No	land use type	Area (ha)	Percentage
1	Arable land	5715.34	3.38
2	Cultivated land	67938.7	40.20
3	Forest land	38409.7	22.73
4	Grazing land	23927.4	14.16
5	Land used for construction	3715.34	2.20
6	Area closures	23334.8	13.81
7	Others	5952.55	3.52
8	Total	168994	100

Source: Ginnir District Agriculture and Natural Development Office, (2016)

Major soil types by Agro-climate

The major soil types in Agarfa district based on soil texture are loam, clay and sandy soils. Sandy soil covers most part of the district (Table 10).Whereas the dominant soil types in Adaba district based on soil textures are loamy and clay soils. Loamy soil covers most part of the district (table 11). Based on textural group, the soil of Ginnir district is categorized into loamy, clay and sandy soils. Loamy soil is dominant soil texture in most parts of the district table 12.

Table 10: Major soil texture by agro-climatic zones in Agarfa District

No	Agro-climate	Soil texture (%)		
		Loam	Clay	Sandy
1	Highland	75	20	5
2	Midland	65	25	10
3	Lowland	15	5	80

Source: Agarfa District Agriculture and Natural Resource Development Office, (2016)

Table 11. Major soil texture by agro-climatic zones in Adaba District

No.	Agro-climate	Soil texture (%)	
1		Loam	Clay
2	High land	45	55
3	Mid land	68	32

Source: Adaba District Agriculture and Natural Resource Development Office, (2016)

Table 12. Major soil texture by agro-climatic zones in Ginnir District

No	Agro-climate	Soil texture (%)		
		Clay	Loam	Sandy
1	High land	20	75	5
2	Mid high land	25	65	10
3	Low land	5	15	80

Source: Ginnir District Agriculture and Natural Resource Development Office (2016)

Water sources

Three water sources were identified in Agarfa district. These are rivers/surface water (seasonal and year round rivers such as Web River), pond water, and ground water. Web River and ground water are used as year round available water source in the district whereas pond water sources are seasonal depending on the availability of rainfall.

Similarly, three water sources were identified in Adaba district. These are rivers/surface water (seasonal and year round rivers such as Web, Maribo, Nanesho, Wachekore, Furuna and Arba rivers), ground water are used as year round available water source in the district whereas pond water sources are seasonal depending on the availability of rainfall. Additionally Melka Wekana Lake which is used for electric power generation and important source for fishery production exists' in this district.

In Ginnir District, there are three potential water sources available; river/surface water, pond water, and ground water. Ginnir district has numerous rivers such as Dinkiti River, Gololcha River, Tebele River and other numerous small tributaries river. Apart from the above mentioned major rivers the following intermittent streams are also found in the district which flow to Genale River. These are; Burka River, Adaa River, Fo'aa Rivers and Alock rivers.Perennial rivers and ground water are used as a year round available water source while seasonal rivers and pond water sources depend on availability of rainfall in the season.

Crop production

The three districts (Agarfa, Adaba, and Ginnir) are known for their high production potential for crops and livestock. Crop production is one of the main livelihood activities in all the three districts. Survey results in Agarfa district showed that field crops produced included teff, wheat (bread, durum and emmer), barley, maize, field pea, faba bean, chickpea, lentil and linseed. The major horticultural crops produced were potato, tomato, onion, pepper, carrot, cabbage, shallot, spices such as fenugreek, etc. Dominant crops produced in the district were wheat (bread and durum), barley, teff, linseed, faba bean, lentil, field pea, potato, tomato, onion and pepper. Similarly, survey results revealed that, in the sampled kebeles of Adaba district, field crops produced were teff, bread wheat, durum wheat, emmer wheat, barley, maize, linseed, rapeseed, field pea, chickpea, faba bean and lentil while the major horticultural crops were potato, tomato, onion, garlic, beet root, carrot, head cabbage, spices such as fenugreek and others. The dominant crops produced in the district were wheat, barley, teff, faba bean, lentil, chickpea, potato and tomato.

Moreover, in Ginnir District, field crops produced were teff, wheat (bread, durum and emmer), barley, sorghum, maize, chickpea, field pea and haricot bean. Major horticultural crops produced were papaya, mango, avocado, banana, pepper, potato, tomato, onion, garlic, beet root, carrot, chat, and spices such as fenugreek, cumin, and coriander, etc. Dominant crops produced in the district were wheat, barley, teff, maize, chickpea, field pea, haricot bean, papaya, mango, avocado, banana, pepper, tomato, onion, potato and chat. In all the three districts, crop production is under rain fed condition (Table 13). However, few farmers have produced vegetables under irrigation.There are two types of irrigation practiced in the districts, traditional and modern. In Adaba district, farmers commonly use traditional irrigation, while Agarfa and Ginnir districts use both modern and traditional irrigation (Table 14).

Table 13. Crop production in the three districts for the last five years under rain fed in *Genna* and *Bona* seasons

No.	Year	District					
		Adaba		Agarfa		Ginnir	
		Belg	*Meher*	*Belg*	*Meher*	*Belg*	*Meher*
1	2003	-	1692	11207	22413	22333	26850
2	2004	-	2143	11313.5	22615	27254	26368
3	2005	-	2589	11843	23686	28574	26362
4	2006	-	3758	12778	25556	29450	27243
5	2007	-	4931	12791	25583	33850	28714

Source: Adaba, Agarfa and Ginnir Districts Agriculture and Natural Resource Development Offices, (2016)

Table 14. Crop production in the three districts for the last five years under traditional and modern irrigation

No.	Year	Districts					
		Adaba		Agarfa		Ginnir	
		Irrigation (ha)		Irrigation (ha)		Irrigation (ha)	
		Modern	Traditional	Modern	Traditional	Modern	Traditional
1	2003	-	1489	500	456.5	431	346
2	2004	-	1796	684	534.17	565	425
3	2005	30	2549	735.5	688.25	625.5	688.5
4	2006	42	2758	2257	1637	1130	1352
5	2007	42	2931	3390	2452	1480.5	1672

Source: Adaba, Agarfa and Ginnir Districts Agriculture and Natural Resource Offices, (2016)

Table 15. Average crop productivity (qt/ha) of local and improved cultivars of different dominant crops produced in Agarfa district for the last five years (2011-2015)

	Local cultivar					Improved cultivar				
Crop	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Bread wheat	-	-	-	-	-	33	36	44	38	46
Teff	9	9	12	13	15	-	-	-	-	-
Sorghum	28	21	30	20	22	-	-	-	-	-
Food barley	27	32	31	34	28	-	-	-	-	-
Maize	34	38	39	32	25	45	47	60	66	64
Faba Bean	17	18	23	20	22	32	35	32	33	32
Potato	260	256	273	268	272	380	384	389	395	402
Tomato	220	223	225	222	224	330	331	336	340	345
Onion	145	149	153	150	155	253	257	260	263	268

Source: Agarfa District Agriculture and Natural Resource Office, (2016)

Table 16. Average crop productivity (qt/ha) of local and improved cultivars of different dominant crops produced in Adaba district for the last five years (2011-2015)

Crop	Local cultivar					Improved cultivar				
	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Bread wheat	17	18	18	20	21	32	36	41	43	42
Teff	6	7	10	10	11	16	16	17	17	17
Food barley	19	21	25	25	25	29	29	33	35	35
Maize	25	29	36	33	39	55	43	45	45	45
Faba Bean	9	10	11	10	11	14	15	16	19	19
Chick pea	9	11	11	10	11	13	14	14	15	15
Field pea	8	9	11	11	12	12	18	17	17	18
Potato	250	260	260	260	270	360	370	370	380	380
Onion	102	103	102	104	160	205	209	234	239	237

Source: Adaba District Agriculture and Natural Resource Office, (2016)

Cropping systems

The term cropping system refers to the crops and crop sequences and the management techniques used on a particular field over a period of years. There are different types of cropping system but most of the farmers in the study districts practice mono cropping. In all the three districts only few farmers use crop rotation only when there is suitable rainfall in the seasons which favor double cropping, particularly in areas where there is a bi-modal rainfall pattern. Common cropping practice in the three districts is mono cropping (cereal after cereal) without fallowing.

Crop management

Fertilizer application

Fertilizers are plant nutrient sources that are applied to soils to supply the nutrients that are deficient in the soil. In the studied districts, there were three types of fertilizers, inorganic, organic and biofertilizers. However, farmers reported that inorganic fertilizer application (Urea and DAP) is common in crop production of the districts. DAP is applied at sowing while urea is applied in split for cereal crops especially wheat. However, the use of fertilizers for other crops is very low as compared to wheat due to high price of fertilizers. According to survey results, use of organic fertilizers is not common in the three studied districts; however, few farmers apply compost and animal manure for horticultural crops in their home garden. Even though there is awareness on the importance of compost for crop production, only few farmers use compost because of its bulk application requirement for supplying the necessary nutrients compare to inorganic fertilizers (DAP and Urea). There is no practice of mulching or crop residues retention on farm lands; and, biofertilizer was only used by few farmers for chick pea in Ginnir and faba bean in Agarfa districts. In general, farmers in the studied districts used different fertilizer rate, method and time of application based on the crop and soil types.

Land preparation and planting

Large proportion of farmers in the studied districts use oxen plough for land preparation. Some farmers who are living in hilly and mountains areas use hand tools for land preparation. Moreover, there were few farmers using tractors for land preparation particularly those who owned relatively larger acreage of land in plain areas in the three districts. Land preparation starts at onset of the rainfall which extends from May to July for *Bona* season and from February to March for *Genna* season. The farm land is ploughed 2-5 times based on rainfall distribution, weed density of the field, crop and soil types.

There were two types of planting methods practiced in the three districts i.e. row planting and broadcasting- the latter being the dominant. This could be due to lack of row planter. However, some model farmers use row planting for crops such as maize and wheat manually using labor. Among farmers using row planting, many of them use hand drilling, plastic bottles and other locally available materials for wheat, and maize. However, the system is laborious and time consuming. In general, farmers in the studied districts used different methods for land preparation, planting, use different seed rate and tillage frequencies depending on the crop and soil types.

Pest management

Crop pests are among the major production constraints reducing crop yields. These include weeds, diseases and insects which require integrated use of different management options that are safe and environmentally friendly. The management of these three important crop pests is described in details as follow.

Weed management

The objective of weed management is to prevent or restrict the development of weeds to a threshold level to reduce/avoid yield loss due to weeds. Farmers in the studied districts reported that broadleaf and grassy weeds were equally important in reducing crop yields, even though there was a difference from crop to crop. Cultural methods of weed management in the studied districts included hand weeding, hoeing and cultivation for major crops. However, for wheat and barley farmers use both hand weeding and herbicides. Survey results showed that ploughing is normally used to reduce the population of pests in the soil including weeds by exposing them to sunlight and desiccation. The most commonly used herbicides are 2-4-D and Pallas but the main problems to use these herbicides by farmers included lack of timely supply and high price.

In wheat and barley dominated areas of the studied districts, mono cropping of cereals (wheat after wheat or barley) coupled with repeated application of broad-leaf herbicides have aggravated severe infestation of grass weeds. Grass weeds are difficult to manage by hand weeding at early growth stages of wheat and barley as it is difficult to differtiate seedlings of weeds from wheat and barley. The main limitations in hand weeding are labor shortage and high cost.

Disease management

Crop disease management is important to prevent or restrict the development of disease to epidemic level. In the studied districts, fungal diseases such as rusts, scald, net blotch, smut, etc of wheat and barley are commonly managed by application of fungicides while there was no disease control measure practiced by the farmers for other crops in the districts. Knowledge gap in identification of diseases and control measures, access to chemicals, price of chemicals and safety issues in using chemicals are the major constraints identified in disease management. Application of fungicide is the last option when resistant varieties of wheat and barley are broken by virulent pathogens. Among fungicides used by the farmers *natura*, *tilt* and *Rex Duo* were the most common and effective fungicides for the control of yellow stem and leaf rusts of wheat.

Insect pest management

Various insect pests were identified and were the major problem in crop production. These insect pests included shootfly, ball worm, epilachna species, grasshopper, cricket, aphids, leaf-hoppers and others .. Besides, newly emerged insect pest was -American Fall Army Worm in 2017/18 cropping season. This migratory insect pest is the most destructive on maize seedlings currently in the field and potentially a serious challenging pest causing damage to all other crops. Hence, this insect requires high attention publically and by government to manage its total damage to crops. Some of the identified insect pests can be managed by the use of insecticides. However, most of the farmers are not practicing insect pests control methods because of knowledge gap, unavailability of insecticides, price of chemicals and safety issue in using chemicals. In general, use of pesticides (herbicide, insecticide, and fungicides) by farmers in the studied districts is limited; this could be due to high price and unavailability of chemicals and knowledge gap (safety precaution).

Crop harvesting

Harvesting and post harvest are the processes of collecting, shelling, threshing, weighing, grading, packing, transporting, storing and marketing field and horticultural products. To reduce post harvest loss all steps of improved harvest and postharvest technologies must be carefully implemented beginning from harvesting up to the end use of products and by-products storage and marketing. There are two harvesting methods in the studied districts, manual and mechanized.

Manual method: Crops such as barley, teff, maize, faba bean, chickpea, onion, potato, tomato, mango, banana and coffee are often harvested manually using sickles, hoeing and hand picking. Barley, faba bean, field pea, chick pea, lentil, sorghum, teff etc after being harvested manually, they may be left on fields for pre-drying of the crop before threshing to facilitate separation of grains from straw. Traditionally, threshing is by hand and animal trampling. Manual method results in yield and quality losses and thus mechanized harvesting is advisable to reduce crop product losses.

Mechanized Method: Survey results showed that the only crop harvested by combine harvester is wheat in areas where the farm land is suitable for the combine harvester in the studied districts. Farmers using combine harvester were complaining about the following major problems:

- Difficulty in getting private combine harvester on time (Accessibility)
- Variety mixing problem during harvesting,
- Cost for collecting straw from field and animal trampling to use as animal feed.
- High price of combine harvester for each quintal of grain yield
- Grain cleaning, drying and storage

Cleaning and drying: Traditional seed cleaning method is winnowing, i.e wind blowing to remove chaffs from the grain. During threshing, many unwanted trashes such as foreign seeds, chaff, stalk, empty grains, stones, soil, sand, etc are mixed with grain and can adversely affect the subsequent storage and processing of pure grain yields. Traditionally, grain is dried by spreading the grains on the ground and exposing to sun light. This method of sun drying of grain is the most common method in the studied districts.

Storage: Most farmers in the districts store their grains in a traditional storage called '*gotera'*- a local storage made from bamboo plastered with mud and teff straw and sacks. Some farmers who produce in larger amount relative to others have crop storage ware house separately. Storage pests such as rat and weevil are important in the studied district.

Major crop production constraints

Increasing crop production in the studied districts is the result of expansion of arable land and increasing productivity per unit area. There are various constraints that contribute for low crop productivity and production. Farmers listed series of constraints that affects the production and productivity of crops in their areas as follow.

Weeds: In the studied districts, there are many grass weed species *(Avena fatua, Bromus pectinatus, Phalaris paradoxa, Setaria pumila,* and *Snowdenia polystachya*) and broad leaf weeds *(Guizotia scabra, Polygonum convolvulus, Gallium sprum* and *Chenopodium spp.)* identified that are economically important in crop production. Among these, *Avena fatua, Bromus pectinatus* and *Phalaris paradoxa* are the most problematic weed species that causing significant crop yield losses in most crops.

Diseases: Survey results showed that the most important crop diseases are yellow, stem, and leaf rusts, septoria on wheat; net blotch, scald and leaf rust on barley; tomato wilt; Irish potato virus; wilt on bananas; powdery mildew, downy mildew and aschochyta blight on field peas; rust on lentils; chocolate spot, rust and aschochyta blight on faba beans are economically important diseases.

Insect pests: Results of the survey revealed that, the most important insect pests are cut worms, locust, army worm, American Fall army worme appeared in March, 2017, epilachna, caterpillars on barley, wheat and vegetables. Crops such as faba beans, field peas, and lentils are also affected by green pea aphid (*Acrytosiphon pisum*) and African bollworm (*Hellicoverpa armigera*). Barley shoot fly is a widely distributed seedling insect pest of barley in the studied districts. Other insects are stalk borer on maize, lady bird beetle on barley.

Storage pests: Rat and weevil are important storage pests in wheat, barley, maize, field peas, chick peas, faba bean and other crops.

Low soil fertility: Fertility problems in the studied districts are aggravated by farmers' continuous cultivation and mono cropping practices. There is almost no crop rotation of cereals with oil crops or pulses and fallowing for maintenance of soil fertility.

Water logged soils: These soils are found in flat plain lands that can hold water with limited or no infiltration and is important problem on Vertisol in Agarfra, Adaba, and Ginnir districts. During main rainy seasons vertisols, require draining of excess water by suitable drainage methods (BBM or Cambered bed) for normal crop seedling and vegetative growths for improved crop productivity and production. Moreover, these soils are potential for off-season production where irrigation facilities are available. In other extreme, climate change that causes recurrent drought, heat stress frost and others are also challenging crop production in the studied districts.

Shortage of inputs: inputs such as improved seed, chemicals (fertilizers and pesticides) are usually distributed to farmers through cooperatives. However, they are not available in adequate types, amounts, quality and timely at affordable price as the need of the farmers in the studied districts. Seasonal labor shortage: In most highlands of the studied districts, majority of the crops are planted often in June/July and harvested at similar time in November/December. This results in shortage of labor during the peak time of weeding, harvesting, and post harvest processing and other farm activities.

Low prices: Low prices of crop products have two negative effects on crop productivity and production. First, they reduce farm income, reducing farmers' ability to invest in their farms. Second, they discourage the use of improved inputs such as fertilizer and improved seeds. During the survey period, prices of some inputs such as improved seed were expensive to buy by the farmers. Example, during the survey period, improved wheat seed is sold at 1500 birr/100kg whereas the grain price of wheat is 650 birr/100kg.

Ranking of constraints: Farmers were requested to make a ranking for the identified constraints which are priority constraints in crop production. The priority constrains in crop production for Agarfa district were weeds, diseases, insect pests, knowledge gaps and shortage of inputs; Adaba district, weeds and disease, insect pests, shortage of inputs and knowledge gaps; and Ginnir district, insect pests, weeds, diseases, knowledge gaps and shortage of inputs. In generally, the most important crop production constraints identified were similar in all the three districts except their slight difference in ranking orders (Table 17).

Table.17. Crop production constraints identified and ranked according to their importance in three studied districts, 2016.

		Studied districts					
		Agarfa		Adaba		Ginnir	
S.N	Major Constraints	Score@	Rank	Score@	Rank	Score@	Rank
1.	Weeds	8.66	1	8.33	1	8.00	2
2.	Insect pests	7.33	3	7.33	2	8.66	1
3.	Disease	7.66	2	8.33	1	7.33	3
4.	Knowledge gaps	6.33	4	5.33	4	5.66	4
5.	Shortage of inputs	5.00	5	5.66	3	5.33	5
6.	Low product prices	2.33	8	3.33	6	2.33	8
7.	High input costs	4.00	6	3.66	5	3.66	6
8.	Water logging	2.66	7	2.00	7	2.66	7
9.	Low soil fertility	0.33	10	0.66	8	1.00	9
10.	Storage pests	0.66	9	0.33	9	0.33	10

Average matrix score for each identified constraints of three kebeles for each district

Summary and recommendations

Crop production is primary source of life in the three districts. Its productivity and production is low and is mainly constrained by diverse abiotic (drought, water logging, low soil fertility, soil erosion, frost and others) and biotic factors (diseases, insects, and weeds). Lack or limited access to improved seeds, agricultural chemicals, and poor crop management practices, poor marketing system (lack of market information, market linkages), low institutional support (knowledge gaps) and lack of value chain development approach to ensure participation and benefit to farmers are also the major constraints to crop production in the studied districts. Based on the results of this study, the following recommendations were given:

- Improve the technical knowledge and skills of farmers and development agents (provide training on improved crop production, husbandry practices and use of quality inputs for effective extension service to increase crop productivity and production).
- Develop efficient input supply system and provide practical technical guidance for improved crop management
- Soil test based fertilizer recommendation for specific crops and soil types.
- Awareness creation for farmers on pest assessment, integrated pest management techniques and safety precaution on the use of agricultural chemicals. Access to credit facility
- Develop farmers' knowledge on cluster based crop commercialization has a paramount importance to improve crop productivity and production.

Livestock production

In the studied districts, crop-livestock mixed farming system is practiced. Owning of livestock is important to influence the adoption of improved livestock technologies that enhance productivity and production of livestock commodities. Livestock production is a means for farmers to minimize risks associated with crop failure. Livestock are also served as the main cash source for financing needs of farmers. The main livestock types owned in all studied districts are cattle, sheep, goat, poultry, equines (horse mules and donkey) camel, and honey bees, fishing is practiced only in Adaba district. The total livestock population in each district is presented in Tables 18, 19 and 20.

Table 18. Livestock types and population of Agarfa District

No.	Type	Number			Breeding method	
		Exotic breed	Cross breed	Local Breed	AI	Natural
1	Cattle	0	27	131348	rare	Common
2	Sheep	0	0	63485	-	Common
3	Goat	0	0	30897	-	Common
4	Donkey	0	0	16984	-	Common
5	Horse	0	0	11810	-	Common
6	Mule	0	0	4983	-	Common
7	Camel	0	0	0	-	Common
8	Poultry	8874	0	32381	-	Common

Source: Agarfa District Livestock and Fishery development Office, 2015/16

Table 19. Livestock types and population in Adaba District

No.	Type	Number			Breeding method	
		Exotic breed	Crossbreed	Local Breed	AI	Natural
1	Cattle	0	1693	242376	Rare	Common
2	Sheep	0	0	113062	-	Common
3	Goat	0	0	38787	-	Common
4	Donkey	0	0	18953	-	Common
5	Horse	0	0	30585	-	Common
6	Mule	0	0	1620	-	Common
7	Camel	0	0	0	-	Common
8	Poultry	2437	0	58723	-	Common

Source: Adaba District Livestock and Fishery Development Office, 2015/16

Table 20. Livestock types and population of Ginnir District

No.	Type	Number			Breeding method	
		Exotic breed	Crossbreed	Local Breed	AI	Natural
1	Cattle	0	2971	203513		Common
2	Sheep	0	0	43450		Common
3	Goat	0	0	50000		Common
4	Donkey	0	0	23524		Common
5	Horse	0	0	15089		Common
6	Mule	0	0	8006		
7	Camel	0	0	76000		Common
8	Poultry	2437	0	50060		Common

Source: Ginnir District Livestock and Fishery development Office, 2015/16

Production system

Livestock production in the studied districts is almost all depending on local animals. Semi-intensive management is used in areas surrounding district towns where few cross breed cattle are available, while improved poultry breeds are very few and free scavenging poultry production system is common practice. Small ruminant production is using local animals and free grazing. The high land browsing, free range grazing in the lowland areas and some communal grazing land in high land areas are the major livestock feeding practices in the studied districts.

Livestock Productivity

Cattle

Most of the cattle breeds used in the studied districts are local breed (Arsi-Bale) with pre-weaning length up to eight months, post-weaning 3-4 years and average age at first heat is four years. The pregnancy length is 9-10 months; average calving interval is more than 17 months. The average milk yield is about 1.5 L/day/cow which is below the current national average 1.9L and much below 6 L/cow/day expected by the end of GTP-II, 2020. Few cross breed cattle (Holstein Friesian) are owned by farmers surrounding district town. Farmers in some villages of the studied districts donot have improved cross breed cattle and rather prefer Boran breed to local in the lowland parts of the districts mostly in the low land areas of Ginnir district. Farmers in villages surrounding Adaba and Agarfa towns have few cross breed dairy cow with the productivity parameters such as pre-weaning 5-8 months, post-weaning 2-3 years, average age at first heat 3 years and pregnancy length 9-10 months. These farmers also mentioned that the calving interval ranges from 14-20 months, while milk yield is 6-12 L/day/cow.

Sheep

Farmers in the studied districts are rearing only indigenous Arsi-Bale sheep. Some lowland parts of Bale which is bordered with Somalia Region, Somale white black head sheep type (locally *wanke*) is common in some kebeles of Ginnir District. In relation to productivity parameters of sheep, pre-weaning is 4-5 months, post-weaning 3-4 months and age at first heat ranges from 7-9 months. Pregnancy length is more than 6 months and average lambing interval ranges from 6-10 months with less prevalence of twinning. The major constraints in sheep production in the high land areas of Adaba, and Agarfa include shortage of grazing land, lack of improved breed and husbandry practices. Sheep is risk aversion commodity during crop failure and considered as poor person ‘live bank’ in the studied districts.

Goats

In the studied districts, almost goat production is based on local breeds (Arsi-Bale goats). Some lowland parts of Bale which is bordered with Somalia Region, Ogaden white color goat type is common in some kebeles of Ginnir District. The productivity parameters of goats such as length of pre-weaning age ranges from 3-4 months, post-weaning from 3-9 months, age to first heat ranges from 7-10 months with pregnancy length more than 6 months and kidding interval ranges from 6-8 months with low possibility of twinning. The importance of the goat milk for human consumption is not common in the studied districts however farmers are aware of the importance of goat milk for infant feeding.The major constraints in goat production include shortage of grazing land, lack of improved breed and husbandry practices. Goat is also considered as poor person’s ‘live bank’. In Adaba and Agarfa districts goats mostly browse on steepy forest area, whereas in some kebeles of Ginnir District particularly in low land areas, free grazing of thorny bush is common. In high land areas of Adaba and Agarfa where Arsi-Bale breed is used, the milk yield is 0.5L/day/goat, whereas in low land areas of Ginnir District goats give 1 L/day/goat.

Poultry

In the studied districts, scavenging poultry production is commonly practiced. Even though the numbers of exotic poultry breeds are not significant, both local and exotic poultry are used by the farmers in these three districts. Some cross breeds with unknown exotic types whose blood level are unknown is produced and used by the farmers which actually are better than the unimproved breeds. Hatching length of both local chicken breed and cross breed is 21 days and the pullet gives eggs in the age of 6-8 months most of them are giving eggs during dry season when plenty feed is available and disease incidence is minimal. Farmers have estimated that less than 40egg/year/hen is produced. Cross breed chicken takes 21 days and pullet give eggs in 6-8 months. Farmers have estimated that under their management condition, these commercial chickens produce less that 240 eggs/year/hen. Management of chicken by the farmer varies depending on the breed types not the same for exotic and local breed since the exotic breed productivity is better than the local, farmers favor management for exotics. Disease incidence is high on all types of chicken breeds and in exotic mortality ranges up to 100%.

Equine

Most of the equine (horse and donkey) available in the studied district are of local breed. Horse is most commonly used for plaughing as compared to donkey in the West Arsi and Bale, whereas donkey is used for transportation and some time for ploughing in high land and lowland districts. Mule is rarely found in lowland of Bale.

Apiculture

Some districts in Bale and West Arsi zones are endowed with natural forest resources which is suitable for organic honey production. However, the production of honey in these ecologies is low due to limited number of colony available in the area and also low productivity of the colony per hive. Farmers produce honey in this area traditionally (they hang up hive in high trees up to 20m, or often collect honey produced in natural cave and in old tree holes). Traditional, transitional and modern types of hive are used by the farmers; however, traditional hive is the most dominant types. According to the data collected from district agricultural office, the average productivity of traditional hive ranges from 7-11kg/hive/year with harvesting frequency ranging from 0-3 times per year. Even though few farmers are using modern hive, lack of accessories and knowledge gap on how to use these modern hives were identified as the major constraints in honey production. During favorable weather conditions, it is possible to harvest honey 1-4 times per year with an average yield of 20kg/year/hive Table 21.

Table 21. Hive types, number of hives, productivity per hive and price of honey in Agarfa Adaba, and Ginnir districts, 2016

District	Type	Number of hives available	Average productivity per hive (kg)	Price/kg
Agarfa	Traditional	16246	11	120
	Intermediate/transitional	2568	25	120
	Modern/Frame hive	1473	14	120
Adaba	Traditional	3552	7	85
	Intermediate/transitional	1648	15	100
	Modern/Frame hive	348	20	120
Ginnir	Traditional	78771	8	80
	Intermediate/transitional	3918	14.95	100
	Modern/Frame hive	2194	23	130

Source: Agarfa, Adaba, and Ginnir districts Livestock and Fishery Development Office, 2015/16

Fishery

Fish production and consumption was not common in the study area except in few kebeles around Wakena Hydroelectric power dam in Adaba district. Farmers in this area mentioned that fish consumption culture did not exist.

Livestock management

Feed sources and feeding system

Crop residues, natural pasture, cultivated fodder crops and stubble grazing are the major livestock feed resources used in studied district. Since the majority of the cultivated land is devoted for crop production, farmers estimated that the major share of livestock feed is obtained from crop residues which contribute approximately 40% of dry matter of the total diet. The animal feed sources used in the area vary from season to season and little bit variation is also observed between small scale dairy producers in the urban area and small holder dairy producers in the rural areas. Majority of the urban dairy producers in the districts were using straw and agro-industrial by-products all year round while, dairy production in the rural area is commonly supported by straw, hay and crop aftermath during dry season. Grazing land (communal, marginal land and "kalo"), green fodder and crop weed is the most important feed source during wet season.

Dry season feeding and management: Communal grazing land is not common except in the high land forest areas of Adaba and lowland bushy areas of Ginnir districts. During dry season, majority of the livestock in Bale and West Arsi zones are feeding on stubble. Farmers don't know about the species composition of their grazing lands and modern pasture land has not yet established in the districts. The utilization of fodder oat as animal feed is practicing in some districts; however, there is a serious shortage in seed supply of improved oat varieties. Besides, practice of mixed cereal-legume forage crop feeding is not common and this practice should be promoted. Use of improved browse trees and shrubs is not common in the districts and this is identified as a knowledge gap which should be filled through training. Straw of cereal and legume crops is the major basal diet used with few supplements of grain and similarly supplements of agricultural byproduct is common practice in rural areas of the districts. In rural areas, barley grain supplementation for horse, oxen and dairy cattle is common when barely production is adequate. In urban areas, industrial byproduct supplement is used for dairy cattle. Free grazing of livestock during dry season (after harvesting) is common practice. Most farmers use river water and in few areas water from ponds and potable water are used for livestock water consumption.

Wet season feeding and management: The basal feed used during wet season in the studied districts included green feed from area closer or '*Kalo'*, and weeds removed from crop fields. Some farmers use cereal straw in addition to green feed. Grain supplementation is not common during wet season in rural area whereas in urban area, supplementation of agro-industrial byproducts is practiced throughout the year for dairy cattle. In some kebeles where maize is produced, farmers practicing cut and carry system of feeding. During wet season river and harvested water are used for livestock water consumption.

Animal health management

Diseases and parasites: The major cattle diseases that constrained livestock productivity and production in the studied districts are bloating, Foot and mouth disease (FMD), Bovine Papillomavarus Disease (BPL), anthrax, frequent coughing, blackleg, mastitis and diarrhea. Farmers manage some of these diseases traditionally by using locally available materials. Farmers are also taking sick animals to animal health clinic to get treatments from animal health experts. Vaccination campaigns are carried out by public veterinary service providers for some diseases such as anthrax, blackleg, pleuro-pneumonia and small ruminant pasteurellosis in the studied districts. '*Martoo'* (circling), '*qufaa'* (cough), pasteurolloisis, and FMD are the major small ruminant diseases that negatively affect their productivity and production. '*Fangil'* Newcastle Disease (NCD) is a common disease of poultry in all the three districts.

Farmers mentioned that there is a case when, strange death of worker bees occur in some kebeles due to unknown reason. The major external parasites that affect cattle and small ruminants are tick, mites and lice. Mite also affects poultry and bees. Farmers use different traditional management methods using locally available materials. Besides, farmers take sick animals to either public or private animal health clinic to get medicine for these parasites Table 22.

Table 22. Disease and external parasites identified in studied districts and their management options, 2016

Livestock type	Major disease	Traditional management option	Modern treatment	Major external parasite	Traditional management option	Modern treatment
Cattle	Bloting	Coca cola, piercing space b/n ribs, greasing the nose	Yet, no treatment	Mite, lice, tick, mangi	No treatment	Acaricide like diazenon
	FMD	No treatment	Different antibiotics			
	BPL	No treatment	Different antibiotics			
	Coughing	No treatment	Different antibiotics			
	PPR (diarrhea)	Hampee and alfata medicine	Different antibiotics	Internal	Hampee and alfata medicine	
	Mastitis	Smoking nest of birds	Different antibiotics		yet, no treatment	
	LSD	yet, no treatment	Different antibiotics	no	yet, no treatment	
	Pasteurelloisis	yet, no treatment	Different antibiotics	no	yet, no treatment	
Horse	African horse sickness	yet, no treatment	Different antibiotics	no	yet, no treatment	
Poultry	*Fangil* (NCD)	yet, no treatment	Different antibiotics	mite	yet, no treatment	
Sheep	Circling (maraamartoo)	yet, no treatment	Different antibiotics	Mite, lice ticks	yet, no treatment	
Goat	Circling (maraamartoo)	yet, no treatment	Different antibiotics		yet, no treatment	
Bee	Strange worker bee death	yet, no treatment	yet, no treatment	mite	yet, no treatment	Yet, no treatment

Source: Adaba, Agarfa and Ginnir District Livestock and Fishery development office, 2015/16

Shelter management: Housing is not common for cattle in the rural area of the studied districts; however, in some kebeles pre-urban and urban areas, farmers were using whole season livestock shelter made up of local materials. Barn is mostly used in rural areas for heifers and bulls, where as calves, pregnant and lactating cows were kept in temporary house. Throughout the year majority of small ruminants and poultry are kept in separate house made up of mud and in some cases they are kept in family house during the night. Donkeys are mostly kept outside whereas temporary house and veranda is usually used for horses.

Breed management: Some farmers were exercising controlled breeding (controlled mating and AI) to get cross breed dairy cattle; however, for other livestock types, there no controlled breeding system. Farmers were not herding their cattle and closely managing the opportunity of selective mating/breeding due to lack of improved bull. In both wet and dry seasons, farmers have raised the issue of poor efficiency of regular AI and mass synchronization services provided by the development agents.

Product processing: Livestock product processing activities such as yoghurt, cheese, butter and honey are mainly carried out traditionally. Smoking and drying methods are common to preserve meat. Processing of honey to increase the quality is not commonly practiced by the farmers, but they mix honey with all hive products except brood to increase the volume of honey. Some attempts such as sieving and filtering were practiced by few farmers to produce quality honey for market. Transition of bee keeping activity from traditional to modern hive and honey extraction from modern hive is hindered by high cost of casting mold (wax frame printer) and honey extractor.

Livestock production constraints

Breed: According to the Ethiopia livestock Master Plan Roadmaps for Growth and Transformation, (2015), Bale and West Arsi zones are part of mixed crop-livestock production system in sufficient rainfall highland typology zone, where crop production as well as forage production potential is high. Expansion of agro-processing such as oil and flour factories in the area increased the availability of animal feeds. Livestock productivity is highly influenced by a complex interaction of the genetic of breed types, production system and environments. The progress of livestock productivity and production for both large and small ruminants is mainly hindered by access to improved breed and knowledge gap on breed management. Interviewed farmers pointed out that, adaptability and institutional issues were also some of the constraints which negatively affect the productivity and production of livestock. Furthermore, poultry productivity and production was mainly influenced by access to improved breed, adaptability and lack of knowledge on poultry husbandry.

Feed sources: The survey results revealed that feed shortages occurred due to factors such as conversion of grazing land to cropland, overgrazing, high price and lack of feed concentrates, scarcity of feed during the dry season, and generally low quality of available pasture and crop residues. Low feed quality, knowledge gap on ratio formulation, feed price and institutional issues were constraints mentioned by farmers. Agro-industrial byproducts from flour and edible oils and grind mills supply bran and oil cakes to market. However farmers pointed out that the prices of these agro-industrial byproducts were increased from time to time and they were unable to purchase these byproducts. Besides, farmers mentioned that bloating was a serious problem in dairy cattle which was mainly related to the poor feed and feeding system.

Forages seed multiplication and extension: Different improved forage varieties have been released, however, these varieties were not multiplied and promoted due to less attention given by concerned bodies including extension services; farmers in all three districts were complaining shortage of improved forage varieties. Lack of full package for released and adapted varieties such as processing and storage technologies have also hindered farmers to easily adopt. Farmers in the area have critically mentioned the shortage of forage chopper and feed processing organization problem in the area.

Inadequate veterinary services: Livestock diseases and parasitic infections are the major bottlenecks to livestock productivity and production. These constraints are more serious during the on-set of rainfall and feed shortage. Veterinary service delivery is inadequate in the studied districts mainly due to shortage of veterinary medicines, health technicians, price of drugs, and vet drugs supply. Only one health technician was assigned to provide services for three kebeles. Thus, the service delivery was not as per the demand of the farmers. During focus group discussion, farmers pointed out that they had knowledge gap on livestock disease identification and management options. In West Arsi and Bale highlands the mortality rate of poultry was as high as 100% during wet season under high disease epidemics.

Shortage of technologies: Farmers use traditional containers to process milk into yoghurt, cheese and butter. There were no modern technologies for processing milk. Feed management for poultry as well as dairy cattle and lack of hatchery for poultry production were the main constraints identified. There were lack of transportation facilities for transporting animal products such as milk and eggs to the market and hence; farmers used traditional materials for transporting milk and eggs to the market.

Lack of product quality control: There was no mechanism for milk quality control from production to consumption. Adulteration of milk was common and raw milk was commonly sold on the road side which exposed the milk to direct sun light. Moreover, the hygiene of the milk is questionable. Retailers collect milk from farmers using different plastic bottles and supply poor quality milk to the market.

Lack of marketing information: It is a common problem for farmers who produce small ruminants. Farmers get price information from neighboring farmers who have sold small ruminants in the nearby market. Besides, some farmers visit the nearby markets to see how these commodities are marketing to make decision on selling his/her sheep or goat.

Low bargaining power: The survey results revealed that prices were usually determined based on negotiations between seller and buyer at the market place. There was no well established pricing method for selling and buying livestock. Farmers face low price to sell their livestock usually at threshing and harvesting time, because most farmers sell their animals during these periods to pay for farming activities.

Access to market: Poor transportation services in the studied district: Roads are a very important infrastructure in the livestock marketing system. The type of road connecting an area determines the type of buyers that can get access to market. It also affects the profitability of most farmers in the livestock marketing. Most rural areas of the studied districts have poor road which is mostly seasonal. Farmers in most kebeles in the districts complain poor access to all weather roads which affect them to sell their agricultural products.

Weak linkages: Vertical linkages at different levels of the value chain support the upgrading capacity of the chain. Rapid response to changing market conditions requires communication and cooperation up and down the chain. Livestock producers in the study areas sell their animals to different market actors. There was no vertical relationship between producers and buyers participating in livestock and its marketing. Additionally livestock producers in the studied areas did not have any marketing groups or cooperatives to increase their bargaining power in selling animals, animal products and procuring inputs.

Limited access to credit: The survey results revealed that, almost all farmers had limited access to credit. Thus, they have to sell their animals (especially small ruminants) in order to meet their immediate cash demands. Even though some credit institutions were operating in the areas, they were based on group collateral and their terms and conditions were not clear. As a result, only few farmers were using these services, but most farmers abstained themselves from these micro finance institutions because they didn't want to pay for the defaulters in their group.

Ranking of constraints

Farmers were requested to make a ranking for the identified constraints which are priority constraints in livestock productivity and production. The priority constrains in livestock productivity and production for Agarfa district were feeds, breeds, diseases, water shortage and market; Adaba district, feeds, breeds, diseases and market; and Ginnir district, feeds, water shortage, breeds, diseases and market in order of importance. In generally, the most important livestock production constraints identified were similar in all the three districts apart from their slight difference in ranking orders except in Ginnir district where water shortage is ranked as the second important constraint next to feed (Table 23).

Table. 23. Livestock production constraints identified and ranked according to their importance in three studied districts, 2016.

S.N	Major constraint	Studied districts					
		Agarfa		Adaba		Ginnir	
		Score@	Rank	Score@	Rank	Score@	Rank
1.	Breed	2.67	2	2.33	2	2.00	3
2.	Feeds	3.33	1	2.67	1	3.67	1
3.	Disease	2.00	3	1.00	3	1.33	4
4.	Market	0.33	5	0.00	4	0.00	5
5.	Water shortage	1.67	4	-	-	3.00	2

@=Average matrix score for each identified constraints of three kebeles for each district

Summary and recommendation

Livestock production system in the studied districts is predominantly carried out traditionally and its productivity is low. Feed type and water source for livestock were influenced by seasons. Animals mostly depend on grazing land and weeds removed from crop fields during wet season and while straw in dry season. Water source for animal consumption during wet season is mainly from rivers and harvested water, whereas during dry season water sources are from perennial rivers, harvested water and potable water. Feeding system differs for urban and rural areas. Urban dairy producers use agro-industrial byproducts while rural areas utilize grazingland and agricultural by products. Breed improvement is has less attention except limited efforts in pre-urban and urban on dairy cattle. The average milk productivity 1.5L/day/cow is below current national average 1.9L/day/cow and very far from national target 6L/day/cow by the end of 2020. Honey production is another important source of income using three different hives. The modern hive importance was complained by the farmers due to bee refusal, poor technology adoption and lack of accessory materials required. Though farmers were not developed fish consumption culture Adaba district has some activity of Fish production in kebeles around Malkawakan hydroelectric dam.

- Feed constraint is the first ranked bottle neck to livestock production in the studied areas followed by poor breed and diseases. Lack of access to improved breed especially dairy cattle was raised as the second serious problem in the districts. The third constraint raised was Disease followed by water shortage and Market respectively. Livestock sector play an important roles on crop production, family nutrition, cultural and social asset. In addition, the contribution of the sector to national economic growth is vital. Based on the results of this study, the following recommendations were given:

- Strong research and extension service programs should be in place to alleviate the identified live stock production constraints (breed improvements, feed production, disease management, veterinary services, knowledge gaps and others)

- Emphasis should be give to AI services, market linkage in value chain, water supply, credit facility, product processing, handling, transportation services, product storage, quality control and others

- Supply of animal product and feeds processing plants

- Strengthening incorporation of forage crops and straw treatment technologies, harmonizing natural resource activities with forage production and supporting this with mechanization in crop dominated areas

- Improve the technical and skills of farmers/pastoralists and development agents (provide training on improved livestock production, husbandry practices and use of quality inputs for effective extension service to increase livestock productivity and production).

Natural Resources and management

Natural resources are the raw materials existing on earth. They include land, water, biodiversity, climate and topography which plays significant role in the success of agriculture, i.e the foundation of the economy. As a result of population pressure, climate change and poor management, natural resources have been threatened by chronic degradation and recurrent droughts.

Soil erosion is one of the major agricultural problems in the highlands. Deforestation, overgrazing, and cultivation of sloppy areas together with the farming practices that do not include conservation measures are the major causes for soil erosion. Degraded soils are the major constraints to agricultural production. Inappropriate soil management causes declining soil fertility.

Water is one of the most important factors that determine the life. It is one of major limiting factor in crop production and plants require water for photosynthesis, growth, and reproduction (Henry *et al.*, 2007). Major factors that influence water availability are rainfall, temperature, evaporation rates, soil quality, vegetation type, as well as water runoff (David *et al.*, 2004). Appropriate and sustainable water resource management is vital for agricultural production. It is essential to maximize both yield and quality of products.

Forests are one of the most important resources to regulate ecosystem balance. They are an integral part of agricultural landscapes and are playing increasingly important roles in degraded area rehabilitation and income provision for rural households. Forests provide food, fodder, pulp, tools, medicinal extracts, used as shade and provide clean air (Hannah, 1999).

Land degradation, a decline in land quality caused by human activities, has been a major global issue during the 20th century and has remained high on the international agenda in the 21st century (FAO, 1996; Imoke *et al*., 2010). It signifies the temporary or permanent loss of ecosystem functions and decline in the land productive capacity (Abdi *et al*., 2013). The human induced problem is the main causes of land degradation among others include improper land use, poor agricultural practices, deforestation and overgrazing (Majule, 2003; Vu *et al*., 2014).

Deforestation and desertification adversely affect agricultural productivity, the health of humans as well as of livestock, and economic activities such as ecotourism. Forest cover helps to overcome land degradation and desertification by stabilizing soils, reducing water and wind erosion and maintaining nutrient cycling in soils. Ethiopia is seriously affected by soil erosion for the centuries. According to Binyam and Desale (2014) the soil erosion rate of Ethiopian highlands is about 10Mg ha^{-1}. This serious soil erosion affects the soil fertility potential. Soil fertility decline is a major constraint to agricultural productivity and production.

Common property resources and management

The available common property resources in studied districts were forest, soil, river water, irrigation water and communal grazing land. These resources are public and owned by community living around the area.

Agarfa district

Water sources

Available water sources in Agarfa districts are river/surface water (Wabe River) and ground water. Shortage of rainfall is repeatedly occurring in the district. In addition to this the amount and distribution of rainfall is decreasing from season to season and crops cultivated in the past season have failed due to drought.

Irrigation

Farmers use only traditional irrigation type by water extracted from Wabe River. The irrigation water was collected from the river using motor pump and distributed through water channel to farmers' fields. Farmers using this irrigation water have cultivated different vegetables and may produce three times per year. However, there is problem in irrigation water distribution and usage. There was training gaps in irrigation agriculture and most farmers depend on traditional knowledge. When comparing the potential of water source, farmers demand and actual irrigated areas, there is imbalance for irrigation use (high demand, but low supply). The total area under irrigation was very small and also there was no adequate irrigation access in the area. This may be due to knowledge gaps and short of irrigation technologies. There was also no water harvesting techniques for supplementary irrigation. In general, expansion of irrigation agriculture is the best option to adapt to climate change impacts that facing current agricultural production in the district.

Soil types

There are three dominant soil types in the district, black Vertisol, Oxisol and Cambisol. In black Vertisol water logging is a serious problem in flat plains. However, even though there was improved technology for this problem, farmers were not using broad bed maker (BBM) to drain excess water from their fields. Soil erosion problem was observed in the district, but farmers construct only water ways to reduce the rate of erosion. In addition to this, there was soil salinity problem. It was observed in water logged areas and its effects were observed on the crops grown. The soil fertility statues of these soil types are different, black Vertisol has high water holding capacity and more fertile; Eutric Vertisol has good water holding capacity and moderately fertile; and Cambisol has poor water holding capacity and less fertile.

Tillage

Crop production requires good seedbed preparation for favorable crop growth and development that results in increasing crop productivity and production. To loosen soil for crop production, tillage practice is one of the methods used for seedbed preparation. Loosening of soil helps to increase plant rooting system and improve aeration in the soils for competitive growth of root systems. In this district tillage frequency depends on soil types, and is about 3 - 6 times. For black Vertisol (5-6 times); Eutric Vertisol (4-5 times); and Cambisol (3-4 times).

Fertilizers use

Organic fertilizer is not common in the district, but some farmers apply animal manure for crop production around homestead. There is good awareness on compost preparation, but only some farmers prepare compost and the majority of the farmers are depend on chemical fertilizers. There was no practice of mulching or maintenance of crop residues on farm lands. Common inorganic fertilizers used by farmers were urea, DAP and currently NPS, and some farmers apply biofertilzers and others. Due to high price of inorganic fertilizers, farmers do not apply recommended fertilizer rate for crop production i.e blanket application. In general, fertilizer application requires soil test and crop response based recommendation for increasing productivity of the targeted crops.

Soil erosion

In the studied district, soil erosion was observed in sloppy areas and based on its degree of severity all types of erosion (sheet, rill and gully) were observed. There was severe soil erosion up to gully formation in the sloppy area; sheet and rill erosion were common in all areas. The major causes of soil erosion are deforestation, population pressure, intensive agriculture, agricultural and urban land expansion. Physical conservation methods constructed in the degraded areas are bund and cut off drains. Bund construction has started only in communal degraded lands, but not expanded to farmers' fields. However, for bunds constructed in communal lands there is no continuity and periodical maintenance, and most of the constructed bunds were damaged. Therefore, attention of community and government for soil conservation and rehabilitation of degraded lands is very essential for sustainable crop production on sustainable natural resource basis.

Forest

Total land area of the district is covered by different land use systems. The dominant land uses are farmland, communal grazing lands and area closure of natural forest. The community is benefited from the closed areas through cut and carries system. There was severely affected remnant natural forest in this district, but this natural forest is extremely affected by deforestation and the coverage of the area becomes shrinking from time to time. Due to this problem, the community who are living in the lower stream was affected by flood during rainy season. This flood becomes severe due to uncontrolled deforestation of the natural forest from the mountainous area.

Adaba District

Water sources

Available water sources in the district were surface water and harvested water. During this survey, farmers mentioned variability in rainfall pattern and distribution that threatening their agricultural production. They also mentioned that the amount and distribution of rainfall was decreasing from season to season.

Irrigation water

Irrigation agriculture is best alternative option for increasing agricultural production to meet the growing demands for food of alarmingly booming population. Commonly, small-scale irrigation is playing an important role in adapting to climate change, achieving food security, and improving household incomes. It increases crop yields, improves crop diversification, and reduces the risk of crop failure (Tilahun 2014).

In the district, both traditional and modern irrigation practices were used by farmers where irrigation water was accessible; and traditional irrigation method was dominant compared to modern irrigation method. Modern irrigation schemes have been constructed by government and farmers who have access to these schemes produce horticultural crops (onion, tomato, cabbage, etc) and increase production under irrigation. In addition some farmers use motor pump for irrigation water supply to produce cash crops. However, many farmers share single irrigation canal for irrigation water source; consequently, there was high competition for irrigation water between upstream and downstream users as well as between farmers with large irrigable fields and small fields. Hence, there was severe shortage of water to produce crops under irrigation.

Farmers mentioned that, there is irrigation water user association (WUA) rules and regulations that direct irrigation water utilization. However, implementation of these regulations has not been effective and no standardized programs and plans to irrigate each cultivated crops, i. e irrigation water use bylaws are not used yet. This showed that water distribution and water use principles were not effectively regulated in the district and requires special attention in the future for equitable access to irrigation water. Comparing the capacity of irrigation water access and irrigated area expansion, irrigation demand is beyond tolerable condition under current climate change impacts. There was market problem for irrigation agriculture. This is one of the major constraints that highly affecting post harvest products (quality and quantity). Irrigation agriculture requires storage facilities and market linkage.

Soil types

There are three major soil types in district, black Vertisol, Oxisol and Cambisol. Of these soil types, black Vertisol has problem of water-logging. To drain excess water in the black Vertisols, broad bed maker (BBM) is used. However BBM and other improved technologies to solve this problem were not promoted in the district. In the study district, soil salinity problem was observed in Cambisol both in rain-fed and irrigated areas. Soil fertility status and water holding capacity varies with soil types. Black Vertisol has high water holding capacity and more fertile; Oxisol has good water holding capacity and moderately fertile; and Cambisol has poor water holding capacity and less fertile.

Soil management

The appropriate use of soil resources and plant nutrients from inorganic and organic sources offers a viable path to achieving high crop production while safeguarding natural resources. During this survey, farmers mentioned different soil management practices used in their localities. These included tillage, fertilizer application and soil/water conservation measures.

Tillage

Farmers in district used tillage to improve soil structure by changing its physical properties such as soil moisture content, soil bulk density and soil penetration resistance. Tillage frequencies varied depending on soil types which ranged from 3-6 times. i.e Black Vertisol (5 - 6 times), Eutric Vertisol (4 - 5 times), and Cambisol (3 - 4 times).

Fertilizers application

Farmers mostly apply inorganic fertilizer as soil fertility management practice while the application of organic fertilizer is less common. Most farmers apply inorganic fertilizers urea, DAP NPS and others as sources of crop nutrients. However, due to high price and unavailability of fertilizers, there is a gap in the use of recommended fertilizer rates. Only some farmers prepare compost and apply on fields for soil fertility improvement. Application of bio-fertilizer for field pea has started in some areas in the district. There was no practice of mulching or maintaining crop residues on farmlands. In general, fertilizer application must be based on soil test and crop response recommendation to increase crop productivity and improving quality of products.

Soil erosion

The problem of soil erosion was observed both in the rain-fed and irrigation agriculture. The degree of erosion becomes severe from time to time, especially in sloppy lands. Inappropriate use of land has degraded forest, grazing and agricultural lands and the soil exposed to different erosion types. Based on its degree of severity, all the three types of erosion (sheet, rill and gully) have occurred in the studied district. This problem was very serious and there was severe soil erosion up to gully formation in the sloppy lands. To decrease the erosion rate and rehabilitate the degraded areas, integrated soil/water conservation measures are important. Field bund construction has started in communal degraded lands for conservation and rehabilitation, but no sustainable maintenance. Consequently, most of the constructed bunds were damaged. Community mobilization work of soil conservation requires technical guidance for appropriate design and constructing physical structure and monitoring for maintenance of damaged structures. Therefore, attention of both community and government for soil conservation and rehabilitation of degraded soils is very essential.

Forests

Adaba district land is covered by different land use systems, forest and cultivated lands. Both natural and plantation forests exist in the district, but due to expansion of agricultural land and urbanization, the coverage of natural forest is decreasing from time to time. Plantation forest is found in some areas. Management of natural forest is minimal and still the remnant natural forests are cut off illegally for logging.

There is regulation for controlling and managing both natural and plantation forests; the types of tree species at planted in the area at present are *Cupressus lustanica, Olia eropea and Junipurus procera.* Dominant tree species planted around the homestead is *Eucalyptus* species. Source of tree seedlings were agricultural office and private forest farms. There were no responsible institutions to produce and supply tree seedlings for the community, and high shortage of seedlings both in tree species types and quantity in the district. Therefore, the demand and supply of seedlings is not match, and responsibility for seedling raising and make available for community is very crucial. Commonly planted tree and shrub species around homestead were *Acaccia abyssinica*, *Cupressus lustanica, Olia eropea and Junipurus procera, Shinus mole, Eucalyptus* spp*., Gravila robusta*, *Pinus* spp*., Cordia africana, Milia azandracta, Tamarandus indica, and Ekebergia capensis.* There is training on forest management given by WAJIB and agricultural office of the district for community.

Planted trees management

Water shortage in the dry season is the major problem of planted seedlings management in Adaba District. Commonly, the seedlings planted around the homestead are relatively managed, but no management for seedlings planted in the communal lands. Management practices in the district for planted seedlings are watering, fencing, weeding and hoeing. Recently there have been different problems observed in matured plantation tree species. The problems inluded *Shinus mole* and *Acacia abyssinica* were affected by worms, drying of trees such as *Eucalyptus* spp., *Casusarina equstifolia* and *Junipurus procera* wood affected by insects. In general natural resources have affected by different constraints such as deforestation, soil erosion, soil fertility declining, climate change (temperature increases/drought, frost, heat stress) and others.

Ginnir District

Water sources

The availability of water sources for agricultural purpose is very limited in the district. There is one water source only river/surface water. Although there was extreme shortage of water, there was no water harvesting techniques applied. This was due to shortage of training and unavailability of plastic sheet for water harvesting in the ponds to avoid wastage of water into the ground. Overall in the district, the amount and distribution of rainfall is decreasing from time to time.

Irrigation

There are both traditional and modern irrigation accesses in the district. The dominant was traditional irrigation used by many farmers. Use of irrigation is laborious in the district and water is extracted manually, but only few farmers extract water using motor pumps. There was high shortage of irrigation water in the district. The major crops cultivated in irrigation were cereals, vegetables and chat. When comparing capacity of irrigation water supply and irrigated areas it was not completely matching. Availability of irrigation in the district was very low and the total area under irrigation was also very small. Since there has been no enough irrigation access, expansion of irrigation is very essential in the area which is commonly exposed to moisture shortage for agriculture.

Soil types

There are three soil types in the district, black Vertisol, Oxisol and Cambisol. Soil cracking was common in black Vertisol in dry season. The soil fertility status and water holding capacity of these soils are varied from each other. Black Vertisols have high water holding capacity and more fertile; Eutric Vertisols have good water holding capacity and moderately fertile, while Cambisols have poor water holding capacity and less fertile.

Soil management

The appropriate use of soil resources and plant nutrients from inorganic and organic sources offers a viable path to achieving high crop production on sustainable natural resource basis. During this survey, farmers mentioned different soil management practices used in their localities. These included tillage, fertilizer application and soil/water conservation measures.

Tillage

Based on soil types, tillage frequency of soil is different, from 3-4 times in the district.

Fertilizer application

Currently majority of the farmers use inorganic fertilizers urea, DAP, NPS and others. Few farmers apply animal manure around their homestead, but there was no mulching or maintaining of crop residues on farmlands. Overall fertilizer application trend of the area was that farmers applying below the recommended rate. This was due to high price, late supply and low moisture stress (drought) in the district.

Soil erosion

All types of erosion were observed in the district and most of the lands were affected by sheet and rill erosions. In the district, soil erosion becomes severe in all land uses. This problem is aggravated in sloppy areas. The major causes of soil erosion are high population growth, deforestation, overgrazing and rugged topography. Physical soil conservation measures used in the district were bund, cut off drains and water ways constructed. The trend of bund construction was good on degraded communal lands, but farmers were not constructing this structure on their own farmlands. For the bunds constructed on communal lands there were no continuity and sustainable maintenance. The effectiveness of the bunds was not more than one year and most of the constructed bunds were damaged, i.e., not supported by knowledge. Bunds have been constructed through community mobilization, but no follow up for maintaining. Hence, soil and water conservation practices should be guided by knowledge and suitable integrated conservation technologies adapted in the district.

Forest

The dominant land use of the district is agricultural land, but there is also promising size of natural forest land. There are no plantation forest and communal grazing lands, but limited tree species *Cupresus lustanica,Cordia africana, Eucalyptus* species, *Junipurus procera, Shinus mole, Tamrindus indica,* and *Milia azandarcta* are planted around their homestead. Seedlings are produced by agricultural office, but the major sources of seedlings are from other farmers and nearest town. There was no nursery established to supply seedlings for farmers, and high shortage of seedlings, i.e., no institution producing and supplying seedlings for farmers. Hence attention for nursery establishment and tree seedlings production for farmers is essential.

Management of natural forest is very low and still the remnant forest is destroyed by informal logging and agricultural land expansion. However, there is rule and regulation for controlling and managing natural forests, but the remnant natural forests are minimized from time to time. The other challenge in this district is clearing of natural forests and provision for investors for crop production is very common. These directions highly affect the remnant natural forest lands that result in forest resources degradation (biodiversity loss) causing vulnerability to climate change. Therefore, protection and conservation of remnant natural forests and planting adaptable multipurpose tree species must be priority focus in the district.

Management problems of planted tree species

Water shortage is the major problem related to managing planted seedlings in the district during dry season. Tree seedlings planted around homestead usually get relatively better management. Common management practices given for planted seedlings were watering, weeding, hoeing, weeding and manure application, but practiced only by very few farmers.

Major problems recently observed: *Shinus mole, Acacia abyssinica, Junipurus procera, Causarina equstifolia* were affected by worms; drying of trees and wood affecting insects in *Eucalyptus* species, *Causarina equstifolia, Cupressus lustanica,* and *Junipurus procera*; and termite damage in lowland areas. For these biotic factors as major constraints, there are no control measures and attention is needed to get solutions through research based on studying the impacts of the pests.

Natural resource management constraints

In the studied districts, farmers ranked major constraints in agricultural production (Tables 28a, b, c). All the listed constraints were identified by group discussion with the target farmers, development agents and agricultural experts of the three districts Agarfa, Adaba, and Ginnir. Since there were great variations among constraints identified in each district representing different agro-ecologies, major constraints identified are presented separately for each district.

The priority constraints of agriculture and natural resources in order of importance for Agarfa District were water-logging, shortage of water, shortage of irrigation, soil erosion, deforestation, shortage of tree seedlings and others (Table 28a); Adaba District, water-logging, shortage of water, shortage of tree seedlings, soil erosion, deforestation, adopting climate smart agriculture, shortage of training on irrigation, irrigation water quality and others (Table 28b); and Ginnir District, shortage of irrigation, shortage of water, deforestation, climate change, lack of water harvesting, frequent drought, tree diseases and insects, and others (Table 28c).

Table 28a. Natural resources constraints identified and ranked according to their importance in Agarfa District, 2016

No.	Major constraint	Score@	Rank
1	Water shortage	7.67	2
2	Water-logging	8.00	1
3	Shortage of irrigation	7.33	3
4	Salinity in waterlogged areas	5.00	5
5	Soil erosion	5.33	4
6	Deforestation	5.00	5
7	Shortage of tree seedlings	3.00	6
8	Shortage of knowledge on management of tree seedlings	2.67	7
9	Tree pests and diseases	1.00	8
10	Adopting climate smart agriculture	0.00	-

@ Average matrix score for each identified constraints of three kebeles of the district
Source: Survey results

Table 28b. Natural resources constraints identified and ranked according to their importance in Adaba District, 2016

No.	Major constraint	Score@	Rank
1	Water-logging	5.67	1
2	Shortage of water	5.67	1
3	Irrigation water quality	2.67	4
4	Shortage of training on irrigation	3.67	3
5	Salinity	0.00	-
6	Soil erosion	4.67	2
7	Deforestation	4.67	2
8	Shortage of tree seedlings	5.67	1
9	Adopting climate smart agriculture	4.68	2

@ Average matrix score for each identified constraints of three kebeles of the district
Source: Survey results

Table 28c. Natural resources constraints identified and ranked according to their importance in Ginnir District, 2016

No.	Major constraint	Score@	Rank
1	Shortage of water	6.00	2
2	Shortage of irrigation	7.33	1
3	Lack of water harvesting	3.67	4
4	Soil erosion	2.67	6
5	Deforestation	4.00	3
6	Frequent drought	3.00	5
7	Climate change	4.00	3
8	Shortage of tree seedlings	2.33	7
9	Tree diseases and insects	3.00	5

@ Average matrix score for each identified constraints of three kebeles of the district
Source: Survey results

Conclusion and Recommendation

Agriculture and natural resources conservation trends of Bale Zone are challenged by a lot of complex constraints. Most activities are done traditionally. Overall there were no crop rotation and shifting agricultural practices except in a very few areas of the study districts. Adopting conservation agriculture is still a great gap. In most of the areas there was no applying of climate smart agriculture (CSA) and dominated by mono-cropping. Traditional agricultural system severely affects the natural resources (land/soil, water and forest) of the studied districts. Generally all the identified major constraints need solutions to solve and improve the livelihoods of farming/pastoral communities living in the districts. Modernization of agriculture in environment friendly approach is a necessity. Therefore, the following solutions are strongly recommended for sustainable agricultural production and natural resource management and utilization.

- Expansion of effective irrigation and using improved technologies to solve irrigation water shortage
- Strong attention for rain water harvesting (knowledge gaps and shortage of technologies)
- Assessment of irrigation water quality
- Identifying water harvesting and moisture conservation techniques
- Awareness creation and training on irrigation agriculture for water users
- Efficient use of irrigation water
- Applying different soil management practices for agricultural lands/soils and rehabilitation of degraded areas
- Adopting conservation agriculture for sustainable agricultural productivity and production
- Focusing on organic matter restoration, integrated soil fertility management rather than depending on only chemical fertilizers

- Protection/conservation of remnant natural and plantation forests
- Proper planning to produce adequate and quality diversified multipurpose tree species seedlings
- Planned tree planting around homestead and degraded lands, i.e., expansion of agro-forestry in suitable areas particularly shortage of lands for agriculture
- Continuous management and supervision of planted tree seedlings
- Searching solutions for newly emerging tree constraints (diseases and pests)
- Adopting climate smart agriculture, and others
- Continuous capacity development for research and development through consistent knowledge and technology accesses, information exchanges and experience sharing among relevant stakeholders (agriculture is multi-institution business)

The above listed measures are related to natural resources which are managed by different stakeholders. Some measures need further research, but for most of the measures, there are already technologies to solve the constraints. However, due to weak extension system, available technologies are not practically reaching farmers and pastoral communities timely as needed. Therefore, technology multiplication and dissemination to farmers/pastoralists through strengthening extension systems and continuing research for solving unaddressed constraints are valuable in sustainable agriculture production and natural resource management and utilization. Sustainable natural resource management is the base of sustainable agricultural transformation.

Agricultural Engineering

Ethiopian agricultural system is predominantly subsistence, characterized by the use of traditional implements and practices. Agriculture, which employs 85% of the population, continues to use hand-tools and tillage equipment (using animal power, mainly oxen) since thousands of years ago. Similarly farmstead operations in crop production, animal husbandry and forest operations are performed with bare hands or traditional farm tools.

Agricultural mechanization, along with other farm inputs such as fertilizers, improved seeds and pesticides, can significantly improve agricultural productivity. It is a powerful tool in achieving sustainable agricultural production through enhancing human capacity with the potential beneficiaries. It increases timeliness, efficiency and consistency in field operations. This is critical for land preparation especially where there is sequential cropping of two seasons per year in most parts of the country.

Agricultural Mechanization includes tools, implements and machines for agricultural land development, crop production, harvesting and preparation for storage, transporting, and on-farm processing. The technology plays a key role in improving agricultural production, and should be considered as an essential factor in agriculture. However, to meet the demands of diverse stakeholders, it is necessary to form integrated system in which researchers, developers, manufacturers, and distributors work in collaboratively to solve farmers' problems (Clarke, 2000).

Oromia has huge potential of agriculture, but low availability of agricultural engineering technologies has been one of the main constraints hindering the modernization of agriculture and food production systems. One of the major causes for low performance and contribution to agricultural development has been the fragmented approach of mechanization (Mrema and Odigboh, 1993). This often arises from poor planning and over-reliance on unpredictable or unsuitable aid-in-kind for many mechanization inputs as well as limited co-ordination within and between government and private sectors dealing with mechanization. Thus, developing appropriate mechanization technologies will improve productivity and production, reduce production losses and contribute to food security and economic benefits.

Starkey (1998) defined farm mechanization as the development and introduction of mechanized assistance of all forms and at any level of sophistication in agricultural production to improve efficiency of human time and labor. The present state of mechanization in Ethiopian agriculture is still far from increasing the rate of farm earnings and productivity due to mechanization plan has not been formulated following a well designed, reliable and thorough analysis.

Farm power sources

Farm power (energy) is an essential input in agriculture for timely field operations, operating different types of farm equipment and stationary jobs like operating irrigation equipment, threshers/shellers/cleaners/graders and other post harvest equipments. Obviously, the first kind of power used in agriculture was human power, and all operations from land preparation through cultivation, harvesting, and processing of final product were performed more or less by hand.

However, as the need arose for increased cultivated land and crop production, the development and invention of heavier and more effective field tolls and machines became imperative. Hence, heavier and larger ploughs and harrows, mechanical planters, cultivators, and harvesting devices requiring more and better power were designed and introduced; and oxen, horses, and mules entered the farm power scene in appreciable number. Consequently, draft animals have provided a large part of the power requirements of agricultural production. The major sources of farm power used for tillage, cultivation, harvesting, threshing, cleaning and transportation in AGP-II districts of Bale and West Arsi zones are human (women, men and children) and draft animals (bullocks, camels, horses, mules and donkeys). Few farmers of the studied districts have used tractors and combine harvesters as farm power sources for tillage, and wheat and barley harvesting, respectively.

Tillage implements

For thousands years of recorded history, humankind has been tilling the soil to increase food production. Soil tillage, in general, is one of the fundamental field operations in agriculture that influences soil properties, environment, and crop production. To assure normal plant growth, the soil should be prepared in such conditions that roots can have enough air, water, and nutrients. Tillage equipment should be capable to prepare a suitable seedbed with minimum expense. Tilling equipments that were being used in the studied districts are categorized in to traditional and modern.

Traditional implements: Only local maresha and small hand tools were used by farmers. All primary, secondary and tertiary tillage operation has been done through these traditional implements.

Improved implements: the only improved implement used for land tillage by smallholder farmers of the study districts was tractor. There were no other improved implements used for primary, secondary and tertiary land tillage such as ARDU plough, AIRIC plough, spike tooth harrow, row cultivator and power tiller in the districts covered by this study.

Methods of sowing

There were two types of planting methods practiced in the studied districts, i.e., row planting and broadcasting. Dominantly broadcasting method of sowing has been practiced, than row planting. During FGD farmers mentioned that crops such as teff, faba bean, potato, maize and wheat were drilled in rows so far. Row planting equipments used in the study area were classified in to two:-

Traditional row planting equipments: Only few farmers have used traditional row plantings. They use hand dropping and holed plastic bottles for crops like teff, wheat and maize planting and fertilizer application. Using such traditional equipments is time consuming, laborious and causes unevenly drilling of seeds and fertilizer. Traditional row sowing methods have the following limitations:

Improved row planting technologies: only tractor mounted wheat and fertilizer row planter is used for planting this crop and applying fertilizer in the studied areas. There was no animal drawn row planter equipments.

Pest management technologies

Cultivation equipments: to get better yield, crops that are planted in row must be cultivated using row cultivator to remove weeds that compete with crop stands and affect crop yields. The equipment still used for row cultivation is traditional hand tools for cultivating maize, wheat, faba bean, potato, tomato, onion, mango, banana, coffee and other cereal crops, vegetables and fruits. Therefore, it takes long time and large labor to cultivate these crops, especially who actively participated in this activity, i.e women and children. There is no animal drawn and mechanized row cultivator used in the studied districts.

Chemical application equipments: Knapsack sprayer is the only chemical application equipment available in the studied districts to spray pesticides for controlling weeds, insects and diseases in crops such as wheat, vegetable and fruit . Although chemical application has advantages in controlling pesticides, lack of safety materials and training on how to apply pesticides has adverse effect on health of farmers.

Water management technologies

Water is a vital resource for agricultural production. It is essential for crop growth and development throughout the season to maximize both crop yield and quality. Water has to be applied in the right amount at the right time and in the right depth to achieve maximum crop productivity and production. At the same time, application of water should avoid wastage of water. Assessing, understanding and measuring how water flows around the farm and recognizing how farming practices affect flows will help farmers to manage water efficiently and reduce pollution risks.

Moisture management: Farmers in study areas managed moisture in their farm lands through frequent tillage that makes the soil loose, aerated and increase water holding capacity but all tillage implements were traditional and not effective. In some areas there were water-logging problem and farmers use BBM to drain excess water from crop fields especially where there are Vertisol during high rainfall conditions.

Irrigation system: There are areas where river water is available near farm lands and farmers are able to produce crop by irrigating their farm land. Majority of the farmers who have access to irrigation water use traditional irrigation method to produce maize, vegetables and fruit crops. There were no farmers using modern irrigation method such as drip and sprinkler irrigation to use their available water efficiently.

Water lifting devices: Water-lifting devices are used to lift water to a height that allows users to easily access water. It can be used to raise groundwater, rainwater stored in underground reservoir, and river water. Only few farmers in the studied districts were using motor pump to irrigate their farm lands while other farmers rent these pumps from the owners during irrigation time. Treadle pumps were not well adopted, however; there were few farmers who use gravity system to irrigating their farm land.

Harvesting technologies

Harvesting is the process of collecting matured cereals, vegetables and fruits from the crop fields. To prevent huge quantitative and qualitative losses of crops, all steps of improved postharvest technology must be carefully implemented beginning from harvesting and ending with consumption and utilization of products and by-products. Mostly wheat, barley, teff, maize, faba bean and chickpea, onion, potato, tomato, mango, banana and coffee in the studied districts were harvested manually using sickles and hand picking. There is no intermediate grain harvesting technologies such as harvester. However, combine harvesters are used for wheat and barley by few farmers in areas where farmlands are suitable for combiner. Farmers mentioned the following problems while using combine harvester for wheat and barley.

- It is difficult to get combine harvester on time due to shortage of combine harvester
- High price for harvesting (high price per quintal)
- Few operators increase the ratios of reel peripheral speed to forward speed (reel speed index) to increase grain losses,
- Variety mixing during harvesting i.e. no proper cleaning of harvesters from one field to another

- Straw collection after harvesting by combiner requires additional cost (i.e labor and animal trampling to use for animal feeds).
- No regulation for the renting and use of combine harvesters in the studied districts, i.e., it is the owners of the harvesters who decide price of harvesting.
- Weed spreading problem
- Additional payment for brokers and combine drivers to get combine harvester on time and proper harvesting
- Cheating the number of quintals harvested (inflated estimation of number of quintal harvested and this make farmers for unnecessary payment)

Post harvest management technologies

Thresher/Sheller: threshing of grain crops is a unit operation which requires sets of processing for effective threshing action which is accomplished through either manual or mechanical operation. Most farmers thresh teff, barley, faba bean, chickpea, and shell maize and others by animal trampling on a flat land surface while some farmers who owned engine operated threshing machine threshes teff and barley and this method is significantly better than manual threshing both in terms of quality and time saving. It was rented for 120 birr/hour for threshing teff and other cereal crops. Due to shortage of engine operated threshing and shelling machines the following problems are reported by the farmers.

- Large number of labour is required in traditional threshing
- Delay in threshing their crop which may sometimes expose them to losses due to rain
- Large amount of post-harvest losses during threshing
- Traditional threshing method takes longer time as compared to engine operated threshing machine and combine harvester and due to this post harvest losses due to pests, animals, etc. are high
- High impurities in crops threshed by animal trampling because of unclean floor, debris and animal dung during trampling and others operation.

Cleaning technologies

Handling of grain produced after harvest is vital, because grains contain various proportions of inert materials other than grains such as stone, pods, chaff and debris. Separation of such contaminating materials is essential to have quality harvested grains for food and other uses. There are different methods used to clean these materials from the grain. In the studied districts, grain cleaning practiced traditionally by winnowing in wind using local materials, such as "*mensh, layeda,* sieve (*gengilcha*)*, sefed* and *kuna*". Sometimes there is no wind blow for winnowing and farmers staying for long time without cleaning the grains. Labor required for grain cleaning is high. There is no grain cleaning and winnowing machine in the study districts and farmers face large post harvest losses.

Agricultural product processing technologies

There are different technologies used for agricultural product processing such as coffee dehulling pulping and demucilaging, milk churning, honey extracting, wax stumping, animal feed chopping and mixing and others. These technologies have their own advantage on adding qualities to agricultural products. However, farmers in the studied districts were processing their agricultural products in traditional methods. This method takes long time, more labor and poor quality. Therefore, introduction of modern agricultural product processing technologies are very essential to enhance processing efficiency and increase quality of agricultural products for consumption and market.

Transportation technologies

Transportation technologies are technologies which are used for transporting agricultural products (crop and animal products), agricultural inputs (seeds, fertilizers, pesticides , and others) from one place to other by using human, animal and mechanical power. Dominantly farmers in the studied areas used traditionally human and equines animals to transport agricultural products. Some farmers use horse and donkey cart but there was no other animal drawn carts. Therefore, introduction of modern transportation technologies in the studied districts is very important.

Storage technologies

Storage is part of agricultural production and is necessary for keeping and maintaining grains to ensure household food supply. The traditional practices for grain storages in the studied districts were storages made from grass, wood and mud, sacks and local "*megazen*". These traditional storages have no guarantee in protecting grain from major storage pests such as rodents, insects and birds. These problems often force farmers to sell their produce immediately after harvesting when crop prices are very low. No farmers were used metal silo for grain storage in areas where this survey was carried out. They don't have suitable storage system for vegetables and fruits, potato, tomato, onion, banana, mango and other crops. Some farmers retain potato underground during dry season which was used to increase shelf life. Therefore, appropriate agricultural product storage facilities are needed based on the types of agricultural products produced to store for longer time and safe storage for consumption as well as selling their products at the time of good marketing prices.

Livelihood system and household economy

Socio-cultural setting and resource endowment

Farmers in the studied districts have different types of social norms that represent their settings in the society.

Social institutions

Farming and pastoral communities of studied districts have long years of experiences in cooperation and this cooperation is the way of life in the whole society. This cooperation may be cultural or religious assets that make the communities to have close relations. For example, '*afosha'* (focuses on funeral ceremony), '*ikub'* (for saving money and self help to members) and '*daboo'* (cooperation on peak times of agricultural activities (harvesting, weeding, ploughing, sowing, etc.).

Agricultural cooperatives are institutional entities established with the objective of increasing production and productivity of agricultural commodities at farmers' levels. They supply farm inputs such as fertilizer, seed and different agrochemicals at kebele level and distribute to farmers. Additionally they are involved in output marketing in some kebeles of the studied districts. They increase the income of the farmers by raising the general price level through increasing bargaining power for the products sold and by lowering the costs of purchased inputs.

Seed producer and marketing cooperatives are also available in some kebeles of the studied districts. They played a great role in provision of basic seeds of high yielding and potentially marketable crops varieties to the farmers. As economic enterprises, they also play a meaningful role in uplifting the socioeconomic conditions of their members and their local communities in accordance with the co-operative principles.

Farm household and survival strategies

Agriculture (crop and livestock production) is the principal sector in the districts, and it is at subsistence level. Since agriculture sector is dependent on climatic conditions, farmers frequently faced food shortage due to failure in crop and livestock production. During such times farmers used different coping mechanisms for survival; use savings, sell livestock to buy food, get assistance from government and NGOs, (safety net program where the program is available), participate in non-farm activities and borrow grain from each other as means of survival strategies during food shortage.

Major income sources

Crop production and livestock are the major income source for farmers in the studied districts. Additionally petty trade and remittance are important sources of income. Farmers in the vicinity of some organizations such as Oromia Seed Enterprise, colleges, research centers and private investors use off-farm activities as means of generating income for their livelihoods.

Input supply institutions

In the study districts, primary cooperatives and Unions are the major supplier of farm equipments and inputs. They supply fertilizers, seeds, farm implements and agro-chemicals to farmers, agricultural investors and other institutions involved in agricultural sector. Moreover, Oromia Seed Enterprise, Sinana Agricultural Research Centre, district agriculture and natural resources office and seed producer cooperatives were providers of seeds of improved varieties to the farmers. Private traders also supply some agricultural inputs viz. herbicides, insecticides, fungicides and vegetable seeds. The districts livestock and fishery development office provide veterinary services and drug supply. They also provide AI services for the farmers through hormone assisted mass insemination approach and also supply forage seeds to farmers. Besides agricultural research centre provide forage varieties and training services to farmers.

Besides, veterinary services and drugs supply were also provided by private companies in all districts at district town and some small towns in the districts. Livestock feed is produced by flour and oil processing private factories and traded by retailer individuals in shops and other market places.

Credit institutions

Financial institutions: Rural households in the studied districts need credit for investment in a range of on-farm and off-farm activities. There are formal and informal financial institutions available in the studied areas that provide credit. Formal financial institutions that lend money to farmers were Oromia Saving and Credit Organization, micro-finance, NGOs (Engine), and different public and private banks. Informally farmers get credit from other farmers, traders, *afosha (idir)* and *Ikub* and these are the major source of credit.

Cross Cutting Issues

Gender

Gender roles and decision making: Women play important role in agricultural activities in the studied districts. They participate in farm activities such as weeding, land preparation and cleaning of seeds, buying farm inputs, harvesting, transporting, threshing and storing. Additionally women participate in herding, tending sick animals, watering, barn cleaning, milking and milk processing related activities. They assist their husbands and other families in transporting farm implements and feeding oxen.

Resource access and decision making: Men and women have equal access to land, livestock, and other resources owned by household. There is improvement on decision making by women farmers on sale of livestock and crop products, and financial management decisions, even though previously these decisions were majorly made by male household heads. Besides, women farmers mentioned that there are improvements in resource ownership and in decision making on resources currently compared to past times.

Human Nutrition

The main food crops used in the studied districts were cereals, pulses and vegetables. Among cereal crops, barley, wheat, emmer wheat and maize are the major ones. Faba bean, field pea, lentil and chickpea were among the pulse crops that mainly utilized for consumption. Vegetable crops such as potato, cabbage, mustard, shallot, beetroot, onion, garlic, carrot and onion were the most commonly used vegetables as food in the districts. The main livestock products consumed in the study districts were milk, butter, egg, cheese and meat. Food prepared from cereal crops is combined with pulse, vegetables and livestock products to have a balanced diet to fill their body nutritional requirements.

Climate smart agriculture

One of the most serious environmental threats facing the world today is climate change. Currently, this issue has got due attention and mainstreamed into relevant social, economic and environmental dimensions. Basically, strategy that aims to manage climate stress also aims to manage risks presented by other socio-political, environmental or economical contexts. Thus, in developing adaptation strategies, one can look more broadly to existing research on sustainable agricultural systems and farmers practices in managing these multiple risks as a basis for building the adaptive capacity of farmers to cope up with future climate change stresses.

The studied districts were facing average production loss and more are likely to face increased climate variability and extreme weather shocks even in the near decades. Climate change could significantly impact agricultural production and food security particularly due to changes both in mean temperatures and rainfall as well as increased variability associated with both variables. Changes in pest and disease patterns could also significantly impact agriculture. Cognizant of these, farmers are using different coping mechanisms to overcome and balance natural shocks. These are preference of early maturing crop seeds, changing livestock types from cattle to small ruminants, use of improved technologies and other coping mechanisms prevalent in the studied districts.

Conclusions and recommendations

In these studied districts, rain-fed agriculture is the dominant agricultural production method which contributes to the largest proportion of total production. Crops grown under rain-fed agriculture are diverse. However, agriculture production is dominated by cereals (particularly wheat and barley) which are produced on large areas in large quantity as compared to other crops. Additionally the productivity of other crops is lower compared to cereals. The dependence on rain-fed agriculture has significantly and negatively affected the life of farming/pastoral communities in particular and economic development in general. This is mainly attributed to traditional production system and continuous climate change. Accordingly, irrigated agriculture is the best option to achieve food security, poverty alleviation and improving the livelihood of the community on sustainable basis. Based on information obtained from PRA results, all the studied districts are endowed with relatively abundant water resources, favorable climate and potential irrigable lands. While the potential benefits of irrigation are great, the actual achievement in many irrigated areas in the studied districts was substantially less than the potential. Therefore strengthening the irrigation sector institutionally, financially and technically (knowledge capacity) is paramount importance. Low cost water harvesting and irrigation technologies such as construction of earth dams, river diversions, hand pumps and others should be expanded and encouraged. On the research side, potential crop varieties based on agro-ecologies and integrated management practices for irrigated agriculture should be given due emphasis. Moreover agricultural research approaches towards small scale irrigation schemes should also be improved accordingly by identifying the major gaps of this sector.

Climate smart agriculture includes proven practical technologies such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agro-forestry, improved grazing and improved water management. CSA also involves innovative practices such as improved weather forecasting, early-warning systems and climate-risk insurance. CSA aims to get existing technologies of the shelf into the hands of farmers, as well as to develop new technologies such as drought-tolerant or flood-tolerant crops to meet the demands of the changing climate. Therefore any strategy designed to improve agricultural practices should include integrated watershed management, integrated soil fertility management, sustainable land management, conservation agriculture, agro-forestry, crop residue management, composting, promotion of improved livestock feed and rangeland management.

It is inconceivable to think of increasing agricultural production without the use of improved, high yielding and disease resistant crop varieties. Local landraces are low yielding and susceptible to different pests. The development and dissemination of these improved varieties is of utmost importance to boost agricultural production. Therefore research priority regarding improved varieties must focus toward generating of stable, high yielding, climate stress tolerant and pest resistant varieties. Improved agronomic practices regarding seed rate and row spacing, planting time and method, soil fertility management and others for each crop should also be implemented based on research recommendations. Furthermore, seed multiplication, delivering and supply system should also be improved targeting the needs of farming/pastoral communities.

Inorganic fertilizer supply and use by farmers are other major constraint of agricultural inputs of the studied districts. High price of these fertilizers, reliance of farmers on inorganic fertilizers, untimely supply of fertilizers, misuse of recommended rate and time of application are the prioritized constraints regarding fertilizer issues. Therefore, fertilizer need assessment and supply should be implemented according to the real need of farmers. The price of fertilizer must also be considering the buying capacity of farmers. Fertilizer supply and recommendation rates must be based on the soil fertility status, following soil test and crop response base recommendations of each specific districts with blended fertilizer based on soil fertility maps developed by ATA.

Favorable environmental conditions for crop production in the studied districts also created conducive environment for pest resurgences. Where there are crops, there are also weeds, insects and diseases. Pest assessment and early observation of disease pressure helps to take immediate intervention before disease outbreak (economic threshold level). Regular inspection and detection of pest in farmers' fields should be focused and immediate management options should be availed for farmers. Farmers are also expected to report pest problems (insects, diseases and weeds) to local extension services and receive prescription from plant protection experts.

Finally, the results of this survey clearly indicated that agricultural production constraints identified and prioritized will guide research directions in developing agricultural technologies and management practices for both rain-fed and irrigation agriculture. These agricultural production constraints identified will be addressed by AGP-II project and other regular governmental development and research interventions based on agro-ecologies and farming systems of the zones.

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Wheat rusts: the major production constraints of the wheat industry in Ethiopia and their management options

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Abstract

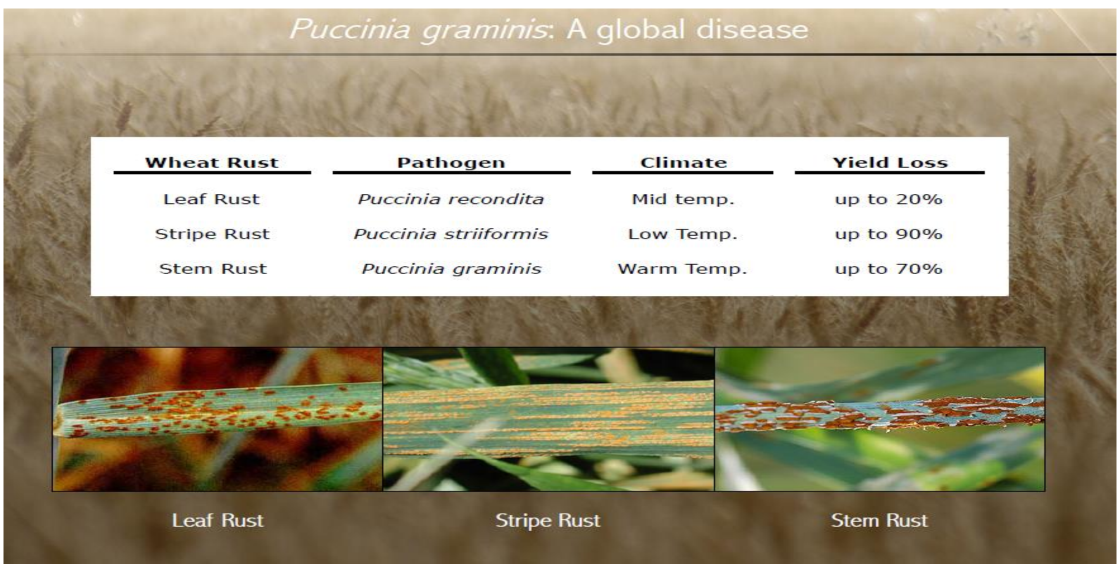
Stripe (yellow) rust, caused by *Puccinia striiformis* f. sp. *tritici*, leaf rust caused by *Puccinia triticina* and stem rust caused by *Puccinia gramini* f.sp. *tritici* are the most destructive diseases of wheat worldwide. Climate change brings rising temperatures, and has increased the variability and intensity of rainfall, contributing to the spread and severity of rust diseases. Emerging variations (or races) of rust are showing that they can adapt to extreme temperatures-a phenomenon not seen before. This phenomenon enhanced the rust epidemics in Ethiopia and eastern part of Africa. Planting resistant cultivars is an effective way to control these diseases, but race-specific resistance genes that introgressed to many of Ethiopian wheat cultivars can be overcome quickly due to the rapid evolving rust population. This narrow genetic basis of resistance in Ethiopian modern wheat cultivars and the strong selection response of pathogen populations have been responsible for periodic and devastating epidemics of the wheat rust diseases. Characterizing new sources of resistance and incorporating multiple genes into elite cultivars is the most widely accepted current mechanism to achieve durable varietal performance against changes in pathogen virulence. Rust management strategies such as preventions, breeding for durable resistant wheat varieties, judicious use of fungicides, pathotypes monitoring, field monitoring and employing practices that minimize inoculums pressure are suggested rust management strategies to mitigate wheat rust epidemics in Ethiopia.

Introduction

Diseases caused by fungal pathogens of small grains can lead to economic losses when unmanaged and conditions are favorable for development. Rust diseases of wheat are among the oldest plant diseases known to humans. Early literature on wheat cultivation mentions these devastating diseases and their ability to destroy entire wheat crops. The rust pathogens of wheat (*Triticum aestivum*) are among the most important crop pathogens causing a continuous threat to crop production (Singh et al., 2008; Dean et al., 2012). Aggressive new strains of wheat rust diseases-stem rust and stripe rust-have decimated wheat yields in recent harvests. Climate change brings rising temperatures, and has increased the variability and intensity of rainfall, contributing to the spread and severity of rust diseases. Emerging variations (or races) of rust are showing that they can adapt to extreme temperatures-a phenomenon not seen before. In Ethiopia, wheat rusts particularly stem and yellow rusts are becoming the major wheat production challenges and recurrent epidemics of these rusts is becoming common in the country

The three important wheat rusts

Three rust species that infect wheat are distributed globally, i.e., yellow (stripe) rust caused by *Puccinia striiformis* (Liu and Hambleton, 2010), leaf (brown) rust caused by *Puccinia triticina* (Goyeau et al., 2006; Bolton et al., 2008) and stem (black) rust caused by *Puccinia graminis* f. sp. *tritici* (Leonard and Szabo, 2005; Singh et al., 2008; Berlin et al., 2013). All the three rusts have been shown to cause huge losses in different areas, years and environments favoring disease epidemics (Dean et al., 2012; Pardey et al., 2013; Beddow et al., 2015; Singh et al., 2016) Figure 1. They are spreading more rapidly than in the past and new variations of the diseases are overcoming presently rust-resistant wheat varieties that have been developed by researchers in the recent years. The detail descriptions of these three rusts are presented in the next paragraphs.



Wheat Rust	Pathogen	Climate	Yield Loss
Leaf Rust	*Puccinia recondita*	Mid temp.	up to 20%
Stripe Rust	*Puccinia striiformis*	Low Temp.	up to 90%
Stem Rust	*Puccinia graminis*	Warm Temp.	up to 70%

Figure 1. The three wheat rusts along with their causative pathogen and average yield loss that they can incur.

Black/Stem Rust

Stem rust (also called black rust), is caused by *Puccinia graminis*. Stem rust is favored by humid conditions and warm temperatures of 15°C to 35°C. The fear of black rust through history- and today- is understandable. An apparently healthy crop three or four weeks before harvest can be reduced to a black tangle of broken stems and shriveled grain. Harvest losses of 100 percent can occur in susceptible crop varieties. Stem rust occurs primarily on stems but can also be found on leaves, sheaths, glumes, awns, and even seed. Symptoms begin as oval to elongate lesions that are generally reddish-brown in color. In the late stages of the disease, erumpent pustules produce numerous black sooty spores. Severe infestations with many stem lesions may weaken plant stems and result in lodging (ICARDA, 2011).

Yellow /Stripe Rust

Yellow rust (also called stripe rust) caused by *Puccinia striiformis* is a very important disease of wheat, particularly in East Africa, Central and West Asia and North Africa. Here it is reckoned to have caused recurrent, severe damage in crops since the dawn of agriculture. The historical view is that stripe rust is principally a disease of wheat grown in cooler climates (2°C - 15°C), and generally associated with higher elevations, northern latitudes or cooler years. But recent outbreaks have defied this assumption with current strains of the disease more adapted to high temperatures, and hence countries closer to the equator. Because the disease attacks from early in the growing season, plants are often stunted and weakened. Crop losses can be severe (50 - 100%), due to damaged plants and shriveled grain. Epidemics of stripe rust continue to cause severe losses and have been reported in Afghanistan, Azerbaijan, Ethiopia, Georgia, Kenya, Kyrgyzstan, Morocco, Iran, Iraq, India, Pakistan, Syria, Tajikistan Turkey, Turkmenistan, and Uzbekistan in recent years. Stripe rust epidemics have also occurred in the Australia, Europe, China and the United States (ICARDA, 2011).

Stripe rust is distinguished by the presence of light yellow, straight-sided pustules that occur in stripes on leaves and heads. These elongate pustules are narrow and vary in length. As the pustules mature, yellow-orange spores are produced. As the disease progresses, tissues around the pustules turn brown and dry, resulting in a scorched appearance. The arrangement of pustules into stripes is an important distinguishing characteristic of this disease. Chlorosis, or yellowing, of leaves can be quite evident with both leaf and stripe rust, and fields with plants displaying severe symptoms may be easily detectable from a distance.

Brown/Leaf rust

Leaf (or brown) rust is chiefly caused by *Puccinia triticina* and occurs to some extent wherever wheat is grown. The disease develops rapidly at temperatures between 10°C and 30°C. Leaf rust losses in grain yield are primarily attributed to reduce flower set and to grain shriveling. In highly susceptible wheat varieties, the crop can be killed by early epidemics. Crop losses due to leaf rust are usually small (less than 10 percent), but have been known to cause up to 20% crop losses. Leaf rust is generally found on leaves but may also infect glumes and awns. Symptoms begin as small circular to oval yellow spots on infected tissue of the upper leaf surface. As the disease progresses, the spots develop into orange-colored pustules that may be surrounded by a yellow halo. The pustules produce a large number of spores that are easily dislodged from the pustule, resulting in an "orange dust" on the leaf surface or on clothes, hands, and equipment. As the disease progresses, black spores may be produced, resulting in a mixture of orange and black lesions on the same leaf. Tiny orange lesions may be present on seed heads, but these lesions do not develop into erumpent pustules. This difference helps to distinguish leaf rust from stem rust (ICARDA, 2011).

Wheat production and importance at global level

Wheat is the world's most important food crop and it is the most traded commodity. In the developing world, it is the second most important crop after rice. Wheat feeds about 2.5 billion poor people (living on less than $2 a day) in some 90 countries and is a crucial source of calories and protein. Wheat makes up 20% of the calories consumed by people globally. Annually, about 717 million tons of wheat is produced from 220 million hectares with a worth of 50 billion USD each year (FAOSTAT, 2013)

Wheat Production in Ethiopia

Wheat in Ethiopia is the major staple and strategic food security crop. It is 4th in area and 3rd in production (CSA, 2014). The country is the largest producer in Sub Saharan Africa with area of 1.6 million ha and annual production of 4 Million MT. In Ethiopia, about 5 Million HH- small scale farmers are engaged in wheat production (CSA, 2014). Wheat in Ethiopia is well adapted at an altitude between 1500 to 2800 m.a.s.l, with rainfall amount > 500mm and Temperature of 15-28^{o}C. Prior to development of improved wheat varieties, average productivity of wheat in Ethiopia is less than 1t/ha. But currently, the national average is close to 2.5t/ha where as progressive farmers can attain yield as high as 8t/ha (Bekele et al., 2015)

Wheat rusts and their importance

Wheat is one of the most critically important staple foods worldwide. Its harvests have come under increasing threat in recent years from new kinds of fungus infections, such as wheat rusts, that are killing these crops. Rust fungi have been known to attack wheat since the earliest records of its cultivation-in classical times, the Romans made sacrifices to Robigus, the Rust god, to protect their wheat from epidemics. Nowadays also, it is well known to farmers and agricultural planners around the world, who have been dealing with it since the early 1900s. But in the past decade, new races have emerged that are overcoming the wheat crops that had been resistant to these rusts to date. The wheat rusts have a long history of causing considerable loss in productivity and quality of wheat.

Rusts are obligate parasites with diverse pathogens with over 120 genera and 6,000 species. They got name from the color of the spore masses seen on an infected plant which is similar to the color of rust on metal. They are the most problematic and potentially devastating diseases of wheat that can cause significant yield losses in the world.

Major epidemics of wheat rusts in the world

At various times in history, epidemics of both yellow and stem rusts have caused massive losses to wheat production globally. These epidemics that occurred in the world at different times are presented below for both stripe and stem rusts:

Stripe rust: Stripe rust has been a disease of wheat mainly in areas with cooler climates (Chen, 2005). More recently, however, the emergence of aggressive races of *Pst* tolerant to higher temperatures has resulted in yield loss in areas normally considered too warm for serious epidemic development. These new strains of *Pst* are currently widespread and threatening wheat production on a global scale (Chen, 2005). In years (2009-2010), wheat growing regions in East Africa, Central and West Asia, and the Caucasus countries experienced one of the largest stripe rust epidemics in the recent history (Solh et al., 2012) (Figure 3) In Ethiopia alone, this epidemic affected more than 600,000 ha of wheat and led to an expenditure of more than $US 3.2 million on fungicides, while significant widespread losses were still realized (GRRC, 2016). Two major yellow rust epidemics were occurred in the world due to appearance of new yellow rust races that overcome major yellow rust resistance genes that incorporated in the majority of wheat cultivars across the world. These are due to a breakdown of the yellow rust resistance gene *Yr9* during 1986-1993 (Figure 2) with crop losses amounting to several hundred million dollars and affected millions of poor farmers and the other is due to breakdown of gene *Yr27* during 2009-2010. In 2009-10, the outbreak of gene *Yr27*- an aggressive new strain of stripe rust- caused significant yield losses in countries such as Azerbaijan, Ethiopia, Iran, Iraq, Kenya, Morocco, Syria, Turkey, Uzbekistan, and threatening the food security and livelihood of resource-poor farmers and their communities (ICARDA, 2011).

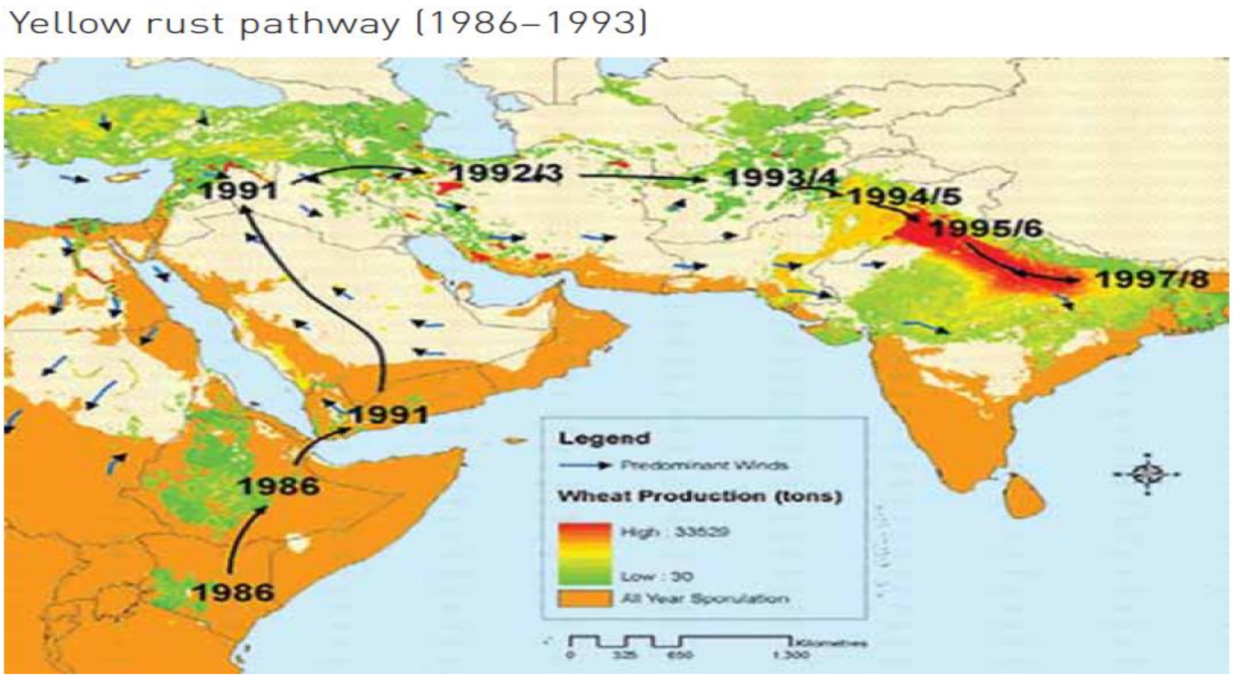


Figure 2. Yellow rust epidemics during 1986 to 1993. (Adopted from Singh et al., 2008)

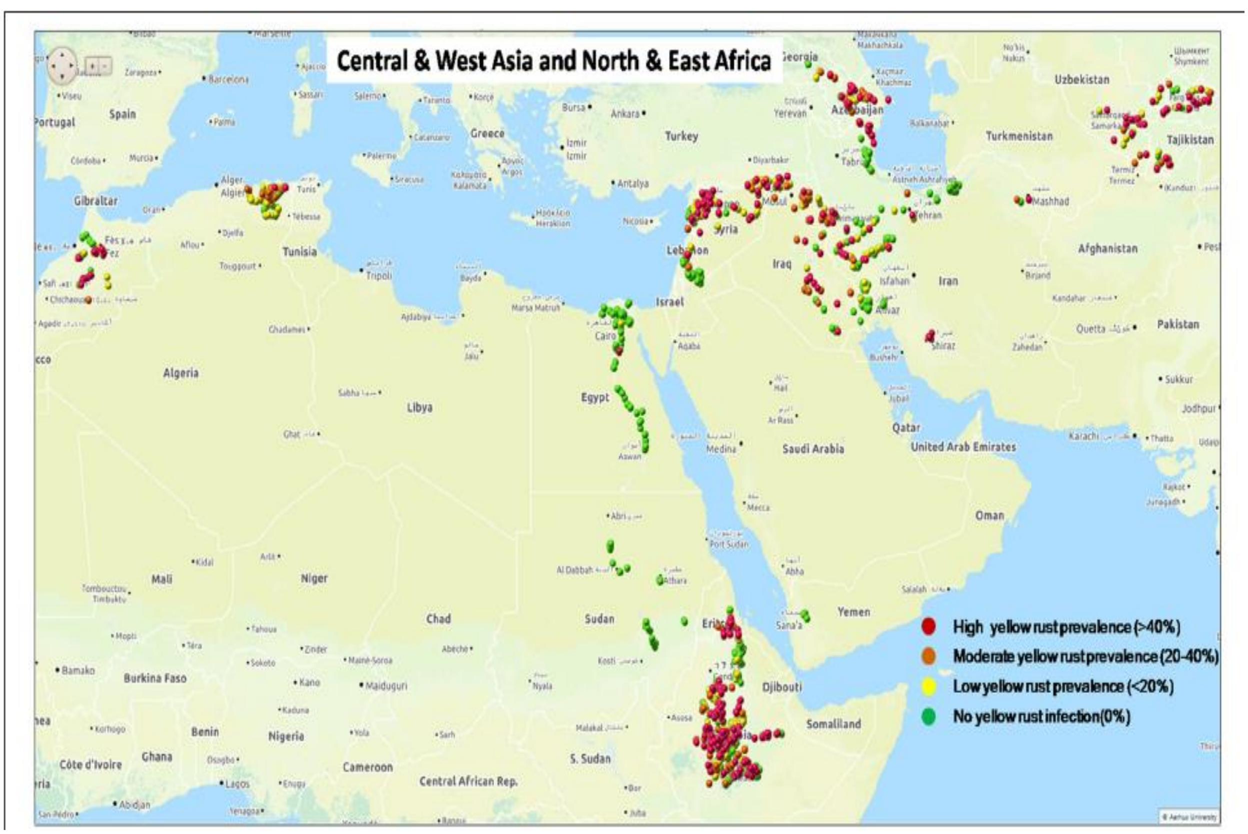


Figure 3. Yellow rust prevalence in CWANA region during 2010 epidemic season ((Adopted from Ali et al., 2017)

Stem rust: The emergence of Ug99, the new virulent strain stem rust fungus, is also showed similar epidemics and affected global wheat production. During the last 40 years, introgression of different combinations of stem rust resistance genes and other epidemic mitigation strategies have reduced global stem rust epidemics (McIntosh and Brown, 1997). However, the discovery of race TTKSK (isolate Ug99) of *Pgt* in Uganda in 1998 has raised a particular concern to global wheat production and food security due to its wide virulence spectrum (Pretorius et al., 2000). Currently, at least eight variants of TTKSK (the Ug99 lineage races) have been described with virulence for additional resistance genes, including *Sr24*, *Sr36*, *Sr9h* and *SrTmp* (Jin and Szabo, 2008). These races are currently spreading across Eastern, Southern and Northern Africa as well as the Middle East (McIntosh and Brown, 1997; Rouse et al., 2014) (Figure 4). In 2013-2014, a new stem rust race designated as TKTTF caused a severe epidemic on the variety 'Digalu' carrying *SrTmp* gene in Ethiopia, particularly in the highlands of Bale (Olivera et al., 2015). The continued emergence of new virulent races of stem rust emphasizes the dynamic challenges of breeding for stem rust resistance. This rust is the most feared wheat disease which evolved to different lineages/races (Figure 4). Ug99 races defeated virtually every race-specific resistance gene and over 90 percent of all wheat varieties showed highly susceptible reaction to these races.

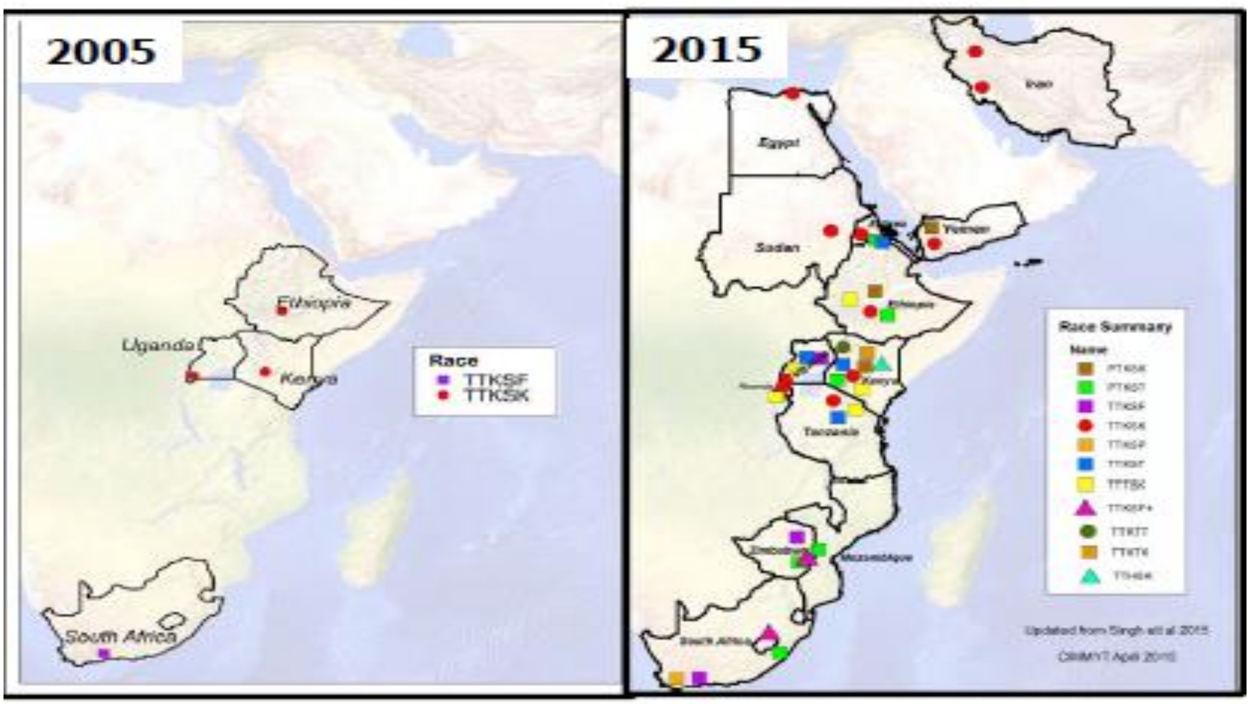


Figure 4. Evolution and Global spread of Ug99 (Adopted from Singh et al., 2015)

Unique feature of rust diseases

The persistence of rust as a significant disease in wheat can be attributed to specific characteristics of the rust fungi. These characteristics includes long distance migration capacity (Zadoks, 1961; Brown and Hovmøller, 2002), high rates of mutation from avirulence to virulence (Hovmøller and Justesen, 2007), adaptation to different climatic conditions (Milus et al., 2009), existence of recombinant and highly diverse populations (Ali et al., 2014; Thach et al.,

2016) and the potential creation of new variants through a sexual cycle (Jin et al., 2010; Rodriguez-Algaba et al., 2014), a capacity to produce a large number of spores-which can be wind-disseminated over long distances and infect wheat under favorable environmental conditions. All these characteristics are unique features of rust fungi which makes its control and management difficult and becoming the major concern in wheat production.

Rust situations in Ethiopia

Wheat is a traditional crop cultivated by about five million households on 1.6 million hectares in Ethiopia. Despite the country's huge potential, the average wheat productivity of 2.5 tons per hectare is lower than the global average of 3 tons per hectare. Wheat diseases caused by *Pucccinia spp*. are the major biotic constraints for wheat production in the country and recent recurrent outbreaks have debilitated many wheat varieties in major production areas in Ethiopia. Stem rust, stripe rust, and leaf rust have been the most damaging fungal diseases of wheat, causing significant yield losses in Ethiopia.

Ethiopia has experienced several rust epidemics in different years (Table 1); however, the epidemics became frequent nowadays. The epidemic of yellow rust which occurred in 1988 on bread wheat variety called Dashen is one of the epidemics that occurred in Ethiopia due to ineffectiveness of major yellow rust resistance gene called *Yr9*. Thus, this popular cultivar droved out of production due to this year's yellow rust epidemics. Similar yellow rust epidemics of aggressive new strain was occurred in 2010 devastating some 600,000 hectares of wheat harvest and caused significant yield losses in Ethiopia particularly on those bread wheat varieties which are susceptible to yellow rust and this incurred an estimated 60 million ETB (3.2 Million US$) spent on fungicides (Bekele et al., 2015). This yellow rust epidemics forced wheat producers to replace the widely grown susceptible varieties such as Kubsa and Galama whose resistance gene broke due to virulence race on gene *Yr27* by the newly released bread wheat varieties such as Danda'a, Hidase, Shorima and Digelu. This is the largest yellow rust epidemic the country faced. A stem rust epidemic was also occurred in Ethiopia by Ug99 stem rust race particularly in the year 2001 and onwards which caused significant yield loss in country. This race made the majority of bread wheat varieties to become highly susceptible. Similarly in 2013-2014, a new stem rust race, identified as TKTTF virulent on *SrTmp* gene, unrelated to the highly virulent Ug99 rust disease, affected 20-40,000 ha (10-40% of the total wheat area in South East of Ethiopia , caused 100 percent yield losses in worst affected areas on bread wheat variety Digalu in some regions particularly in Bale highlands (Figure 5). Of all rusts, stem rust is the most feared disease of wheat cause severe devastation. Hence, currently breeding for rust resistance is the major breeding objective in wheat improvement in Ethiopia to combat rust epidemic.

Figure 5. Stem rust epidemic in Bale, Agarfa, 2013

Table 1. Recurrent Rust Epidemics occurred in Ethiopia

Year	Disease	Cultivar	Gene
1988	Yellow Rust	Dashen	*Yr9*
1993/94	Stem Rust	Enkoy	*Sr36*
2010	*Yellow Rust*	*Kubsa, Galema*	*Yr27 +*
2013/14	Stem Rust	Digalu	*SrTmp +?*

Why recurrent rusts epidemics in Ethiopia?

The main reason that aggravated wheat rust epidemics in Ethiopia are indicated as follow:

- Continuous release of cultivars with similar parentages
- Absence of resistance in cultivars preferred by farmers & the rapid break down of resistance gene in the existing cultivars
- Wheat monoculture
- Extensive use of one or two wheat varieties (mega cultivars)
- Year round wheat production-green bridging
- Spores from neighbouring countries
- Limited use of chemicals

Rust management strategies:

Prevention: The wheat rust pathogens are wind transported pathogens that can travel long distance across regions. However, it is always a good idea to prevent transport of exotic races or strains of the wheat pathogen from other regions. Clothing and footwear should be changed after visiting a field with wheat rusts to avoid human aided transport of rusts from one region to another. This is particularly evident for international visitors as spores stick to clothes and shoes remain viable for several weeks.

Breeding for durable resistant wheat varieties: Planting resistant cultivars is widely accepted as the most effective, economic, easy-to-use, and environmental-friendly way to control wheat rust diseases (Chen, 2013). However, breeding resistant cultivars can be complicated by several biological characteristics of the pathogen, e.g., long distance aerial dispersal of urediniospores and ever-changing virulent races (Brown and Hovmøller, 2002; Chen, 2005). The rapid, long-distance aerial dispersal or unintentional introduction by travelers can lead to new invasions and reestablishments of the diseases in previously disease-free or seasonally pathogen-absent regions (Wellings, 2011; Sharma-Poudyal et al., 2013).

One of the only early prevention methods for avoiding rust diseases or minimizing their impact is to plant a variety with known resistance. Variety resistance is the most economical method of control. In some cases, avoiding rust is not possible because of constant changes in strains (races) of the pathogens. For example, varieties formerly rated as “resistant” have, in recent years, begun to show signs of susceptibility at various locations. In many situations, the varieties remained resistant for only three to four years before showing signs of susceptibility. To mitigate losses due to rust diseases in wheat, world wheat production has largely depended on the use of resistant wheat varieties (Burdon et al., 2014; Hulbert and Pumphrey, 2014). The emergence of pathogen populations virulent against deployed resistance genes has caused not only tremendous yield and quality losses, but has also led to frequent replacement of the otherwise agronomically superior cultivars, as well as interference with progress in improving other important traits (Burdon et al., 2014). Achieving durable varietal performance has therefore been the primary focus of many breeding programs in wheat. Two categories of resistance genes have been widely recognized in wheat breeding for rust resistance; all-stage resistance (also called seedling resistance) and adult-plant resistance (APR) (Chen, 2005). Developing cultivars carrying effective seedling resistance in combination with APR genes is more desirable to minimize the damage caused by new mutants of the pathogen (Burdon et al., 2014).

The deployment of cultivars with durable rust resistance in wheat is particularly desirable in regions such as Ethiopia and the neighboring countries in East Africa that are characterized by the presence of year-round inoculums due to nearly constant wheat cropping seasons and a suitable environment. These conditions provide the pathogen not only with a continuous substrate both in area and in time due to a green bridge between the seasons, but may also result in rapid selection for virulent races of the pathogen.

The new races, under favorable weather conditions, could shorten the life time of wheat cultivars with only race-specific resistance and cause destructive epidemics (Hovmøller et al., 2016). Thus, understanding pathogens evolution is critical and valuable not only for predicting and monitoring the population changes but also for developing cultivars with durable resistance for sustainable control of the disease. Hence developing wheat cultivars with durable resistance is the best and preferred option to contain rust epidemics in rust prone areas.

Judicious use of fungicides: When a variety does not have adequate resistance, fungicide should be used to suppress the disease and reduce yield loss. Spraying fungicides too early or late will result in inadequate disease control, loss of profits, and wasted time and money. The most effective time to apply fungicides is between last leaf emergence and complete head emergence. Applying fungicide after flowering oftentimes is not economically feasible because considerable damage has likely occurred to the flag leaf by this point. Protecting the flag leaf is of utmost importance. Fungicides are preventative and will not bring back healthy tissue once infection has occurred. Applications after milk and into soft dough stages are too late and do not provide much, if any, yield protection. If infection is severe early on the lower leaves, then spraying before last leaf emergence may be warranted. Most damage is done when infection is high during heading and flowering. In general, fungicides provide about two to three weeks of protection from further infection. Profitable returns from more than one spraying are highly unlikely, so it is imperative that the one application occurs at the optimal time. It is important to remember that fungicides are a preventative measure rather than a cure to the problem. Also, spraying will not increase yields, but will help preserve the yield potential that already exist in the field. Preventing yield loss should be the goal of a fungicide program, not enhancing yield beyond what is expected under favorable, non-diseased conditions.

Pathotypes monitoring: Monitoring population dynamics of rusts is necessary for national monitoring and trans-border information exchange on pathotype population to provide an early warning information to the wheat producers so as to have a fungicide reserve and make the necessary preparation to reduce/avoid the expected yield loss. This will help them to manage wheat rusts incase of rust epidemics.

Field Monitoring: Good monitoring allows for timely fungicide application and avoids unnecessary use of fungicide. As fungicides vary in efficacy and duration of effectiveness (20 to 40 days depending upon chemicals), growers should begin checking fields about 2 to 5 weeks after application to determine if another application is needed. Varieties with race-specific resistance may become susceptible if new virulent races occur in the region. Monitoring fields planted with varieties having this type of resistance can prevent unexpected damage.

Employing practices that minimize inoculums pressure: Limiting the amount of inoculum is an intrinsic component of reducing the probability that the rust organism can change genetically to parasitize previously resistant varieties.

- Strategies that have worked well in the past to reduce the amount of inoculums includes:
- Removal of volunteer wheat that could harbor rust in the off-season
- Eradicate barberry plants, the alternative host.
- Using multiple effective genes for rust resistance in the one variety
- Removal from commercial production of varieties when they become susceptible
- Avoiding wheat monocropping practices and practicing crop rotation

Diversified cropping strategies: Diversified cropping of wheat- avoiding the sowing of mega-varieties across large cropped areas- is another possible defense against wheat rust. In most areas of the Middle East, East Africa and South Asia, farmers have been planting the same varieties for 20-30 years. This practice is not advisable in a situation where the rust races are mutating and new ones are emerging much more rapidly than the past and overcoming resistance in the current varieties. As it takes about 10 years to develop a wheat variety with new resistance- and no one knows when and where new rust races will appear- the most effective strategy to combat new rust races is to diversify cropping patterns, and have various types of rust resistant varieties readily available.

Conclusion and way forwards

Climate change brings rising temperatures, and has increased the variability and intensity of rainfall, contributing to the spread and severity of rust diseases. Emerging variations (or races) of rust are showing that they can adapt to extreme temperatures- a phenomenon not seen before. Scientists and agricultural specialists around the globe are working to more effectively monitor, track and combat the spread of wheat rust diseases. Early warning system and well-organized surveying and surveillance are the keys to better managing and reducing wheat rust in the country particularly when the rust epidemics are becoming frequent to reduce damage that could occur due to rusts. This helps farmers, policymakers, national agricultural research and extension services to rapidly respond to outbreaks. Practicing methods that reduce rust inoculums including avoiding the use of mega variety/ies is imperative. Besides, removing wheat varieties that became susceptible from production is required to minimize the evolution of new races.

Improving the breeding strategies and development of resistant varieties using new tools (Molecular tools- MAS, GWS and using other cutting-age technologies) to develop wheat with durable /multiple resistance genes is necessary to combat wheat rust in the country. Additionally, capacity building of farmers and extension on disease management in the field is crucial to reduce the challenge due to rust pathogen.

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Review of Maize Lethal Necrosis (MLN), a Potential Food Security Threat of Maize Belt Farming Community of Western Ethiopia

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Abstracts

Maize Lethal Necrosis Disease (MLND) is the newly introduced aggressive disease of maize caused by co-infection of two viruses: Maize Chlorotic Mottle Virus (MCMV) and Potyviridae (Wheat Streak Mosaic Virus (WSMV), Maize Dwarf Mosaic Virus (MDMV), or Sugarcane Mosaic Virus (SCMV). The co-infection and the synergic effect of MCMV and SCMV is the common cause MLND worldwide. MLND identified in Latin America before 40 years and introduced to Africa recently. The rut of introduction to Africa crossing the ocean was still not apparent. All tropical commercial maize varieties developed before MLND introduction are highly susceptible. Tropical environment is suitable for insect victors and continues maize growing year round is another risk of high disease pressure and fast distribution. MNLD has no cure, integrated pest management like use of disease free seed, vector management, appropriate agronomic management practise are strongly advised. Experimentally designed yield loss was not reported from Ethiopia, but 100% loss was reported during its first occurrence in Rift valley. Yield loss of about 90-100% was repeatly reported from Kenya. After several gregarious breeding and selection through thousands of maize genotypes, six resistant maize varieties with yield potential of more than 6 ton ha^{-1} were developed in Kenya. Strong research, national policy and resource priority is imperative to avert the economic and social disaster of this pest where maize is the major staple food of poor farming community.

Key words: Viruses, yield loss, susceptible, pest management and insect-vector

Introduction

Maize is an important strategic crop which is grown by millions of farmers in the world both as a food crop and a cash crop. It is the most important crop in Ethiopia, produced by more than 10 million household. Further, there are more than 50 million Ethiopians are direct or indirectly benefited from maize. Maize ranks first in production per unit (3.23 ton ha^{-1}) and second in area of production followed to teff (CSA 2015 and 2016). Production per unit area of maize in Ethiopia is highest in Africa but still below the world average production which is 3.52 ton ha^{-1}. Several production constraints contribute for the lower yield of Ethiopian maize production as compared to global production. The biotic stress like disease caused by several plant pathogen and insect pests are the major potential yield limiting factors. This staple food of most Ethiopian has been currently seriously threatened by the recent outbreak of pests without boarder, Particularly Maize Lethal Necrosis Disease (MLND) and American Fall Army Worm (*Spodoptera frugiperda* Smith. MLND is caused by synergistic co-infection of two virus, Maize *Chlorotic Mottle Virus (MCMV)* from the family *Tombusviridae* and *Potyviridae* like Wheat Streak Mosaic Virus (*WSMV*), Maize Dwarf Mosaic Virus (MDMV), or Sugarcane Mosaic Virus

(SCMV (Goldberg and Brakke 1987; Niblett and Claflin 1978). The co-infection of MCMV and SCMV is the common cause MLND worldwide. However, the mechanism underlying the synergistic interaction between these two viruses remains indefinable. However, Zihao *et. al.*, 2016 found that the co-infection of MCMV and SCMV increased the accumulation of MCMV which consequently leads to sever infection and fast plant tissue death. That means a single infection of virus MCMV or SCMV cannot cause MLND. Maize lethal necrosis disease (MLND) has emerged as a devastating disease in eastern Africa since 2011 (Wangai *et al.*, 2012). In eastern Africa MLND was found to be as a result of synergistic interaction of *Maize Chlorotic Mottle Nirus* (MCMV) and S*ugarcane Mosaic Virus* (SCMV). Although each of these viruses individually can cause disease, the synergistic interactions are more pronounced (Manje *et al.*, 2015).

Origin and Dispersal of MLND

MLND was first identified in Peru in 1973 (Castillo and Hebert 1974) and subsequently reported from USA 1976 (Niblett and Caflin, 1978). Introduction of MLND in to African continent had been after 40 years of its identification. Kenya is the first country to report MLND in Africa. Wangai *et al.* 2012, reported the occurrence and sever infection of MLND from South Rift Valley-Bomet and Naivasha districts of Kenya in 2012. Subsequently infection of MLND rapidly moved to all direction of Africa. Later on, sever infection was reported from Rwanda (Adams *et al.* 2014), the Democratic Republic of Congo (Lukanda *et al*. 2014), Tanzania, Uganda, South Sudan and Ethiopia (FAO, 2014).

MLND in Ethiopia

A team of scientists from CIMMYT Ethiopia, Ethiopian National Research and Minstery of Agriculture had made quick country wide assessment and confirm occurrence of MLND in Ethiopia for the first time in July 2014 from Upper Awash Valley (George *et, al*., 2015). The rut of introduction to Ethiopia was suspected from border of Kenya where the pathogen reported for the first time in Africa (Wangai *et al.* 2012). However, how and why this pathogen crosses the continent and get to Africa after 40 years was still not apparent. The disease has now gained fast momentum in spreading to all direction of African countries where maize crop is grown without sufficient knowledge how to manage the disease. Prevalence, severity and economic damage of MLND in East Africa are more severe than the other world. Possible factors that contributed to the devastating effect of MLND in eastern Africa the is the introduction of new and perhaps highly virulent strains of MCMV and SCMV, conducive environment for survival and spread of insect-vectors of the two viruses and continuous maize cropping in certain regions leading to build-up of virus inoculums (Cabanas *et al*., 2013 and Manje *et al.*, 2015). Genomic study aimed to investigate MLND causing viruses in Ethiopia. Manistu *et al*., 2017, collected MLND infected maize samples mainly from maize belt region of country like Benishangul-Gumuzi, Oromia and South Peoples Nation and Nationalities (SPNN) Regional State. They found that MLND was caused by MCMV and SCMV. Further, they also confirmed that SCMV is more diversified than MCMV in the country. Some isolates share haplotype similarity with Kenyan and Rwandan isolates, which may be an indication where the virus originated from (Souza *et al.*, 2012 and Manistu *et al*., 2017). Similarly, Cabanas *et al*., 2013 indicate that in East Africa, the MLND was frequently caused by SCMV in synergism with MCMV.

Social and Economic Impact of MLND

All commercial varieties in Ethiopia developed before the occurrence of MLND are found to be susceptible. Conducive environment for survival and spread of insect vectors and continuous maize cropping in certain regions of the country leads to build-up of virus inoculums. Economical and social risk that could occur due this pathogen in Ethiopia would be high, because of several special cases that favor the disease development in the maize belt the region. Experientially designed yield loss of MLND in Ethiopia was however, not yet well conducted and documented. At early stage of is occurrence (in 2014), many maize farms were totally turned-over and replaced by other early maturing crop at Rift Valley where sever infection was reported for the first time and silent damage was occurred before its detection. Similarly, total loss of several hybrid seed production farm of private and public seed enterprise was reported in 2015 from Western Ethiopia. Similarly, in Kenya, highly affected area resulted in 90-100% yield loss (Adams *et al.* 2012, Ochieng *et al*. 2012). Maize field infected early in the cropping cycle resulted in complete yield loss (Wangai *et al*., 2012).

From experiences in Kenya, it was reported that MLND could cut Kenya's maize production by as much as 30% (Bradley, 2016). Reduced maize yields due to the impact of MLND would affect people’s livelihoods as a result of reduced incomes leading to increased financial stress on families, inability to afford basics needs and education for their children. The increased use of pesticides to control the vectors in the production of maize may also have a negative impact on the environment and adds to additional costs on maize production. De Groote *et al*. (2016) conducted community based survey of assessment and distribution of MLN disease in Kenya and reported reduction of 22 -32% of the average maize production in 2013, with an estimated economic loss of 187 million US dollar. In 2012, yield losses of up to 90% resulted in an estimated grain loss of 126,000 metric tons valued at $52 million in Kenya alone (Mahuku *et al.*, 2015).

Physiological and Morphological Character of MLND

Peculiar character of MLND is chlorotic mottling of the leaves, severe stunting and necrosis which as a result hinders the physiological processes of the plant such as photosynthesis, chlorophyll formation as well as denaturing enzymes necessary for the crop which further leads to low maize yields or plant death (Wangai *et al*., 2012). MLND causes a variety of symptoms depending upon genotype, age of infection and environmental conditions. The other common symptoms of MLND include; excessive tillering, severe stunting resulting in premature plant death, shortened male inflorescences, sterile pollen, rotting cobs which develops very few grains, leaf necrosis progressed from the leaf margin to the midrib and dead heart or death of the plants.

Hosts rang of MLND

Experimental result showed that the host range of MLND restricted to the *Poaceae* family where maize is the main natural host (Gordon *et al.*, 1984). They found that the following crop species were susceptible by mechanical inoculation: *Bromus* spp., *Digitaria sanguinalis, Eragrostis trichodes, Hordeum* spp., *Panicum* spp., *Setaria* spp., *Sorghum* spp. and *Triticum aestivum (*Bockelman *et al.*, 1982).

Transmission and survival of MLND

MLND causing viruses can be transmitted by a range of insect vectors endemic in East Africa including maize thrips, aphids, beetles and root worms (Cabanas *et al.* 2013, Brault *et al*. 2010). Insect vectors are the primary mode of plant to plant and field to field transmission of MLND. Both viruses can also be transmitted by seed contamination which, can contribute to rapid and long-range dissemination of the disease (Jensen *et al*. 1991: Zhang *et al*. 2011). MCMV is transmitted mechanically and spread by several insect vectors including maize thrips (*Frankliniella williamsi*) (Jiang *et al*., 1990), maize rootworms (*Diabrotica undecimpunctata*, *Diabrotica longicornis* and *Diabrotica virgifera*), cereal leaf beetles (*Oulema melanopus*), corn flea beetle (*Systena frontalis*) and *Chaetocnema pulicaria* (Jensen, 1985).

Approach of Integrated Management Strategies of MLND

MLND has no cure but the disease can be controlled through employing integrated pest management approaches. Scouting of the field should be done and once the diseased plants are found, those plants need to be up-rooted, buried deep or burnt in an isolated part of the farm. The use of treated and certified seed is encouraged to control the vectors coupled with foliar sprays just before or when the plant reaches knee height to control the population of vectors. Keeping the field free of weeds helps to minimise host plants for vectors and reduced alternative host. Integrated nutrient management (application of organic and inorganic) fertilizers to boosts the plants vigour and encourage maize defence against the virus.

The national and regional government policy intervention has also significant role in MLND management. Establishing of nationally and regionally coordinated active and strong task forces comprising different discipline for monitoring and advising the progress of disease is critically imperative. Frequent technical consultative forum at regional and national level, revising the regional quarantine lows and regulations both for seed and other source of inoculums is also significantly important (De Groote *et al*., 2002).Scientist in East Africa proposed two levels of MLND management approaches. The national /regional approached and farm level approach. At farm level, maintaining the maize farm clean and free from weeds, execution of early and better land preparation, timely planting, the use of the most appropriate and recommended maize varieties, proper fertilization, and regular crop rotation and up-rooting or roughing of the affected plant. The Ministry of Agriculture and Natural resource or Regional bureau of agriculture set aside funds for addressing issues related to MLND, Support small scale farmers with subsidized registered systemic and contact insecticide for management of vectors, Support rapid response alert and disease surveillance for early detection. Formulation of a strategy against maize mono-cropping system, strengthen quarantine by lows, establishing national and regional multidisciplinary task forces.

MLND resistant variety development

Development of virus-resistant varieties is an economically viable and environmentally sustainable approach for disease control, however this requires identification of resistant genotypes, and incorporation of the disease resistance into agronomically desirable varieties. Screening maize germ plasm against MLND demands expensive laboratory facilities and skill. In east Africa, a single fully equipped MLN screening laboratory was established in Kenya by CIMMYT and the Kenyan government at Naivasha district in 2013 (CRP Maize 2013). Since 2013, CIMMYT and its partners have screened more than 95,000 maize germplasm including elite inbred lines from CIMMYT and the International Institute of Tropical Agriculture (IITA) at Kenya, Naivasha. Very recently nearly 100,000 maize germplasms have been screened against MLND at Kenya and found nine first generation MLND-tolerant elite maize hybrids and released in East Africa (Batan, 2016). Several second-generation, CIMMY-derived, MLND-resistant hybrids are currently being tested under national performance trials in Kenya, Tanzania and Uganda. Yoseph *et al*., 2017 screened more than 430 crosses against MLND at Naivasha, Kenya laboratory. They found five MLND resistant inbred lines: CKDHL120918, CKTI0137, CKTI0138, CML494, and CKDHL500 which had negative and significant general combining ability (GCA) for MLND severity and positive GCA for grain yield. This new MLND tolerant inbred lines and single cross hybrids of tropical maize variety has a yield potential 6.0-6.6 t ha^{-1}. These varieties could used as source to improve both public and private commercial maize breeding programs in eastern Africa

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A Review of Termite Biology, Ecology and Prospects for Integrated Pest Management Approaches

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ABSTRACT

Termites are highly specialized social insect with diversified species classified under Class Insecta *and Order* Isoptera. *Termites comprise a large and diverse group of species (about 4000 species) which are ecologically and economically important organisms that feed on cellulose in symbiotic association with* protozoa *and some bacteria species. Ecologically, termites have both negative and positive impacts. Ecological benefit is their significant role in decomposing cellulose, nutrient recycling, improving soil structure, improving infiltration and soil fertility. Biological benefit of termite is the use some termite species as food source for human being in some countries. Termite has however, significant negative ecological and economical impact inducing disaster climatic changes. Termite reproduces and eats in non-stop fashion having power of removing all land cover vegetation within short season and catalyzes land slide and community displacement. Disaster ecological effect has occurred when termite population allowed grow-over and over weighing the natural ecological supply. Knowledge of termite ecology and biology such as reproduction, social structure and behavior is an important part of integrated termite management. Integration of compatible management option such as termite population management, soil fertility improvement and plantation of tolerant plant species, biological control and application of soil acting insecticide are widely applicable to limit termite population and their damage. Termite mound poisoning using termite mound injection technique is economically and technically suitable option for mound building termite for small scale farming communities. Total termite eradication is impractical because of their ecological benefit, however, reduction of termite population through integrated pest management and keeping the natural ecological balance is practically approved key to combat the adverse effect of termites.*

Key Words and phrases: integrated pest management, termite biology, termite social structure

INTRODUCTION

The word termite is of a Greek origin, Tarmes means wood boring worms. Taxonomical classification of termite was reported by Engel and Krishna (2004). They classified termites based on their food source and summarized into *Animalia kingdom*, *Arthropoda phylum*, *Insecta class*, *Isoptera order* and split into six families: *Hodotermitidae* (damp wood termites), *Kalotermitidae* (dry wood termites), *Mastotermitidae*, *Rhinotermitidae* (subterranean termites), *Termitidae* and *Termopsidae*. Morphological structure of termites consists of a thorax joined broadly to the abdomen without the waist characteristic like bees, ants and wasps (Grimaldi, Engel, 2005). Behaviourally, termites are prime examples in using decentralised and self-organised social life systems through swarm intelligence and cooperation to exploit food sources and detect environments. Termites comprise a large and diverse group of ecologically and economically important insects that feed on cellulose. About 4000 species of termites estimated to exist on earth, of which 2600 recognised species cause economically serious damage to buildings, crops or plantation, forests and also eat bones and carcasses. Africa is by far the richest continent in termite diversity. About 85% of the economically important species found in Tropical Africa farm and rangeland (Eggleton 2000). Accordingly, termites have ecological and biological benefits, however, termites are also the most destructive agents of our ecosystems and their management requests sound strategies and biological knowledge.

Ecological benefit of termite

Termites are cryptic social insects that play an important role in the carbon cycle and act as important ecosystem engineers in most of the world's tropical ecosystems. They contribute to the carbon cycle by feeding on a wide range of living, dead, and decaying plant matter (Bignell and Eggleton, 2000; Traniello and Leuthold, 2000), Nutrient recycling by combination of wood and other plant residues, modifying soil physical properties such as texture, water infiltration, and improve soil nutrient contents at various spatial scales (Dangerfield, *et al.,* 1998).

A distinct controversy exists between the pest management researcher and ecologists considering termite as 'pest', or 'ecological engineers'. There is no doubt that some termite species cause significant damage to crops, rangeland, trees, and structural timber and stored products. However, termites are also important ecosystem that have been shown to play a significant role in shaping ecosystem function and as a hot spots of plant growth, animal productivity and diversity (Pringle *et al.,* 2010; Bonachela *et al.,* 2015, Costa *et al*., 2009, De Souza *et al.,* 2009). Most species of termites have symbiotic bacteria within their intestines that help in converting cellulose into food for the colony which is impossible for higher animals. Although termites are soft-bodied insects, their hard saw-toothed jaws work like shears and are able to bite off extremely small fragments of wood and some species destroy all live plants within a short period of time causing heavy ecological impact by removing all vegetation cover (Ulrich and Nicole, 2002).

Ecologically, termites have both negative and positive impacts. The positive advantages are that they are helpful in decomposing hard soil and let air to enter deep in the ground for further decomposition, nutrient recycling and create favourable shelter or habitat for reptiles. Larger termite mounds also provide habitats for smaller animals like birds, scorpion, lizards, snakes and the like that are seasonally inundated by a rainy season. Becker (1976) explained that all termites eat cellulose in various forms as a plant fibre, which is a rich energy source, but remains difficult to digest so that they have symbiotic bacteria in their digestive system, which enhances them in decomposing cellulose into carbohydrates and sugar. Hagen (1858) also reported that termite gut contains four different flagellated protozoa that assist digestion. Termites rely primarily upon symbiotic protozoa and other microbes in their gut to digest the cellulose and absorb the end products, whereas gut protozoa in turn rely on symbiotic bacteria embedded on their surfaces to produce some of the necessary digestive enzymes (Eggleton, Taysu, 2001).

Gradual removal of vegetation cover causes climatic change that have consequences like the appearances of new types of diseases, which more or less affect humans, animals and plants. Thus, when the environment loses its substantial biological wealth, biotic ecosystems transfer into abiotic stress leading to removal of vegetation cover, the disappearance of species, disturbance of hydrological cycle and climatic change leads in to desertification and terrible conditions (Piper, 2007). Under high pressure of termite infestation total vegetation can be removed and land left without vegetation and exposed to sever erosion and land slide. This is the case where thousand hectares of fertile land of western Oromia (Ethiopia) currently left barren land and malformed and unproductive. Termites often cause shortage of food, fodder, fuel energy, construction and industrial materials, death of wild life and natural resources.

Biological benefit of termite

Some authors reported that termite has been widely used as food source in many countries throughout parts of Asia, America and Africa and used as sources of diet (Nyeko and Olubayo, 2005). According to survey report from Uganda, most people consumed *T. microcarpus* for its medicinal value and just as a food. Nutritive value analyses of termite species demonstrate that low fat, rich in protein, minerals and vitamins (Kabasa *et al*., 2006, Opige *et al., 2006).* In Cameroon, *T. titanicus* is dried and mixed with meat for the consumption of underweight children (Yongabi *et al., 2004). Termitomyces* species are also used in the treatment of various human diseases (Kabasa *et al.* 2006) Figure 1. Some communities also have an intimate knowledge of the association between termites and edible mushrooms (Nyeko and Olubayo, 2005, Kabasa *et al*., 2006).


Figure 2: Commercial and homemade termite dish

The *Macrotermitinae* cultivate edible mushrooms in the genus *Termitomyces* on termite mound soil. Harvesting of naturally grown edible mushrooms from termite mound soil is also common practise in rural Ethiopian. Quantitative studies in Burkina Faso demonstrated termite infested soil have significantly increases soil infiltration rates and reduce moisture stress (Mando *et al.*, 1999). Experimental study show that yield of sugar cane planted on termite mound soil was five times greater than yield of adjacent soil (Cadet *et al*., 2004). Similarly, plant biomass and grass growth were significantly higher around termite soil compared with the open field (Steinke and Nell, 1989). Most research shows that termite mound soil contains significantly higher concentrations of total N and exchangeable cations than the surrounding area (Holt and Lepage 2000, Chikuvire *et al.,* 2007). Similar result from Bako Agricultural Research Centre (Ethiopia) showed termite mound soil significantly increase yield of cereals, pulse and forage crops continuously for five years. In addition, termite mound soil has other positive effects on crops such as suppression of invasive weeds. For example *Straiga* infestation in sorghum effectively suppressed by termite mound soil (Andrianjaka *et al.*, 2007).

Termite biology and social structure

Reproduction of termites:

The knowledge of termite biology (reproduction, social structure and behaviour) should be a part of integrated termite management. According to Eggleton (2000) as a social insect, termites live in social colonies (Fig 3). At their maturity stage termite colony population varies from several hundred to several million individual including reproductive females, males, sterile workers and soldiers. A group of soldiers commonly contain members of both sexes in equal ratio, each developed from fertilised eggs. At their initial sage of their reproduction, termites have two pairs of membranous wings (Fig 2), nearly equal in size that break along a suture when shed, leaving only the wing base or scale attached to the thorax, which is the most distinguishable characteristic of isopteran termite. Behaviourally, termites are prime examples in using decentralized and self-organized social life systems through swarm intelligence and cooperation to exploit food sources and environments that could not be available to any single insect acting alone. A typical colony of termites contains nymph alates (semi- mature young), workers (pale-coloured heads), soldiers (red-coloured heads) and reproductive individuals of box both sexes (queen and king) (Fig 6 A and B.)

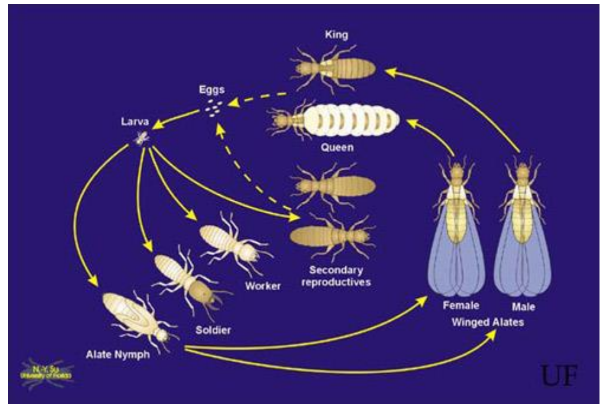

Figure 2: Winged Queen at early stage (alates) **Fig 3: Termite reproduction & social structure**

Eggleton and Tayasu (2001) explain that termites have social complex structures of workers, soldiers and alates beside the queen and the king with complex mutualism within guts and fungi groups.

Social structure of termites

Termites are social insect like ants, bees, and wasps, however, termite colonies are highly integrated than other social insects. There is a reproductive and labour division in termite colony. Termite colonies can vary in size from only two individuals (a mated pair or embryonic colony) to hundreds of thousands or perhaps even millions of individuals. Termite colonies contain several forms of castes, including: larvae or immature, workers, soldiers, nymphs and reproductive (queen and king)

Soldiers: Can vary greatly in morphology but, generally, have larger, yellowish-brown or brownish heads and larger mandibles than workers. They guard the colony and defend it against predators (Fig 4).

Figure 4: Soldier caste of dry wood, subterranean and damp wood termites

Queen and king: Are reproductive/ or sexual adults. Have yellow-brown or black bodies (Fig 5). Initially they have two pairs of wings of equal size and are referred to as alates. After their swarming flight they shed their wings and establish new colonies. The main function of termite queen is to lay eggs, sometimes thousands in a single day. A king or male reproductive is always by her side. New kings and queens are winged during their early adult life and generally fly less than 100 meters from their colony (Fig 2). Once they land on the ground they find a mate and begin the search for a nest site. A colony begins when a mated pair constructs a small underground chamber, which they enter and seal. Termite queen reported be long lived unlike other insect. Queens and kings can have a life span of a decade or more.

Termite reproduction rate was studied and reported from western Ethiopia by Wako 2015. He found an average; termite queens lay about 25 eggs per minute, 36,000 eggs per day and 13,140,000 eggs annually. He also reported that the death of a queen does not affect the colony, because four small queens are formed and one of them becomes the queen and replaced the dead queen promptly. Killing queens in mounds or nests is not a solution to eradicate termites, because the standby females from the colony may instantaneously replace the dead one within 24 hours.

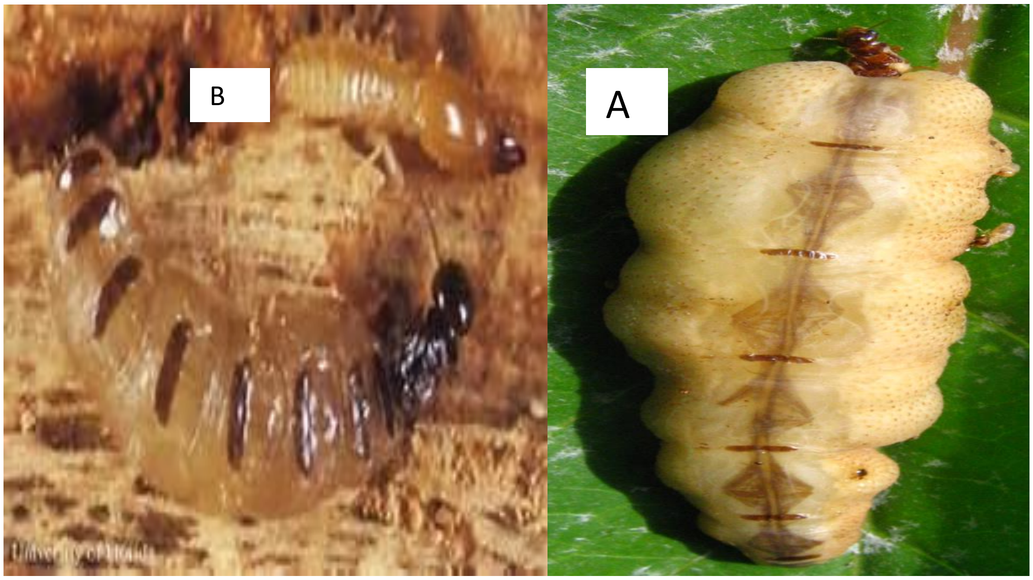

Figure 5: Termite queen (A) and king(B)

Reproductive rate of termite can be varied depending on favourable condition. According to Vagner (1987) a queen of termite laid one egg every 2-3 seconds, 20,000 to 35,000 of eggs per day and 12 million eggs annually for several years. Conversely, if overproduction of one caste occurs, selective cannibalism applied and restores their balance naturally. Swarming period is the most dangerous when millions of young females and males fly out in the evening during the spring or short after the rain. Self-organising systems of activity guided by the swarm intelligences, in which the winged males and females return to the ground and shed their wings. The royal couple lives in a royal chamber in the soil, enters the chamber and seals the opening. The queen is originally slim and winged corpuscle that develops into an amorphous shape of 6 cm long cream coloured body and lives in a special isolated chamber or royal cell and commonly mates with adult males (king) for fertilisation. After mating, the queen starts laying yellowish white eggs and hatch after an incubation period of 50–60 days.

Supplementary reproductive: Most termite colony has secondary reproductive from the reserve line. In case of death of primary reproductive, supplementary reproductive can be produced from within the ranks of a mature colony and take over the reproductive function of the colony. Supplementary reproductive's are often lighter in colour than the primary pair and are commonly found in clusters of four to six or more. Recommendation of termite management by queen removing was not effective and makes more difficult due the ability to produce supplementary reproductive, and this phenomenon was not understood for a long time.

Termite integrated management approaches

In order to alleviate the negative impact of termites on environments or to fight against the damage of termite application of insecticide may be effective to certain extents, but cannot be the sole and best recommendation due to its negative environmental impact. Application of

Integrated Pest Management (IPM) approach is the best way to manage termites. Termite IPM focuses on optimization of termite control in an ecologically and economically sound manner. Application of termite IPM in agricultural is however, at enfant stage and the most difficult and expensive applied research.

Termite IPM was devised to address the problems associated with agricultural intensification during the 1990s (Dent, 2000). The central core of IPM initiation are environmental pollution and public hazards, secondary pest outbreaks, host plant resistance breakdown and pesticide resistance. Pesticide resistance, however, has never been recorded from social insects such as termites (Mumford and Norton, 1984). When *Chlorinated hydrocarbons* were widely used for termite management, little attention was given to IPM. Hence it was strongly effective and long lasting. Due to its high potential risk, it was banned from world market and incites application of IPM (La Fage, 1986).

Most effective termite IPMs

Termite population management: Termite population control at colony level targets to an interconnected foraging group. This population control measure targeted to kill all genealogically related members of the colony (Myles 1996). Insecticide with long lasting and non repellent active ingredient could crashed down about 100, 000 to 1, 000, 000 population of a subterranean termite those sharing the same tunnels at a distance rang of 100 m (Grace *et al*., 1989; Su *et al*., 1993).

Biological control agents: Field and laboratory studies have consistently demonstrated the pathogenicity of biological agents such as the entomopathogenic fungi like *Metarhizium species*, and *Beauveria species* were identified as effective biological termite control agents (Lai *et al*., 1982). *Beaveria* and *Metarhizum* were demonstrated in west Ethiopia and showed effective control ageist subterranean termites. For wide application, however, there was no bulk supply on local market. Field application of biological control in most case are not successful, because termites are known to be repelled by pathogenic microbes, the discovery of non-repellent strains are key to the successful control (Staples and Milner, 1996).

Metabolic inhibitors: This trap-treat-release approach depends on the behavior of the termites to distribute the toxicant among nest mates. A higher concentration of toxicant can be incorporated in coatings than in edible baits without eliciting repellency (Myles, 1996). Application of trap-treat-release approach was significantly suppressed termite damage in the field (Myles, 1996).

Insect growth regulators: Injection of a *juvenile hormone* in the colony enhance soldiers population in colony and significantly reduced workers population and resulted in colony starvation, (Hrdy and Krecek, 1972; Hrdy, 1973; Haverty, 1977). Field application of *juvenile hormone (fenoxycarb)* resulted in significant reduction of field damage of subterranean termites (Jones, 1989).

Termite IPM in Western Ethiopia

Soil mulching: Mulching materials pull away termites from host plant as termite prefer dry matters than live plants. For example experiment at Bako Agricultural Research Centre showed that maize stover mulching under maize and hot pepper significantly reduced termite damage to maize and hot pepper. Mulch improved soil organic matter which favor predatory activates of ants. Ants infest termite mounds and colonize as natural predator. Red ants activity and population increased under mulched plots **(**Korensky 1974).

Predatory: Red ants are the first class enemies of termites (Korensky 1974). In view of that, one can feed red ants with meat and settle a damp of ants near the mounds or nests of termites and continuously march ants against termites to devastate them through time. It is confirmed that red ant workers enter into the mound, rush diffusively through all cavities and collect all eggs and destroy or eat them. Red ants are the real enemies of termites and so that the soldiers perform practical defending task against ants.

Earth pigs or Aardvarks: A mmammalian termite digger locally known as ***'Awaldigessa'*** is nocturnal animals that are widely distributed all over Ethiopia and naturally control termite population. They begin searching for termites at night and capable to dig very deep into the hard soil and hunt for termite. Aardvarks are insect hunter animals or termite-eaters using their thin and very long tongues to collect termites and consume as major sources of food.

Earth pigs (Fig.7) cause total destruction of termite colony and repeated the same action on the same colony seasonally following regeneration of the colony. It has a natural inherent capacity to detect invisible mounds which is difficult to locate even by experienced researchers. Communities of western Ethiopia reported increase of termite population and crop damage after local hunters migrated from neighboring region targeting this animal for their daily consumption.

Figure 7: 'Awaldigesa'/ Earth Pigs

Soil conservation structure: Cross sectional cutting of soil in bench terracing cuts termite tunnels in sub soil and expose the tunnels to flooding, and temporally block foraging activates of worker termites. Foraging activity of termite were significantly reduced causing starvation and blocking migration of colony to the food source. Soil conservation structures used as a briar and reduce termite colony.

Plantation: Defensive plants could be applied for termite management, which are typically achieved by secreting anti-feeding chemicals such as oils, resin and lignin into the woody cell walls. Many of the strongly termite resistant tree species have heartwood timber, which is extremely dense due to accumulation of resins that reduces the ability of termites to efficiently digest the cellulose (Abe *et al.*, 2002).

Neem trees are useful repellent in imposing negative influence on activities, lifecycle and population of termites due to the reason that they contain special properties, which can affect the lifecycle of insects (Ruskin, 1992). Plantation of termite tolerant tree species and forage grasses on highly degraded lands has been proved that they highly improves termite damage and degraded land can easily rehabilitated and recovered.

Termite population control: Termite population control technique is to eliminate or suppress termite populations of some colony. Indigenous knowledge of termite population control such as mound poisoning**,** mound destruction**,** queen removal, mound smoking/ tunnel fumigating and mound flooding are duly acknowledged and scientifically approved showing significant impact in termite management. Such techniques are widely promoted and currently under wide extension.

Application of soil acting insecticides: The objective of this technique is to exclude foraging termite colons (workers) from crop roots. Several soil acting and safely degraded modern generation insecticide were tested and recommended for Western Ethiopia. Commercial insecticide like *Chlorpyrifos 60% EC, Endosulphan 60% EC and Cypermethrin* 60% EC are recommenced as soil application (drenching) under rows of crop at rate of 5 liter/ha.

Termite mound poisoning: Queen removal is not effective because most termite colony have secondary reproductive from the reserved line**.** Mechanical termite mound destruction to find queen from deep specialized structure is more difficult and labour intensive. A technique of total mound poisoning (Fig 9: A and B) without mechanical destruction which resulted in total colony poisoning was developed by Bako Agricultural Research Centre (Teshome, 2008). It is highly effective, cheap and easy for application and designed from local material (galvanized iron pipe) can easily manufactured by local metal workers (Fig.8 [A,B and C])

Soil fertility management: Termite depends on cellules materials obtained from dead organic matter. Termite damage is usually high in poor soil than organic matter rich soil. Soil fertility improvement is an integral part of termite management.

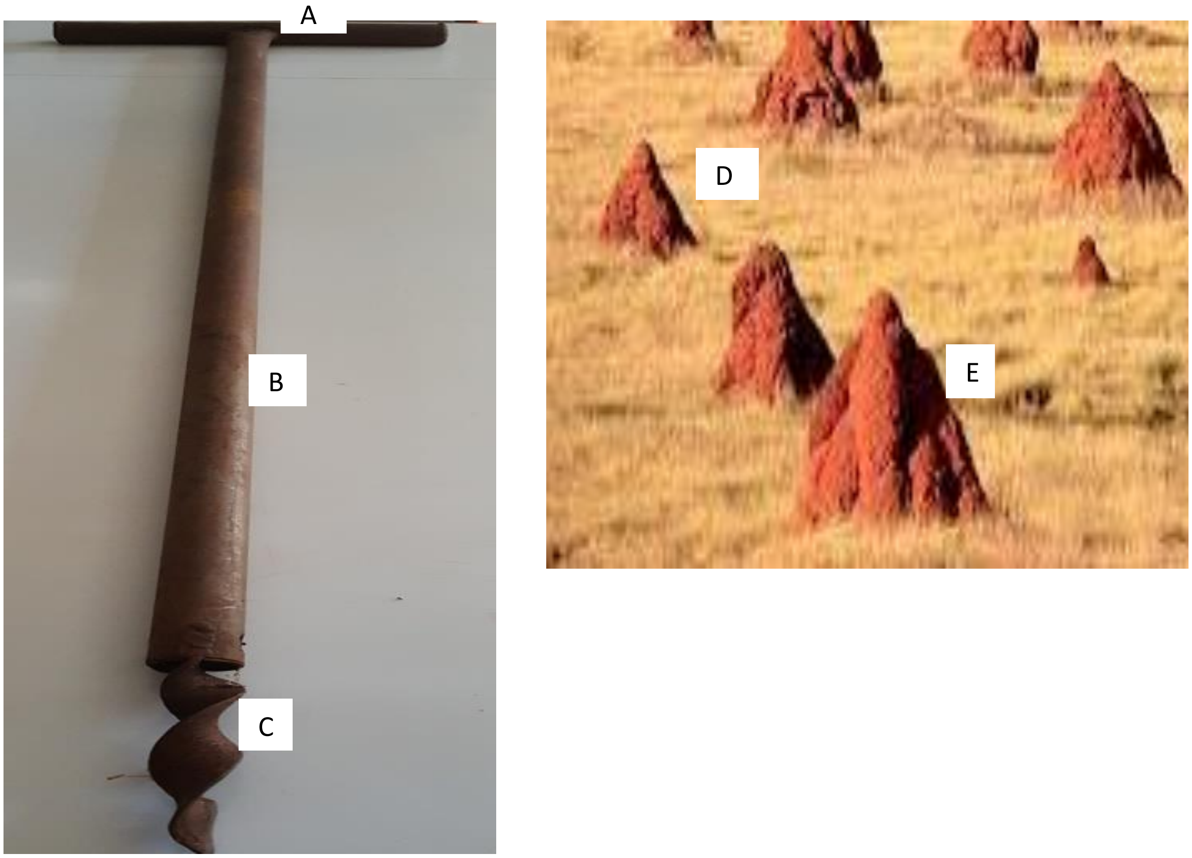

Figure 8: Termite mound injector (A) top handle (B) injection hole (C) curved mound cutting edge (D) small size mound and (E) medium to large moude size.

Termite mound auger is a modification of soil auger med of metal pipe with ½ inch width and 1.50 m height with perpendicularly fixed handle from top (Fig.8-A) and curved sharp perforated edge from bottom side (Fig. 8-C) for penetration and chemical injection (Fig. 8-B). Termite mound size varied depending on colony size and age of mounds. Depending on size of mound two techniques of injection was recommended. For relatively larger mounds (Fig. 8-E) three point injections mainly from vertical top and from two sides and one vertical injection for smaller mounds (Fig.8-D).

Figure 9: Mound penetration (A) mound poisoning or insecticide injection (B)

Rate of chemical application also varied depending on mound size. For bigger mound 100-120 ml of *Chlorpyrifos 60% EC or Endosulphan 60% EC or Cypermethrin* 60% EC diluted in 30 litters of water and smaller mound and 80 ml insecticide at 20 ml of insecticide was recommended. The technique was found to be 95% effective and resulted in immediate knocking down of termite colony and resulted in irreversible mound destruction within two months.

CONCLUSION

Termites are highly diverse species and extremely specialized social insect. Termites have both ecologically beneficial and disaster effect. Termites are cellulose digesting organism in symbiotic association with *protoza* and bacteria which are impossible in other organism. This organism have important role in nutrient recycling, decomposition, improving soil structure and fertility, improving vegetation growth and food source for human in some parts of world. Despite their ecological importance termite cause ecological disasters removing all vegetation and cause climate change, makes un-productive land, induce land slide and displacement of agricultural community. Economical and ecological losses due to termite are not well documented in Ethiopia despite of huge agricultural lands become unproductive due to termite effect and the challenge is currently increasing. Well designed integrated pest management strategies are highly demanded to combat the disaster impact of termite on agricultural ecosystem. Implementation of termite IPM needs knowledge of termite biology, ecology and social behaviour. Integration of all possible and compatible termites IPM options including soil fertility management and rehabilitations of termite affected land are critically important and need continuous implementation strategies.

Termite population management like mound destruction, encouraging natural enemy such as red ants and mammalian earth pigs, farmers knowledge like mound fumigation (flooding and smoking) have significant role in subterranean termite population management. Mound destruction and queen removal cannot be sustainable management option as termite has inherent capacity to replace new queen. Mound poisoning technique using insecticide injection is effective and cheap technology for small scale farming community where mound making termite species are dominated. Total avoidance and eradication of termite species is impractical in ecosystem however, keeping the balance is advised to maintain ecological benefit and avoid disaster effect of termite.

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