Local Knowledge of Farmers on Opportunities and Constraints to Sustainable Intensification of Crop-Livestock-Trees Mixed Systems in Lemo Woreda, SNNPR Region, Ethiopian Highlands

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Plates: Photos of Jawe and Upper gana, Lemo woreda. Taken by Anne Kuria, July, 2013

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Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

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1. INTRODUCTION

Agriculture in the 21st century faces multiple challenges: it has to produce more food and fibre to feed a growing population with a smaller rural labour force, more feedstocks for a potentially huge bioenergy market, contribute to overall development in the many agriculture-dependent developing countries, adopt more efficient and sustainable production methods and adapt to climate change (FAO, 2009b). As the world's human population of over 7.3 billion is expected to hit 9.1billion by 2050, food needs have also increased. Maintaining the momentum of growth in agricultural productivity will remain crucial in the coming decades as production of basic staple foods needs to increase by 60 percent if it is to meet expected demand growth (FAO, 2009a). With farming being the dominant land use in Ethiopia, options for increasing food security and improving livelihoods include agricultural land expansion which has led to deforestation and loss of important ecological goods and services; and intensified agricultural production., which has led to land degradation and exhaustion leading to a decline in land productivity (Bishaw, 2001) (Oba & Kotile, 2001)

Extensive agriculture involves expansion into new lands, but the competition for land from other human activities makes this an increasingly unlikely and costly solution, particularly if protecting biodiversity and the public goods provided by natural ecosystems is given higher priority (Millennium Ecosystem Assessment, 2005). Therefore, intensive agriculture remains the most viable solution to increasing food production. Traditionally agricultural intensification has been defined in three different ways: increasing yields per hectare, increasing cropping intensity (i.e. two or more crops) per unit of land or other inputs (water), and changing land use from low- value crops or commodities to those that receive higher market prices. However, these approaches have negatively affected the environment, hence the need to undertake agricultural intensification sustainably (Pretty, Toulmin, & Williams, 2011). Sustainable agricultural intensification therefore is defined as producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services.

Ethiopia's economy and the wellbeing of its people are closely linked to agriculture and the use of natural resources, hence the Ethiopian Government launched innovative approaches that include a "Climate Resilient Green Economy" initiative which include implementation of agroforestry practices, conservation agriculture, reforestation of degraded lands and land affected by gullies and slopes including exclosures. In line with this initiative, the Africa RISING project focuses on sustainable intensification (SI) of mixed tree-crops-livestock systems in the Ethiopian highlands at the household scale, with impacts ultimately geared towards influencing change at the landscape scale in the long-run. Sustainable intensification will very often involve more complex mixes of domesticated plant and animal species and associated management techniques, requiring greater skills and knowledge by farmers. To increase production efficiently and sustainably, farmers therefore need to understand under what conditions agricultural inputs (seeds, fertilizers and pesticides) can either complement or contradict biological processes and ecosystem services that inherently support agriculture ((Pretty, Toulmin, & Williams, 2011); Settle and Hama Garba, 2011). Therefore, in order to understand the complex interactions between all the main components of smallholder mixed farming systems, the World Agroforestry Centre (ICRAF) has been undertaking local knowledge studies to elicit local knowledge of farmers regarding how they understand and interact with resources that their livelihoods depend on. This was done in the eight AfricaRISING (AR) sites in the Ethiopian highlands, with two sites being located in each of the four main regions of Ethiopia namely: Tigray, Amhara, Oromo and the Southern Nations, Nationalities and People's Region (SNNPR). This report presents results from two of the AR sites located in Lemo woreda (Jawe and Upper gana kebele) , located in the SNNPR region.

Conducted under the Africa RISING project, the overall objective of the study was to characterize local knowledge of farmers about resources which their livelihood depends on. This research is one of the several studies that are geared towards contributing to the achievement of sustainable tree-crop-livestock intensification as a pillar for the Ethiopian Climate Resilient Green Economy Initiative by providing opportunities for integrating early win tree species and management options in fields, farms and landscapes customized to local conditions and circumstances. Through identifying opportunities through which trees-crop-livestock mixed system can be sustainably intensified, this will contribute towards achieving whole System Level Outcomes (SLO's) namely: reducing rural poverty and promoting income diversification, improving food security, improving nutrition and health and ensuring sustainable management of natural resources. Sustainable intensification of these mixed farming systems will be achieved by expanding the scope of options promoted by the Africa RISING initiative, and by targeting species and management options appropriately to specific site conditions and farmer circumstances.

1.1 Specific objectives of the study were:

1. To assess land use and livelihood strategies at the household level
2. To identify and map out community resources
3. To determine temporal variation in availability of provisioning resources (fodder, crops, fuel, etc.)
4. To characterize existing tree cover and assess the drivers of land use/ tree cover change
5. To identify existing challenges and assess opportunities for sustainable intensification

1.2 Research Questions

1. What is the range of land use and livelihood systems in the Lemo and Basona woreda?
2. What are the main resources farmers utilize and when in the year are they available?
3. What functions do trees play in farmers' livelihoods in these sites?
4. How have tree cover and land use systems changed over time?
5. What are the constraints to agricultural intensification and what are opportunities for intervention?

2 RESEARCH METHODOLOGY

2.1 Study area characteristics

Lemo Woreda (Jawe and Upper Gana kebeles) is bordered on the south by an exclave of the Benishangul-Gumuz Region, on the southwest by Sasiga, on the west by the Benishangul-Gumuz Region, on the north by Ibantu, and on the east by Gida Kiremu (Figure 1). The administrative center of the woreda is Gelila. Hadiygna / Hadiya language is spoken in this Lemo woreda.

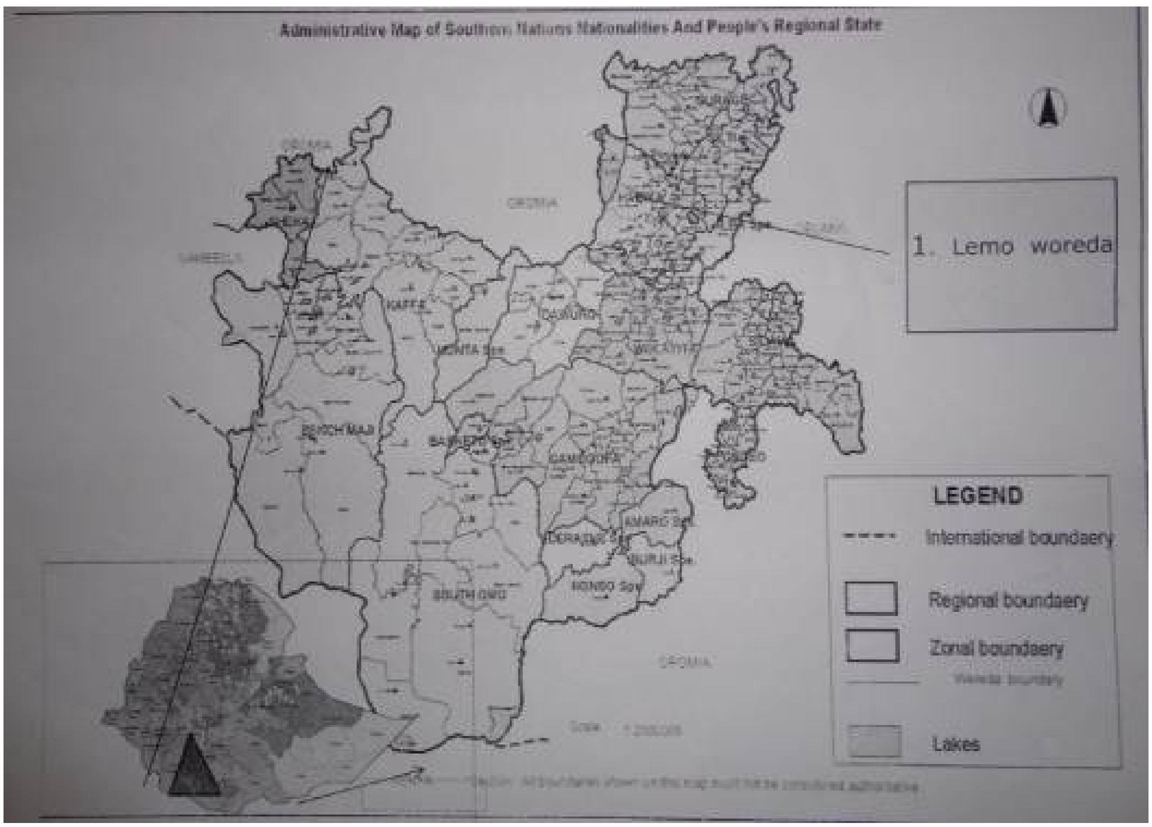

Figure 1: Map showing location of Lemo woreda Source: Lemo woreda agricultural office

Table 1 below provides some additional background information of both Jawe and Upper gana kebeles

Table 1: Background information of Jawe and Upper Gana kebele

LEMO WOREDA	Jawe Kebele	Upper Gana kebele
Agroecological zones	Mainly Weyna dega	Mainly Weyna dega
Topography	Less undulated/ sloped	More undulated/ sloped
Population	Total -6647 (male-3257, female-3390)	Total -6195 (male-3107, female-3088)
Household numbers	1160	750
Total Areas of kebele	1313ha.	1898.6 ha.
Rainfall	980-1200mm	900-1400mm
Altitude	2129 to 2244masl	2129- 2400masl
Cultivated land	1161ha. (973ha-annual crop, 188-perrenial crop)	1218ha.
Grazing land	88 ha.	Household grazing land- 4.5ha.
Forested land	2ha natural forest, 26ha planted forest	

Source: Jawe and Upper gana kebele administration offices

2.2 AKT Methodology

The Knowledge Based Systems (KBS) approach developed at Bangor University was used for collecting local knowledge about agricultural intensification on mixed crop-livestock-tree systems. This study was guided by local knowledge elicitation guidelines (Pratap *et al.* 2009; Sinclair and Walker 1998; Walker and Sinclair 1998); where three stages namely: scoping, definition and compilation were undertaken (Figure 2). Local knowledge elicitation exercise took place between July 16th to August 9th, 2013. Various activities of AKT methodology undertaken are highlighted below.

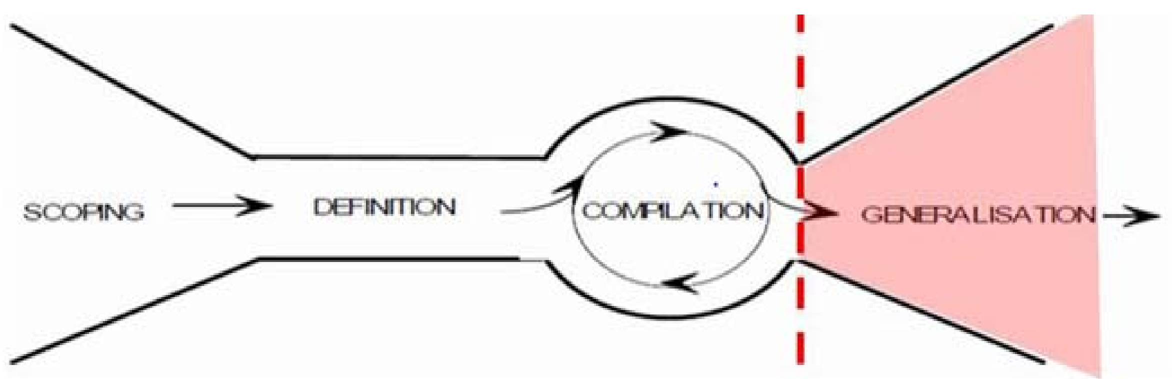

Figure 2: Local knowledge elicitation stages Source (Sinclair & Walker, 1998; Walker & Sinclair, 1998)

Scoping Stage: At this stage, activities included:

- Key informant interviews were held with agricultural officers and development agents working with crop, livestock, and natural resource management departments (Figure 3a). This exercise helped to characterize the landscape and predominant land use issues, and informed the stratification and sampling design for the major interviewing stage.

Figure 3: Development Agents being interviewed in Jawe kebele (a); and ICRAF's Dr. Aster Geberkristos and Dr. Kiros Hadgu, and Lemo woreda's agricultural officer Mr. Tamrat Aerjno paid a visit to a model farmer in Upper Gana kebele (b) Photos by Anne Kuria, July 2013, 2013

- Transect walks were conducted and fed into characterization of the landscape and land use practices, and also helped the team in identifying the main stratification criteria to use when selecting the farmers (Figure 3b).

Definition stage

This stage was undertaken to define knowledge boundaries, and the strata. During this stage, farmers were selected for focus group discussions and household interviews to characterize land use and livelihoods at the landscape level and individual farm level respectively. The 2 kebeles in each woreda had been pre-selected during project inception stage based on various criteria including farmers having at least 25% land under wheat production. Also, another criteria was previous or current engagement with National Agricultural Research System (NARS) and partner programmes in order to capitalize on potential synergies with existing activities; and previous and current engagements with Agricultural Growth Program (AGP) activities and previous / current USAID-supported initiatives. Also, the two kebeles selected were further differentiated in terms of market access because access to markets is one of the major drivers of intensification that is relatively easily and rapidly assessed.

Focus group discussions (FGDs) were conducted whereby farmers participated in various activities such as: participatory village resource mapping, historical timelines, seasonal cropping calendars and land use and livelihood mapping (Figure 4). These activities helped to characterize farmers' access to resources and livelihood strategies.

Figure 4: Yohannes Horamo guiding farmers through a village resource mapping exercise as Tamrat Aerjno looks on in Upper gana (left); and Habtamu Debelie moderating a similar exercise in Jawe kebele. Photos by Anne Kuria, July 2013, July 2013

Compilation Stage

This stage was achieved through an iterative approach involving eliciting and recording knowledge from individual farmers, then evaluating the knowledge obtained, then going back to the same farmers to probe for more indepth information or clarifications until the desired information was obtained. Activities undertaken during household interviews included.

- Farm characterization was done through drawing farm sketches with the farmers or generally identifying and describing resources found on the farm such as niches with trees on farm, soils, crops, livestock and other resources.
- Also undertaken was landuse and livelihood analysis with the aim of synthesizing information about the use of land and other resources by the different groups of farmers within each kebele in order to understand the various dimensions of farmers' livelihood strategies and associated opportunities and constraints.

- In order to assess the role of trees on farmers' livelihoods, tree species identification and assessment of utilities and services exercise was carried out.
- Tree management and phenology- in order to assess farmers capacity to maintain trees onfarm and in landscapes;
- Seasonal calendars of fodder, fuelwood, and other tree products were undertaken in order to assess the availability of these products throughout the year; and identify opportunities (gaps) for future interventions

Local knowledge interviews should minimize farmers' disruption of their working schedule. Weather permitting, interviews were carried out outside the farmers' house and on the farmer's land so that it was easy for both the farmers and the interviewers to visualize resources being talked about and could refer to such resources explicitly (Figure 5).

Figure 5: an interviewee pointing at a resource during farm sketch drawing exercise in Jawe kebele
Photo by Anne Kuria, July 2013, 2013

2.3 Sample stratification in Lemo woreda:

- **Slope gradient:** Due to the sloped nature of the landscape in Lemo woreda, it was hypothesized that farmers from the upper and lower catchments held varying knowledge about the landscape dynamics; and they also experience varying farming experiences and challenges.
- **Gender**-Men and women played different roles within the farming system, and often had varying access to and control over resources. Hence it was hypothesized that they held varying knowledge on the same. Equal number of farmers were selected from each strata, with consideration being put on gender (Table 2)

- **Age**- It was hypothesized that knowledge differed with age; with older farmers having more elaborate knowledge especially with regards to the drivers of land use change; while younger farmers could hold more knowledge about agricultural technologies etc.
- **Wealth status**- Also, consideration was placed on wealth/ resource endowment variations among farmers (low, medium, high) mainly through selecting farmers with small, medium and large household land holding. It was hypothesized that access to land influenced farmers' land-uses, production, income and livelihood strategies; and influenced the way they related to resources. Table 2 below shows the stratification criteria and number of interviewees involved in the exercise.

Table 2: Farmer stratification criteria

Activities	Jawe kebele		Upper gana kebele	
Landscape characterization				
Meet/ Interview with key informants/ transect walks/ strata	3 Development Agents's- crop, livestock, Natural Resource Management		3 Development Agents's- crop, livestock, Natural Resource Management	
	Men	Women	Men	Women
Participatory resource mapping	4	4	4	4
Historical timeline	4	4	4	4
Seasonal cropping calendar	4	4	4	4
Livestock feed calendar	5	5	5	5
Land use and livelihood	4	4	4	4
First interviews farmers	5	5	5	5
Second interviews farmers	5	5	4	4
Nursery survey	1			
Feedback discussion	5	6	6	5

2.4 Feedback sessions

After the characterization exercise was complete, the researchers spent the last day in each of the two sites giving farmers feedback on the knowledge they had shared during interviews (Figure 6). This was an opportunity to thank the farmers for availing their time and sharing information; and it was also to highlight to farmers key information which they provided; and to also confirm whether the information represented best represented the farmers' views and knowledge.

Figure 6: Yohannes Horamo taking farmers through feedback sessions in Upper gana and Jawe
Photos by Anne Kuria, July 2013, July 2013

3. RESULTS

This section presents findings from local knowledge elicited from farmers in Lemo woreda in two kebeles namely Jawe and Upper gana. Areas covered in this section are: participatory resource mapping, farm characterization, landuse and livelihood strategies, crop and livestock husbandry and interactions, drivers of landuse change, trees and associated management and opportunities to sustainable intensification.

Table 3: Number of statements of each type used in the 'Lemo_africarising_ knowledge base.

TYPE	Number of statements	Conditions attached
all	401	151
attribute	38	12
causal	323	138
comparison	40	1
link	0	0

Formal term usage

Type	Number of formal terms
all	487
action	46
attribute	95
comparison	2
link	0
object	187
process	32
value	125

3.1 Participatory Community Resource Mapping

Upper Gana Kebele:

During focus groups, farmers from the lower and the upper catchments were requested to draw resource maps of the entire kebele. This exercise was to allow farmers to map their territories and indicate which places and which resources and assets were used for which purposes.

Upper Gana kebele kebele was about 11km from Hosanna – the main town for the area, approximately 5 hours from Hosanna town. There was an all – weather murram road from Hosanna to Upper gana. Farmers transported their farm produce using donkeys or carrying. A local market serves the entire kebele.

Water resource: Farmers reported that the area had only 1 permanent river (Ajacho river) and about 5 springs. Unkoyo, Deagermo and Cheruro rivers which were present before 1983ec (1991) have completely dried up (figure 7). There is also Gombora river, which originates from this kebele, but flows downwards to other kebeles. There were also 2 dams, usually used to water livestock, especially during the dry season. There were 10 tapped water stations that provided water from Migiriba springs that was used for domestic use.

Grazing land: Grazing lands (Figure 10) which were there during the Derg regime were replaced by settlements and farming fields, hence there was no communal grazing land. Farmers therefore relied mainly on feed resources from their farms, which often were never enough. Other farmers bought livestock feed, while some rented out their livestock during the feed insecure months to spread the feeding burden. Therefore, intensifying and diversifying onfarm feed sources would be ideal for this kind of setup.

Tree resources: There was no natural forest remaining in the kebele; as it was cleared to provide timber for construction of houses and also to pave way for settlements and agricultural expansion. There were however woodlots planted on individual farms. Further, there was no government or community tree nurseries in Upper gana areas. Only individual nurseries existed, with farmers raising mainly *Eucalyptus* and coffee seedlings. Therefore, for agroforestry to have an impact, there is need for establishment of communal nurseries where farmers can access seedlings for the desired products and services, ensuring species diversity is promoted. Due to the absence of natural / communal forests, increasing tree diversity and density onfarm would enable farmers to desired goods and services. Farmers also identified 7 gullies, with the longest one estimated to be about 150m long. Gullies were mainly caused by massive surface runoff downslope due to absence of trees in the upper catchment areas and lack of water harvesting in the upper catchment, coupled with heavy rains falling on the easily eroded soils. Therefore, water harvesting and increasing ground/ tree cover in the upper catchment would help arrest the soil erosion. Also, it would be important to plant trees combined with checkdams to rehabilitate the gullies.

Farmer Training Centres- There was one FTC where farmers were occasionally trained on farming best practices. The FTC nursery lacked diversity of seedlings of tree species, with *Cordia africana* being the main one raised. There were also livestock forage namely: *Sesbania sesban*, ***Pennisetum*** pedicellatum (desho grass), and *Pennisetum purpureum* (elephant grass). The facility was not fully utilized especially for demonstration purposes in order to equip farmers with skills on farming.

Other infrastructure: There was no veterinary office in Lemo woreda, thus livestock disease control services were unavailable. This contributed to death and poor productivity by sick livestock.

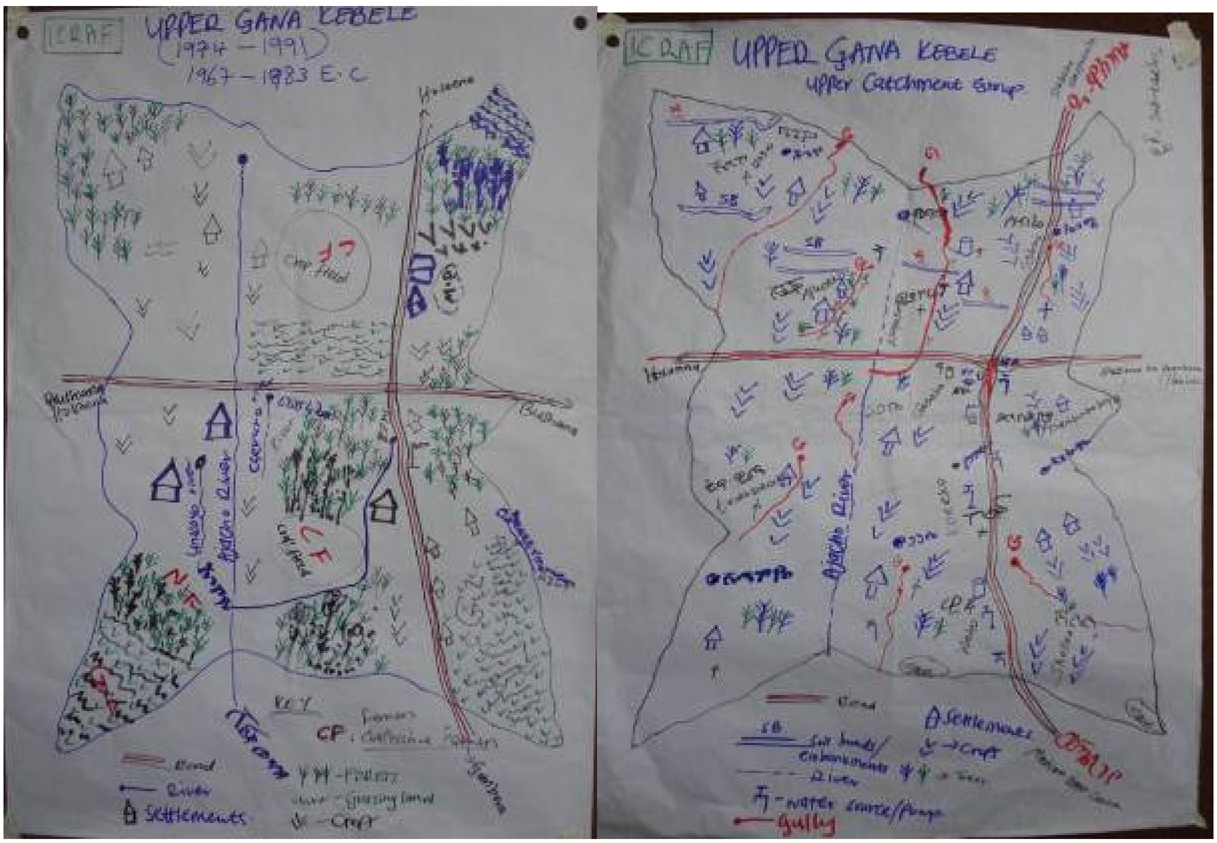

Figure 7: Resource maps of Upper Gana kebele in the Derg regime -1974-1991 (left) and current status (right)   Source: Upper gana farmers, 2013

Jawe Kebele

Jawe kebele was nearer to the market, about 7km from Hosanna main centre, about 2.5 to 3 hours from Hosanna town/ market. It was accessible through a dirt/ murram road, with the main mode of transport being walking, afew public vehicles passed near the area. Farmers transported their farm produce mainly through donkeys.

Water resource: Jawe kebele was served by 1 permanent river – Gombora river located at the lower catchment area. Farmers in the upper catchment walk for atleast 1 hour to access it. There was also Ajo river, a seasonal river which flowed along the Western boundary of the kebele. Farmers in the upper catchment had less access to water as it river/s were located in the lower catchment, hence they had constructed 2 dams, especially used for livestock watering. Also, there were several pumped water sites in the village. Farmers in this kebele complained about lack of adequate water, especially during the dry season. Lack of water harvesting had led to the inability of farmers to tap into irrigated agriculture, hence they relied on rain-fed agriculture, thereby reducing their chance of making an improved livelihood through access to food and additional income, There is therefore need to explore water harvesting strategies in order to diversify livelihood options.

Tree/ forest resources

There was no government or community tree nurseries in Jawe. Only individual nurseries existed, with farmers raising mainly *Eucalyptus* and coffee seedlings. Therefore, sources of germplasm for frmers included: planting fruit seeds after consuming the fruits, borrowing from neighbors and friends, buying seedlings from neighbours or from Hosanna town. According to the development agents and farmers, water scarcity discouraged the government and community members from establishing tree nurseries. In the Derg era, there was a natural forest along Gombora river (Figure 8), which has since been cleared, leading to massive gully erosion along the river (Figures 9).

Figure 8: Resource map for Jawe kebele between 1974-1991   Source: upper catchment farmers

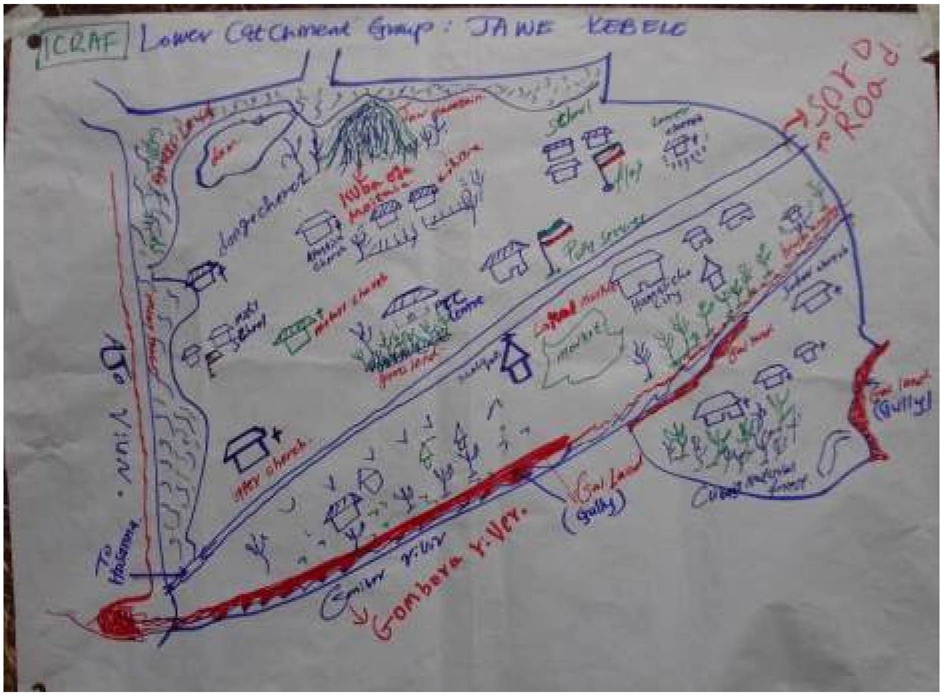

Figure 9: Current Village resource map for Jawe kebele Source: lower catchment farmers

Grassland: There was a small area of grassland remaining in the upper catchment border. Before 1991 (Figure 11). Farmers relied on the community grazing land to supplement livestock feed from March to December. However, with agricultural and settlement expansion, the grassland is gradually reducing., and due to the shrinking size of the communal grazing land, grass was becoming inadequate, and farmers had started relying more on onfarm feed sources. There is therefore great need to diversify and intensify on on-farm feed

Farmer Training centre: There was one FTC in Upper Gana kebele whereby farmers were learning about the new agricultural technologies. In Jawe, fodder planted include: *desho* grass and *gatumalya* grasses. The FTCs had one nursery with low species diversity with only *Cordia africana, Grevillea robusta,* and *Sesbania sesban. There is need to maximize on the use of FTCs for training purposes.*

3.2 General Layout of Farms

Farm sketches were carried out to map out resources at the household level. Lemo area is characterized by highly intensified farming system within small privately owned land, with the actual average land holding of farmers interviewed in Jawe kebele being 1.2ha. (ranging from 0.38ha. to 3ha.), while that of Upper gana was 1.5 (ranging from 0.06ha to 3.3ha). Land is not very fragmented, with individual farmers having only one or two fields. Figure 10 below shows characterization resources and land-use at the farm level.

Tree niches on farm varied depending on the location of the field. Farms that hosted the homestead had trees along the boundary, while those in the cropfields separate from the homestead were not fenced and had no trees / live fences along boundaries. Because cut and carry system of livestock feeding was practiced, there were no crop loses experienced from livestock browsing. Enset, khat and coffee were grown near the homestead. Grass enclosures were also located in the homestead. Annual crops were monocropped on different sections of the field on a rotational basis. Vegetables and fruit trees were usually grown near the homestead for convenient access to the products and to prevent theft. One way of intensifying the system would be to integrate short rotation fallows into the system to improve soil fertility and at the same time provide fodder.

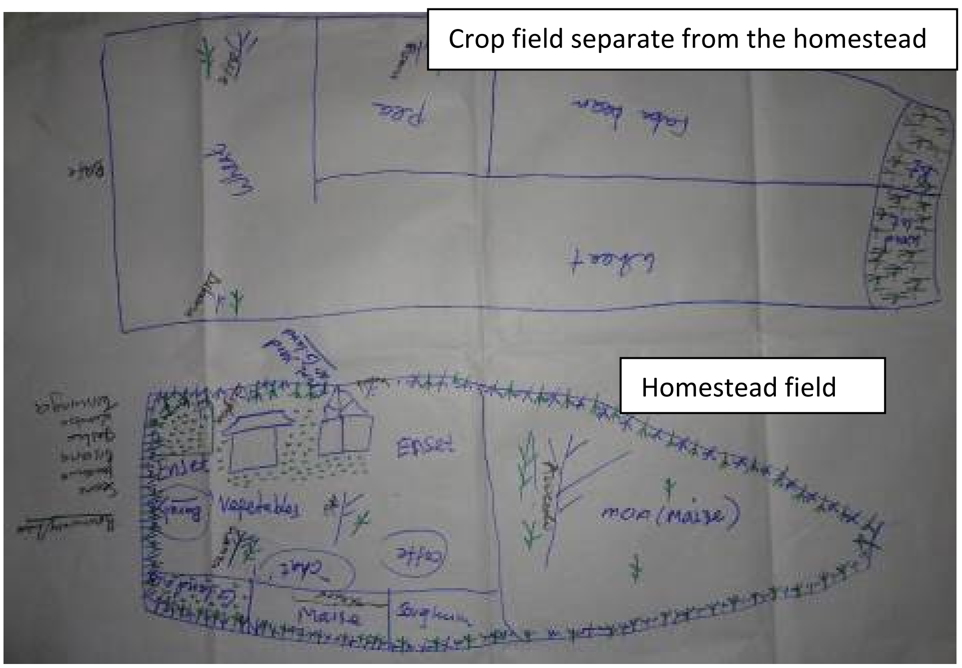

Figure 10: Farm sketch of a household in Upper gana kebele, Lemo Source: farmer

3.2 Landuse and Livelihood Strategies

Information gathered during focus groups (resource mapping, cropping calendar) and individual household interviews about the use of land and other resources by different genders of farmers within the kebeles was synthesized to create a landuse and livelihood diagram. There was no difference between the Jawe and Upper gana kebeles, hence one diagram was created using information from both kebeles.

Planting of major annual crops was done by men except teff which was done by women. Crop supervision, application of pesticides and tree planting and management are men's roles. Women mainly engaged in hoeing and harvesting, planting vegetables and fattening of livestock (Figure 11). Farmers reported experiencing food shortage/ scarcity from May to August and also on October. During this period, their main coping mechanisms were seeking paid labour within or in neighboring villages, selling livestock, renting of land to get income to buy food and other items.

- Both men and women took up major chores such as harvesting crops based on the intensity / volumes of crop production, that is, men were involved in harvesting during the long-rainy season while women harvested during the short-rainy season
- Men were involved in selling the most economically valued products such as trees, coffee and khat; while women were involved in the less valuable products.
- Men had more roles in the main crop production system (crop fields)while women had more roles in the home compound
- In all sites, men were involved in making decisions and undertaking economically valued inputs such as fertilizers and herbicides
- Children played supportive roles in the crop fields in all areas

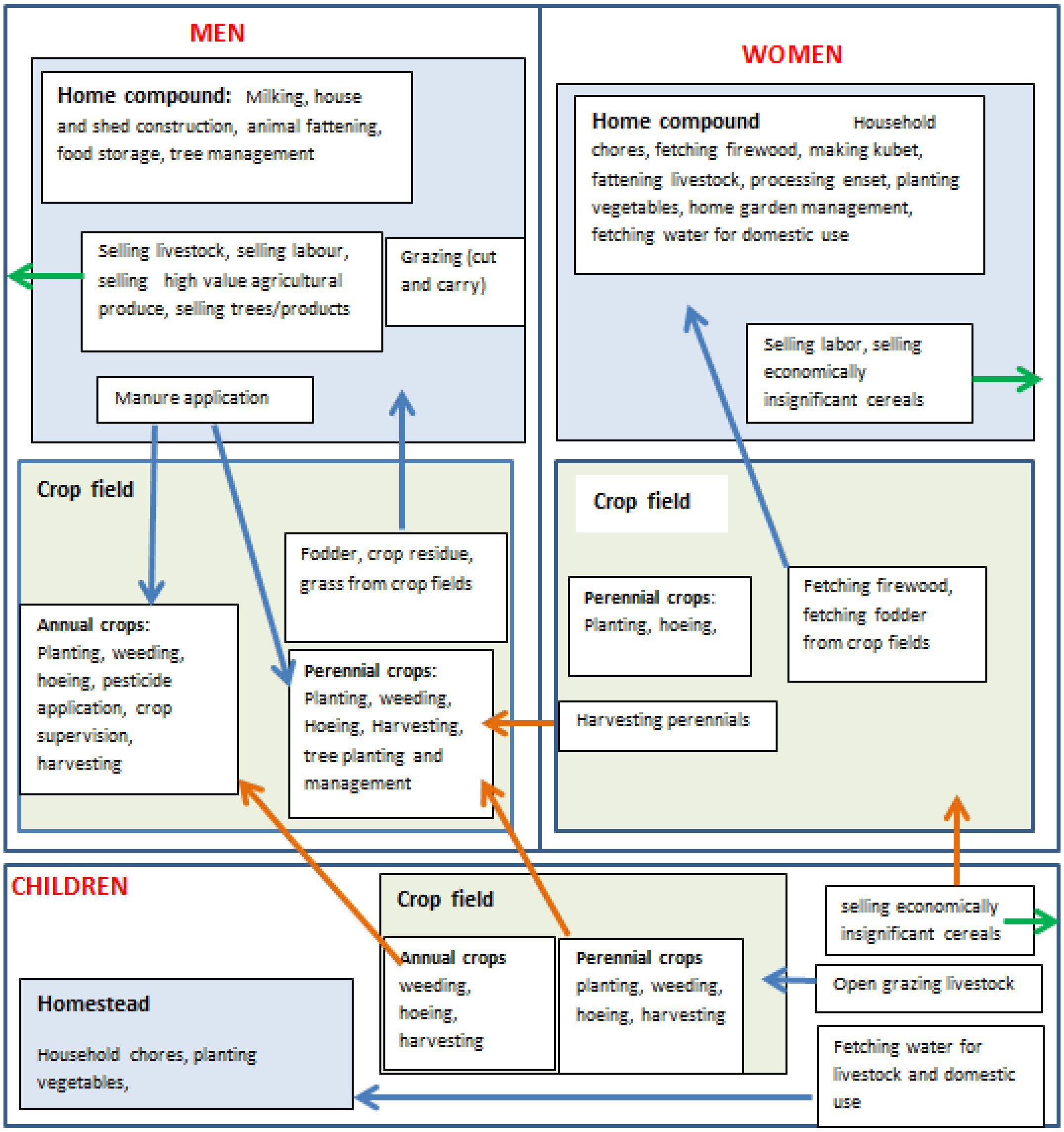

Figure 11: Livelihood and land use diagram of farmers in Jawe and Upper gana kebeles, Lemo. Source: based on information gathered from farmers during focus group discussions and individual interviews. Key: Blue- flow of materials, orange-flow of labour, Green arrows- income/ sale

3.3 Common knowledge held by farmers in different stratification criteria

As had been hypothesized, farmers in different strata held varying knowledge about the mixed farming system as highlighted below:

- **Common knowledge held by Jawe kebele farmers**: farmers were knowledgeable about location of various soils on the landscape and fields; livestock manure increases crop productivity, coffee berry disease is prevalent and leads to reduced productivity. Farmers also reduced livestock numbers due to fodder scarcity, and local livestock breeds led to low productivity. Tree fodder was commonly utilized. **Common knowledge held by Upper gana kebele farmers**: farmers experienced fuel scarcity from june to September due to onset of rains, and were more knowledgeable about tree attributes for timber, firewood; and soil erosion / erosion control issues since erosion was common in this kebele. Farmers had more fodder sources such as: grass from crop fields, frontyard, grazing enclosures, and tree fodder. They also acknowledged the importance of value addition such as on enset in attracting more income. Chemical fertilizers were costly hence were less used, while small land sizes led to less crop productivity.

- **Knowledge held by farmers along varying slope gradient**: farmers interviewed in the lower catchment reported that coffee berry 'korera' disease was prevalent, which was contributing to reduced production and ultimately income from sale of coffee berries. Fodder scarcity was also a serious challenge in the lower catchment. Farmers also observed slow maturity rate of fruits, especially avocadoes. Still, lower catchment farmers were more knowledgeable about 'kashar bucha' soil type, which is red and located at upper part if field/ catchment is sloped and less fertile. They also widely used crop residues for fodder. Conversely, in upper catchment- 5 out of 10 farmers interviewed had knowledge on the characteristics of the good soil 'hemach bucha', dark/ brownish/black fertile and located usually in lower part of the slopy field/ catchment and they had detailed knowledge about upper-lower catchment dynamics with regards to soil erosion/ surface runoff. They also experienced fuelwood scarcity during rainy season. They had many fodder sources including tree fodder, grazing enclosures, front yard, and crop residues; and had indepth attributes of the fodder sources. They also had value addition especially to enset (processing) for both food and income.

- **Knowledge held by different gender:** Knowledge held women farmers- women had detailed knowledge about 'kashar bucha' soil type, that it is reddish, usually found at the upper part of the field if sloped, is easily eroded and is less fertile. They also held indepth knowledge about crop residue and utility of *Vernonia amygdalina* as fodder. They were utilizing *Cordia africana* leaves as mulch because of the high nutrient content. They had also observed that the growth/ maturity rate of avocadoes was slow in the area, but could not explain why. Women also reported that they were not planting trees on their farm due to lack of germplasm. Men on the other hand had knowledge about 'hemach bucha'- that is is blackish-brown in colour, is located at the lower parts of the field if sloped and is very fertile. Men also had knowledge about tree attributes for firewood, timber, soil fertility, fodder tree species. For fodder sources, they had knowledge about the nutritional value and utility period for various fodder sources; and also knowledge about tree management such as why pollarding is done in order to reduce shading effects of trees to crops. Lastly, men had indepth and elaborate knowledge about soil erosion and surface runoff processes and control including functions of erosion control structures.

- **Knowledge according to different household land holding:** Farmers who had land less than or equal to 1 ha. Had indepth knowledge about kashar bucha- its location at the upper fields, and were concerned about its low fertility level and high erosion rate (mostly due to intensive and continuous cropping). Due to fodder scarcity, they also utilized fodder trees and grasses harvested from crop fields during weeding played a key role I their livestock feed. They experienced fuelwood scarcity, and observed that their small land sizes were causing low crop productivity leading to food insecurity. Further, they were concerned about the canopy density of trees due to competition for space with cropland, and were also concerned with the slow maturity of fruits. They also lacked seedlings to propagate more trees. Conversely, farmers who owned >1.1 ha.- had more knowledge about 'hemach bucha' soil characteristics. They were however more concerned about crop diseases such as the enset bacterial wilt 'alooya' disease and coffee berry disease, and were also concerned about the high cost of inputs such as fertilizers. They had an additional fodder source- had set aside some land for private livestock enclosures, and also utilized crop residues. They were more aware about soil erosion concepts and also had knowledge about timber and firewood attributes of trees.

- **Age**- Older farmers (>51) years had more knowledge about tree-crop interactions such as the rooting system of Eucalyptus, Grevillea, Croton, Erythrina; and also livestock-crop interactions- such as labour, drought power, income potential of the crop-livestock mixed system. On the other hand, younger farmers (21-50 years)- had more knowledge about soil erosion and control; and were more interested in income potential of products such as value addition to enset. They were also concerned about the high cost of inputs such as fertilizers, and disease control especially for enset bacterial wilt since this reduced productivity of enset which they relied on heavily for income and subsistence. They also had knowledge on utility and attributes of products from some common trees

3.4 Soils

Soils are the natural resource that holds/ hosts crops from planting to maturity, hence influence crop growth. With sustainable intensification, soil is repeatedly and continuously put into use at an intensified basis. Therefore, understanding indicators of soil quality was an important step to addressing challenges that are soil-related; and in designing appropriate soil management options for Lemo woreda such as: which soil required more inputs/ fertilizer, which soil needed more erosion control measures to be put in place among others, and one that would require specific management actions such as drainage and aeration. Soil was referred to as bucha in Hadiya language. Farmers classified soils into various textures and characteristics shown in table 4 below.

Table 4: Soil characterization by farmers in Jawe and Upper gana kebele

Jawe kebele	Upper Gana kebele
Kashar bucha- also referred to as dora or shaklama, this soil is red, loamy-clay in texture, and is soil mainly left behind following continuous surface runoff. It is found on the upper part of the fields if the gradient is sloped. It is less fertile than hemach bucha, hence requires additional fertilizer.	**Kashar bucha**- red soil, with less proportions of clay, well drained but less fertile than hemach bucha. Just like in Jawe, this soil is found mainly on the upper part of the fields where erosion has taken place
Hemach bucha- dark brownish black soil, it is the most fertile of all soils found in the area, and is mainly found at the bottom of the field if sloped. It is easily eroded	**Hemach bucha**- darkish brown soil, most fertile, found at the bottom of the fields on sloped areas as a result of deposition from upper areas due to surface runoff
Marare_bucha- refers to clay soil, very fine particles and sticky. It is mainly found along swampy/ river banks. It is more fertile than kashar bucha but less fertile than hemach bucha	-

3.5 Crop production

Farmers reported that Lemo woreda experienced two rainy seasons namely the shorter 'belg' season which occured from February and April; and the main 'meher' rainy season occurring from June to September. Usually, early maturing crops such as maizewere planted in the belg season while slow maturity crops such as wheat were mainly planted in 'meher' season (Tables 5 and 6). However farmers reported that if the short rains failed in March, they did not plant any crop in that season (which led to food shortage); but they instead concentrated on ploughing their land repeatedly (between 2 to 7 times) to smoothen the soil which helped in better germination and growth of crops especially the fine-seeded crops such as teff and wheat. They would therefore plant during the 'meher' long rainy season. Ploughing was also said to help mix the soil with organic matter thereby enhancing fertility and increasing the chances of getting higher yields in the 'meher' planting season. However, continuous and repeated ploughing of land led to soil being light which increased soil loss through surface runoff, leading to low soil fertility and low yields. Farmers reported experiencing food shortage/ scarcity from May to August and also on October.

In Jawe kebele, the main annual crops grown (the first three being in order of volume planted) were: wheat, teff, irsh potatoes, barley, maize, fava beans, peas, sorghum, cabbage, carrots, onions. Wheat, teff, irish potatoes and fava bean were the main cash/ income crops. In Upper gana kebele, the main crops grown (the first four in order of volume) were: wheat, teff, maize, fava bean, peas, and vegetables; with wheat, teff, favabean and pea being the main cash crops. The main perennial crops grown in both kebeles, the first three being cultivated widely for income were: enset, coffee, khat, sugarcane, avocadoes, mangoes and timber trees**.** Therefore, there is need to increase crop volumes of the less grown crops in order to tap into the potential income form this. Such would also mean farmers harvesting rain water so that they can increase income all year round, such as by growing vegetables.

Enset was the main perennial crop in both kebeles, a source of food all year round. It normally matured for harvesting three years after planting. Most farmers relied heavily on enset for many products and income (Figure 12): it is a source of food (bulla and kocho) and income (b), fibre for income (c), fodder (d), making mats for household bedding materials and for income (e) and fibre used as 'nails' for joining bamboo poles for thatching tukul houses (f) . However, enset was under threat of bacterial wilt 'alooya' disease, hence controlling diseases would help stabilize enset production.

Figure 12: Enset (Enset ventricosum) products Photos by Anne Kuria, July 2013, July 2013

Some farmers also mentioned that local crop varieties such as irish potatoes and maize performed poorly.There is therefore need for the government to make available, seeds from improved crop varieties in order to boost production.

Farming system was dominantly monocropping, with farmers practicing crop rotation alternating legumes and cereals to maintain soil fertility. Due to land scarcity, only an insignificant number of farmers practiced fallow periods. Although crop rotation helped to maintain soil fertility, continuous cropping with no fallow periods led to soil exhaustion hence decreased fertility. Hence there would be need to integrate short rotation shrubs into the cropping system to maintain soil fertility and encourage mulch/biomass production.

Other factors that have influenced crop productivity and yields are discussed below.

Climate variability, dating back from early 1980's has had a negative impact on crop productivity through changing rainfall pattern from bimodal to unimodal. In Upper gana, majority of the main crops were planted once annually (during 'meher' season) namely: wheat, barley, teff, fava bean and pea. This resulted in reduced annual productivity from crops; which not only affected household food security and income, but also led to livestock fodder scarcity, which ultimately affected livestock productivity (quantity and quality of products and income potential). Therefore, intensifying crop production would require looking into ways of supplementing rain-fed agriculture through for instance water harvesting, so that farmers can have continued availability of food and income throughout the year. Further, an increase in human population led to a decrease in the average household land holding, which has led to decreased land under crop cultivation (Figure 13). Therefore, farmers must look into ways of intensifying their limited land resource through increasing productivity by employing agricultural best practices.

On the other hand,, transition from landlord system to private land ownership in the Derg era led to better management of land and general farming activities which enhanced crop yields.

Soil erosion- An increase in intensity of rainfall intensity was reported to causing an increase in speed of surface runoff, especially where the field gradient was sloped and the amount of soil cover was low. Increased surface off in return led to an increase the loss of soil, leading to soil fertility decline, which ultimately led to decreased crop yields. Therefore, one of the steps in achieving managing the resource base would be to reduce the manageable drivers of surface runoff such as increasing ground cover.

Untimely and inappropriate application of fertilizer- The DAs also reported that some farmers did not apply chemical fertilizers timely, hence late application, especially towards end of the rainy season reduced efficiency (period of fertilizer availability/ take-up), leading to sub-optimal utilization of chemical nutrients. This in return led to reduced crop growth, leading to reduced yields. Other farmers did not apply the recommended quantities and quality of fertilizers, also leading to low crop yields. Training farmers on the requirements for optimal crop growth with regards to chemical fertilizers such as timely application, and using the recommended quality and quantity of fertilizer would help to increase crop productivity.

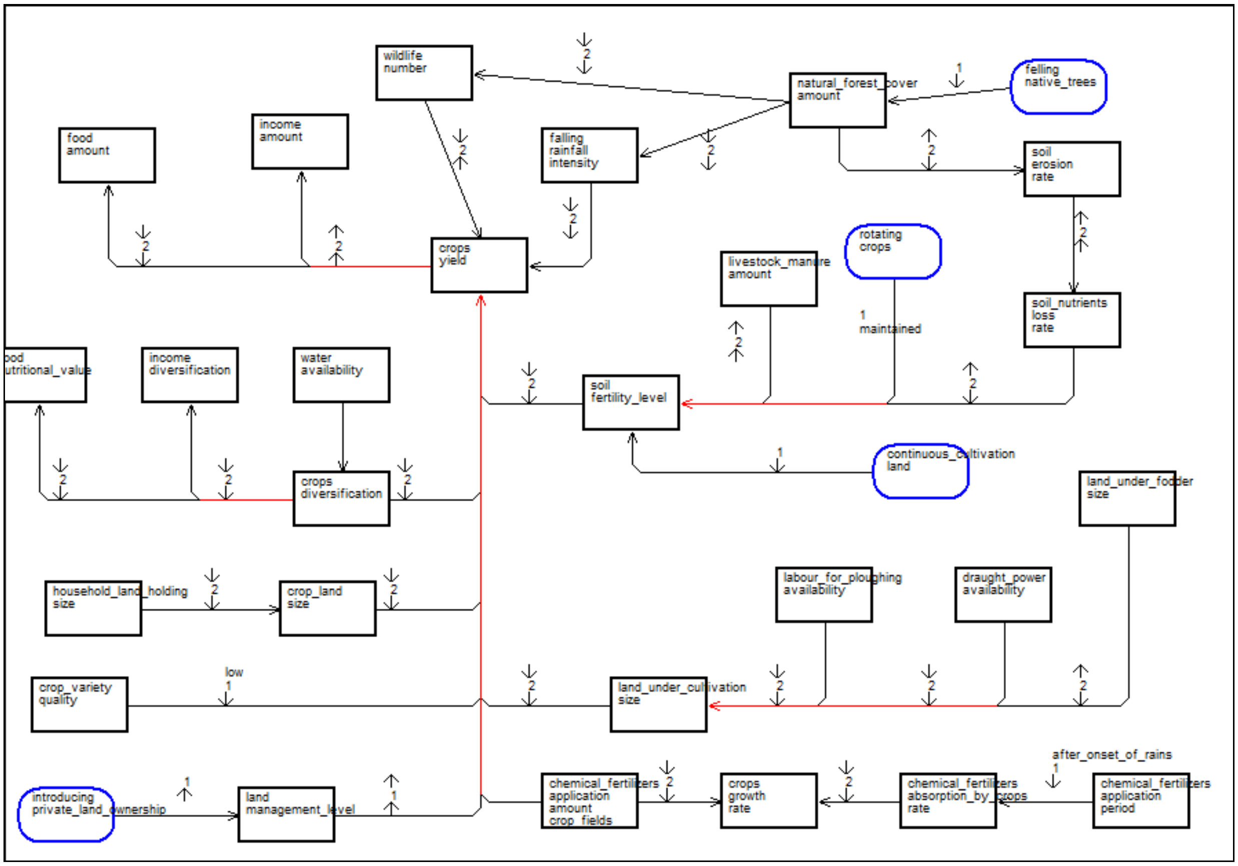

Figure 13: AKT diagram showing factors influencing crop productivity Source: Lemo_africarising.kb

KEY: Nodes represent attributes of objects, processes or actions. Arrows connecting nodes show the direction of causal influence. The upper small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the lower arrow refers to the effect node. Numbers between small arrows indicate whether the relationship is two-way (2), in which case an increase in A causing a decrease in B also implies that a decrease in A would cause an increase B, or one-way (1), where this reversibility does not apply.

Inferior/ local crop varieties, pests and diseases- Majority of farmers reported only having access to local varieties of crops which gave low yields, and were also highly prone to pests and diseases. Perennial crops mainly affected by diseases was enset affected by bacterial wilt (alooya disease), and coffee attacked by berry disease. Almost all farmers interviewed perceived enset 'alooya' disease (Figure 14) as the greatest threat to their livelihood, with one farmer stating that 'Enset is my life'. Other crops affected by diseases are: fava bean, wheat, and maize. Pests on the other hand mostly affect cereals and pulses during storage stage leading to loss of crop produce. Therefore, investing in improved crop varieties, and crop disease control where improved varieties are not available would help to boost crop production.


Figure 14: A model farmer showing ICRAF team 'alooya' disease infested enset

Photos by Anne Kuria, July 2013

Water scarcity- scarcity of water limited farmers' ability to diversify crops through irrigation leading to less income sources and lack of diversified family nutrition, which affects health. Availability of water would help farmers to grow vegetables and other crops which are a source of nutrition and income to households.During the feedback sessions held at the end of the local knowledge study, the challenges mentioned and expressed earlier from FGDs and individual interviews with farmers and DAs (presented above) were presented back to the farmers for them to prioritize them according to which ones affected them more seriously and were most common (Table 5)

Table 5: Challenges affecting crop productivity as prioritized by farmers in Jawe and upper Gana

Jawe Kebele	Upper Gana kebele
1. Land scarcity	1. Land scarcity
2. Water scarcity	2. Enset Alooya disease
3. Enset Alooya disease	3. High cost of farm inputs- fertilizer/seeds
4. High cost of farm inputs:	4. Coffee berry disease-
5. Decreasing productivity - loss of soil nutrients	5. Soil erosion- (the upper catchment)
6. Lack of improved crop varieties eg disease-resistant potatoes	6. Decreasing land productivity due to loss of soil nutrients
7. Market fluctuations of crop produce	7. Market fluctuations
8. Post harvest /storage loss of crop produce	8. Unreliable rainfall and water scarcity
9. Labour shortage - oxen and donkey.	9. Crop pests and diseases
	10. Labour shortage: oxen, donkeys, mules

Crop production technologies

In order to tackle the challenges facing crop production, the woreda office of agriculture and other partners were working through the Development Agents to promote technologies that improve crop productivity.

1. **Mono-cropping**: monocropping was being promoted by DAs based on the principle that it made crop management easy including the undertaking of activities such as weeding and integrated pest management.

2. **Row planting**: Since the technology of row planting was introduced, a number of farmers had adopted this technology in both Jawe and Upper gana areas at the time of this study. Unlike the traditional broadcast-planting, DAs and farmers alike reported that row planting technology was advantageous in that it ensured easy management of crops such as while weeding and hoeing; and it also reduced wastage of crop seeds. However, some farmers found it difficult to implement this technology since it was termed as being labour intensive. Acceptability and adoption of agricultural technologies is influenced by among other factors, the amount of labour required, with labour intensive technologies being less adopted.

3. **Model farmers**: Model farmers were selected to catalyze scaling up of agricultural best practices: In upper Gana, 10 model farmers had been trained in and were adopting various technologies namely: row planting wheat & favabeans, livestock forage management, hen production, bee keeping, and apple production. In Jawe kebele, 9 model farmers were also practicing row planting of wheat, fava bean and irish potatoes; and were also planting fodder species namely: *Sesbania sesban*, grasses including Pennisetum pedicellatum (*desho)*, Pennisetum purpureum (elephant), vetch and clover. The technologies were becoming popular, with neighbouring farmers learning from model farmers and adopting on their individual farms and teaching other interested farmers.

Soil and water conservation measures

Due to the sloped nature of some terrains, coupled with high rainfall intensity and low soil cover, surface runoff was reported as a serious problem on some areas of the kebeles. Also, continuous and repeated ploughing of soil made it susceptible to runoff. This was especially serious in Upper Gana kebele whereby trees had been cut down in the upper catchment and the terrain was more sloped.. This led to loss of soil nutrients, thereby affecting fertility of soil and crop yields. Therefore, woreda agricultural office, through the DAs had been employing various soil and water conservation measures, especially on sloped areas. Physical soil and water conservation structures used were: soil bunds, trenches (Figure 18), embankments and check dams. The main function of these physical structures, which are usually were constructed across the slope in the upper parts of the field was to reduce the speed of surface runoff, and enhance soil interception and water infiltration, thereby reducing soil erosion as illustrated in the AKT diagram on figure 16 and diagrams on Figure 15.

Figure 15: River siltation, Pennisetum pedicellatum (desho grass) planted along soil bunds; and Croton macrostachyus trees planted along erosion control trenches Photos by Anne Kuria, July 2013

These physical structures were being reinforced using biological measures such as planting trees and grasses along the soil and water conservation structures. The role of biological interventions was to stabilize soil along the physical structures; and also to reduce the speed of surface run-off, thereby increasing the infiltration rate of water, which resulted into high interception rate of the soil. This in return reduced loss of soil and ultimately lowered severity of soil erosion, which led to availability of more soil nutrients to crops, thereby boosting productivity.

Below (Figure 16) is an AKT diagram showing functions of different soil and water conservation structures.

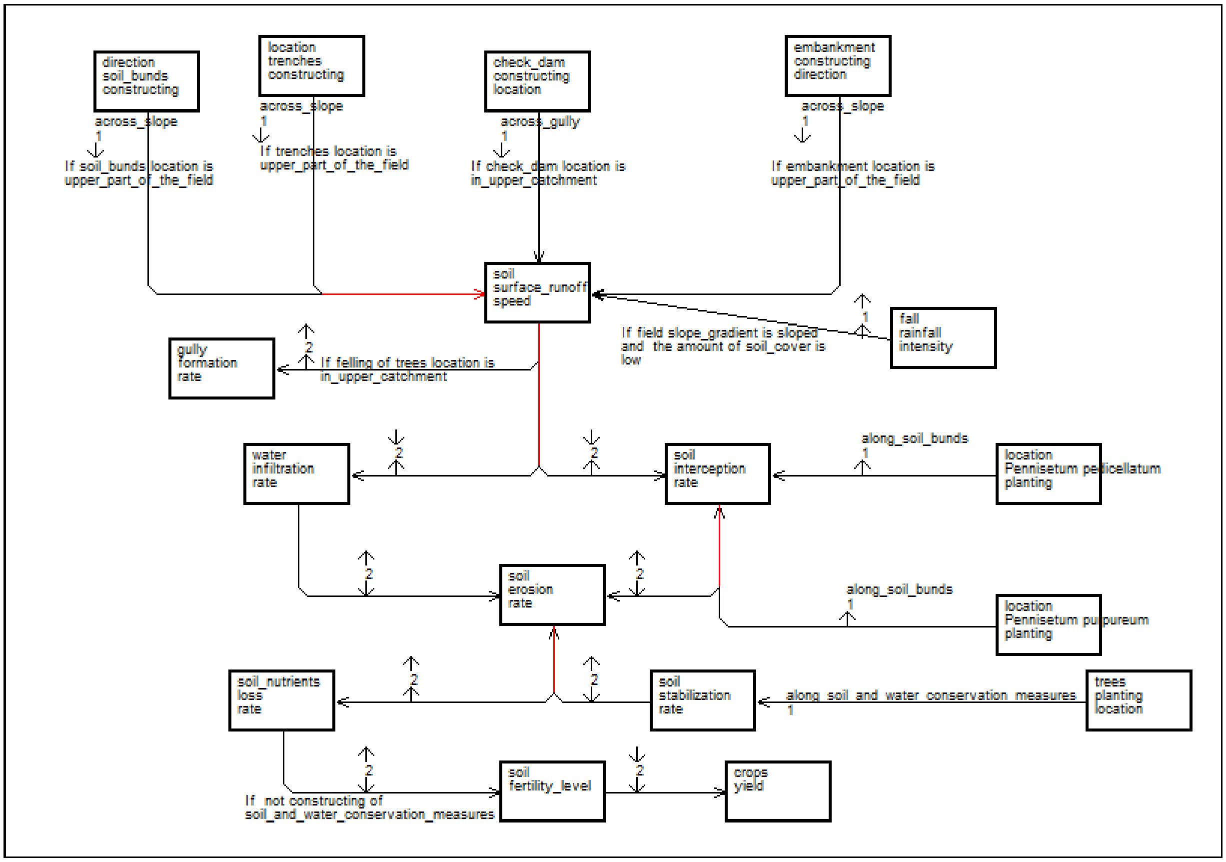

Figure 16: AKT diagram on soil and water conservation measures according to farmers and DA's
Source: Lemo_africarising.kb

KEY: Nodes represent attributes of objects, processes or actions. Arrows connecting nodes show the direction of causal influence. The upper small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the lower arrow refers to the effect node. Numbers between small arrows indicate whether the relationship is two-way (2), in which case an increase in A causing a decrease in B also implies that a decrease in A would cause an increase B, or one-way (1), where this reversibility does not apply.

3.6 Crop-livestock interactions based on feed

Crops and livestock components were found to complement each other in a lot of ways, though competed in afew ways. In Lemo woreda, sustaining a mixed livestock-crop system in the limited/ absence of communal grazing land involved trade-offs, with some farmers setting aside and converting portions of crop land for fodder/ grass production, which led to cultivation of less crop amounts. On the other hand, clearing of more grasslands to pave way for crop expansion led to a reduction in the size of croplands.

Crop residues were a source of fodder for livestock. The quality of crop fodder influenced livestock health and quality of products such as milk and meat, with the quality of the products affecting their market potential. Residues from barley, wheat and fava bean were named to be the most nutritious crop residues, and they also played a critical role in fodder provision throughout the area. A decrease in the cropping numbers per year (from bimodal to unimodal) led to a decrease in residue availability to livestock. Livestock also benefited the crops through provision of manure. Therefore, a decrease in livestock numbers usually led to decreased amount of manure, which led to low soil nutrient availability for crops hence reduced crop productivity; as chemical fertilizer was costly hence is only utilized minimally for a few crops (Figure 17). Further, decreased livestock numbers also led to reduced draught power availability (oxen, donkey) hence farmers with bigger land were unable to cultivate the entire field, leading to decreased areas under crop cultivation. Also, those farmers who did not have draught animals would borrow rent livestock from neighbours and in most cases repay them in kind using a portion of the crops harvested. Livestock such as donkeys were used t transport the crop produce, hence were their link to the markets,

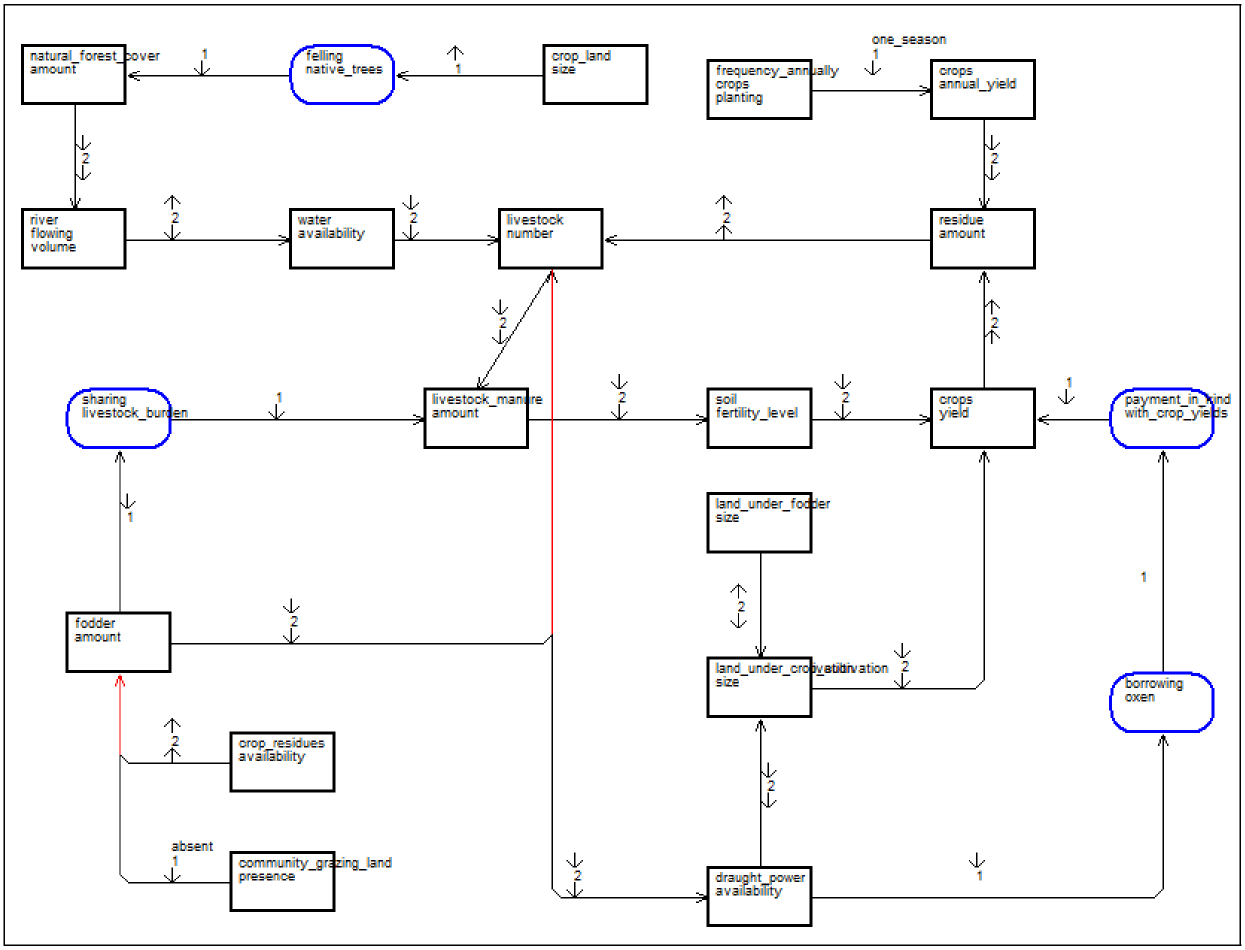

Figure 17: AKT diagram on crop-livestock interaction in Lemo woreda Source: lemo_africarising.kb

KEY: Nodes represent attributes of objects, processes or actions. Arrows connecting nodes show the direction of causal influence. The upper small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the lower arrow refers to the effect node. Numbers between small arrows indicate whether the relationship is two-way (2), in which case an increase in A causing a decrease in B also implies that a decrease in A would cause an increase B, or one-way (1), where this reversibility does not apply.

3.7 Livestock production

The main livestock found in Jawe and Upper gana were: cows (average 2-5 cows per household), oxen, goats, horses, mules, and chicken. Livestock plays critical roles in mixed farming systems such as: crop manure, draught labour, improving nutrition and income source. Fattening of livestock was usually done from August and September ahead of the *meskel* festivities when livestock would fetch highest prices, hence income for the farmer. Some farmers also practiced apiculture, though at a small scale. There was limited no market for honey, hence majority of bee farmers used the honey for household purposes.

In Lemo, government policy required farmers to practice cut and carry system, although they are allowed to practice open/ free grazing where there was a communal grazing land. There were various sources of fodder comprising of crop residue, grasses and tree leaves. The main tree species used as fodder included: enset, *Vernonia amygdalina, Adathoda schimperiana, Sesbania sesban, Erythrina abyssinica, Grevillea robusta* and *Persea americana*. Cultivated grasses included: *Pennisetum purpureum* (elephant grass), *Pennisetum pedicellatum* (desho grass), rhodes grass and clover. Some farmers had also set aside grazing enclosures in their homestead (Figure 18), while majority grazed their cattle on homestead frontyards.

Figure 18: grasses growing in enset field in Upper gana; homestead grazing enclosure in Jawe Photos by Anne Kuria, July 2013, July 2013

All fodder utilized on farms is presented in the AKT tree below (Figure 19).

```
fodder_sources
   ├─crop_residues
   ├─cultivated_grasses
   │  ├─Pennisetum pedicellatum
   │  ├─Pennisetum purpureum
   │  ├─clover
   │  └─rhodes_grass
   ├─fodder_trees
   │  ├─Adhatoda schimperiana
   │  ├─Enset ventricosum
   │  ├─Erythrina abyssinica
   │  ├─Grevillea robusta
   │  ├─Persea americana
   │  ├─Sesbania sesban
   │  └─Vernonia amygdalina
   ├─grass_from_community_grazing_land
   ├─grass_from_crop_fields
   ├─household_frontyard_grass
   └─private_grazing_enclosure
```

Figure 19: AKT tool output for fodder sources object hierarchy tree   Source: limo_africarising.kb

There was no significant difference in fodder seasonality of both kebeles. Various grass sources played a role in fodder provision between June and October (table 6). Crop residues played a key feed role especially between November and February. Trees on the other hand played a key role in bridging the fodder gap and complementing crop residues during the most critical (dry) periods in January and February, when there was no other source of fodder, especially for Upper gana which had no communal grazing land.

Table 6: Fodder seasonal calendar in Jawe and Upper gana kebeles, Lemo.

Livestock Feed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Front yard grasses	_	_	X	X	X	X	X	X	X	X	X	X
Homestead grazing enclosure	_	_	X	X	X	X	X	X	X	X	X	X
Communal grazing land (Jawe)	_	_	X	X	X	X	X	X	X	X	X	X
Grasses from crop fields	_	_	_	_	_	X	X	X	X	X	_	_
Crop residues	X	X	X	X	X	_	_	_	_	_	X	X
Planted grasses	_	_	X	X	X	X	X	X	X	X	X	X
Tree fodder	X	X	X	X	X	X	X	X	X	X	X	X
Fodder shortage	X	X	X	X	X	_	_	_	_	_	_	X

Key: Dark green- months that majority of farmers use the fodder, Light green- months that minority of farmers use the fodder, Cream- Communal land is only found in Jawe kebele , Yellow- months of severe fodder shortage

Challenges affecting livestock numbers and / or productivity include:

- Fodder scarcity- this limited the number of livestock reared, adversely affected the health of the livestock and led to low quality products. In extreme cases, livestock died from starvation. To bridge the fodder gap, some farmers had resulted to buying fodder from neighbors and sharing livestock to spread the risks and feed burden.

- Water scarcity: in Jawe, there was only 1 permanent river called Gombora and 1 seasonal river Ajo. Due to water scarcity at some periods during the year, the community had also dug a well and constructed 1 dam called Donge, whose water was mainly used for livestock consumption. In Upper gana, there is one major river called Ajacho, and a few springs. Although the government through the DAs wes encouraging farmers to practice water harvesting in order to be able to diversify on other income generating crops such as vegetables, this had not been the case. Some farmers reported lack of knowhow and raw materials for water harvesting. Water scarcity was detrimental to livestock productivity and management.

- Inferior local breeds (cow, goats, sheep, chicken) led to low livestock productivity
- Livestock diseases led to death or low productivity of livestock

3.8 Community knowledge exchange groups

Community exchange groups played a critical role in the scaling up of farming best practices through providing avenues through which ideas, technologies and knowledge was shared from extension to farmers or among the farmers themselves. Such included:

- Model farmers: Model farmers played a key role in scaling up of knowledge and practice of best farming technologies. In Lemo woreda, this approach proved to be an effective in providing a practical platform for farmers to learn from each other and adopt these technologies.

- **FTCs**- Farmer Training centres were also avenues of farmers to learn about the new technologies through demonstration by the development agents. For example, in Jawe, - demonstration fodder planted include: *desho* grass and *gatumalya* grasses (Figure 20). The FTC had one nursery which has species such as *Cordia africana, Grevillea robusta,* and *Sesbania sesban.* To achieve impacts, more demonstrations should be established in order to maximize on the learning by farmers on all technologies being established,

Figure 20: DAs crop and livestock demonstrating the appropriate height for cutting Pennisetum purpureum; and Pennisetum pedicellatum (desho grass) and Sesbania sesban (right) in Jawe FTC Photos by Anne Kuria, July 2013

- **Cooperatives:** Cooperatives played a key role in uniting farmers together to achieve a common goal such as purchasing fertilizers and improved seeds and herbicides. There was one main cooperative found in Jawe kebele called '*Akebabiwo Hulegeb Hibiret Sira Mahiner*' cooperative and *'Hulegadu'* farmers mixed cooperative in Upper gana. Interventions could target such cooperatives to scale up farming best practices among farmers.

- **Community groups in Jawe and Upper Gana kebeles**:

Farmers were organized into informal groups which playe a key role in their day to day lives namely:

- Geja group- this was a labour-sharing group whereby farmers engaged in working on each others' farms. Such a group could be targeted to pass on skills to farmers such as in soil and water conservation interventions which they then implement collectively.

- Ikub group- money, food and other items were collected and given to needy farmers / priority. They also prepare and share food.

- Edder –all farmers belonged to this group to help each other in case of death of one member- they collected food and money and shared during this period

3.9 Drivers of land use/ tree cover change

It was important to understand the contributing factors to the current status of resources and landuses. To record events that had led to the current status of land use and tree cover in the Africa RISING sites, historical timelines were drawnby farmers from both kebeles. According to farmers, landuse and tree cover began changing during the transition period from Haile selasie and Derg era around 1992 (1983 Ethiopian calendar). Table 7 and Figure 21 below presents these changes, and their causal relationships are discussed guided by an AKT causal diagram below this table.

Table 7: Historical timeline of land use change in Jawe and Upper Gana kebeles- Lemo woreda

JAWE KEBELE Derg regime -1974-1991 (1967- 1983 Ethio calendar)	UPPER GANA KEBELE Derg regime -1974-1991 (1967- 1983 Ethio calendar)
Livestock: High livestock numbers due to fodder availability - Hafacha, chataba diseases led to low livestock numbers -There was no livestock veterinary services -High number of non-ruminant (draught) animals	**Livestock:-** -High livestock numbers due to adequate fodder availability. -Water was available and adequate hence livestock numbers were high.

(horse, donkey and mule)-hence labour availability	
Crops: lack of fertilizer supply led to farmers cultivating less/limited land, hence less crop production -Lack of free market to sell their farm products -No improved seed supply hence low productivity	**Crops:** -There was a decrease in crop productivity due to lack of fertilizer and improved seeds -Cow dung was the main source of fertilizer for soil -Due to large household land holding, farmers practiced fallow periods, which helped to maintain soil fertility. -The main crops grown were maize and sorghum.
Tree, forest cover and water resource: Due to high tree density, there was high river water flow -Rainfall was high and well distributed -There was a severe drought in 1983 which led to death of livestock and people -Onfarm tree planting began in this era	**Tree, forest cover and water:** A large percentage of the village was covered with natural forests. -There was no flooding due to high tree density -Wildlife numbers were high, which enhanced soil fertility through dung. But wildlife destroyed crops -There was high availability of forest resources such as fruits , fodder & firewood -Due to high tree density, there were many springs, the volume of river water flow was also high, and there was better rainfall distribution, longer duration, high intensity -However, in 1983, there was severe drought
Political climate: There was war and political instability -People lived in limited areas, with no freedom of movement/ settlement, which led to villagization. -Main roads were constructed under the Derg regime through joint efforts by the government and the community (who provided labour). There was only one primary school and 1 farmer co-operative	**Land Ownership and infrastructure:-** This era marked the end the 'land lord tenant system through introducing private land ownership; which promoted security of tenure -There was no portable/ piped water source There was less infrastructure (one school (grade 1 to 4)
Jawe Kebele **EPRDF regime -1991 – 2001 (1983-1993)/ present**	**Upper Gana Kebele** **EPRDF regime -1991 – 2001 (1983-1993)/ present**
Crops: Crop productivity increased as a result of wide adoption of modern farming techniques and professional follow-up of farmers by agricultural extension officers. -Farmers also had more access to farm inputs such as improved seeds, chemical fertilizer and pesticides hence increased crop productivity.	**Crops:** There was increased crop productivity due to availability of fertilizer and access to improved seeds -Farmers began adopting and growing a wide variety of crops/ crop types, i.e, diversification and intensification -Heavy land fragmentation, led to a decrease in land holding, thereby reducing land under crop cultivation.
Livestock: there was a decrease in livestock numbers due to decrease in size of grazing land/ fodder availability -There was a decrease in bee numbers- due to shortage of forage as a result of massive deforestation; and due to widespread use of	**Livestock:** Livestock numbers, especially cow decreased due to shortage of fodder -There was increased livestock productivity as a result of disease control through improved and easily accessible veterinary services

pesticides and herbicides Livestock diseases decreased due to veterinary services	
Tree and forest cover and Water resource: Forests were cleared for construction materials-timber and to pave way for settlements and cropland/ expansion as a result of increased human population -Deforestation led to tree product scarcity thereby leading to on-farm tree planting as farmers looked for alternative sources of trees products and services Defforestation led to: Gombora river, the permanent main water source in Jawe kebele becoming seasonal -There was a sharp decrease in the number of springs -There was a sharp decrease in the volume of river flow -Decreased rainfall intensity, distribution and duration	Tree and forest cover and water resource: There was a sharp decrease in forest cover due to population pressure which has led to conversion of forest land into settlements and land for crop cultivation; -It also led to harvesting of fuelwood and timber - Some farmers saw the need to clear forests in order to eliminate wild animals which were destroying crops -Number of springs and their water discharge rate decreased due to planting of Eucalyptus plantations around/ adjacent to springs; and deforestation of the natural forest -River flow and volume also decreased the disappearance of tributaries due to defforestation
Infrastructure: Improved infrastructure such as: more schools, health centres, communication, water supply, -Feeder roads that linked various kebeles and sub-kebeles enabled the community access social amenities	Infrastructure: There was better water supply /portable, -Though construction of murram roads, there was easy access to markets for crops and other farm products. This increased income of farmers and led to development

These changes in landuse and tree cover are presented in the form of a causal AKT diagram (Figure 25). During the Derg regime (1974 to 1991), there was significant land use changes, many of them linked to loss of natural forests, which had an effect on water resource. Cutting down of natural forests led to a decrease in ground water recharge, leading to reduced river flow volume and number of springs. Rainfall duration and intensity also decreased (Figure 21). Less water availability affected crop productivity, fodder availability and livestock wellbeing. On the other hand, due to high wildlife numbers that fed on crops, clearing of natural forests led to reduced wildlife, hence reducing crop loss to wildlife.

In the EPRDF era, increased human population triggered changes such as an increase in number of settlements and a decrease in average household land holding. Due to reduced land holding, there was competition among landuses, with an increase in land under cultivation leading to a decrease in the size of community grazing land, which had a direct impact on fodder and livestock numbers and productivity.

Reduced natural tree cover also led to a decrease in availability of tree products such as fruit, timber, and firewood.

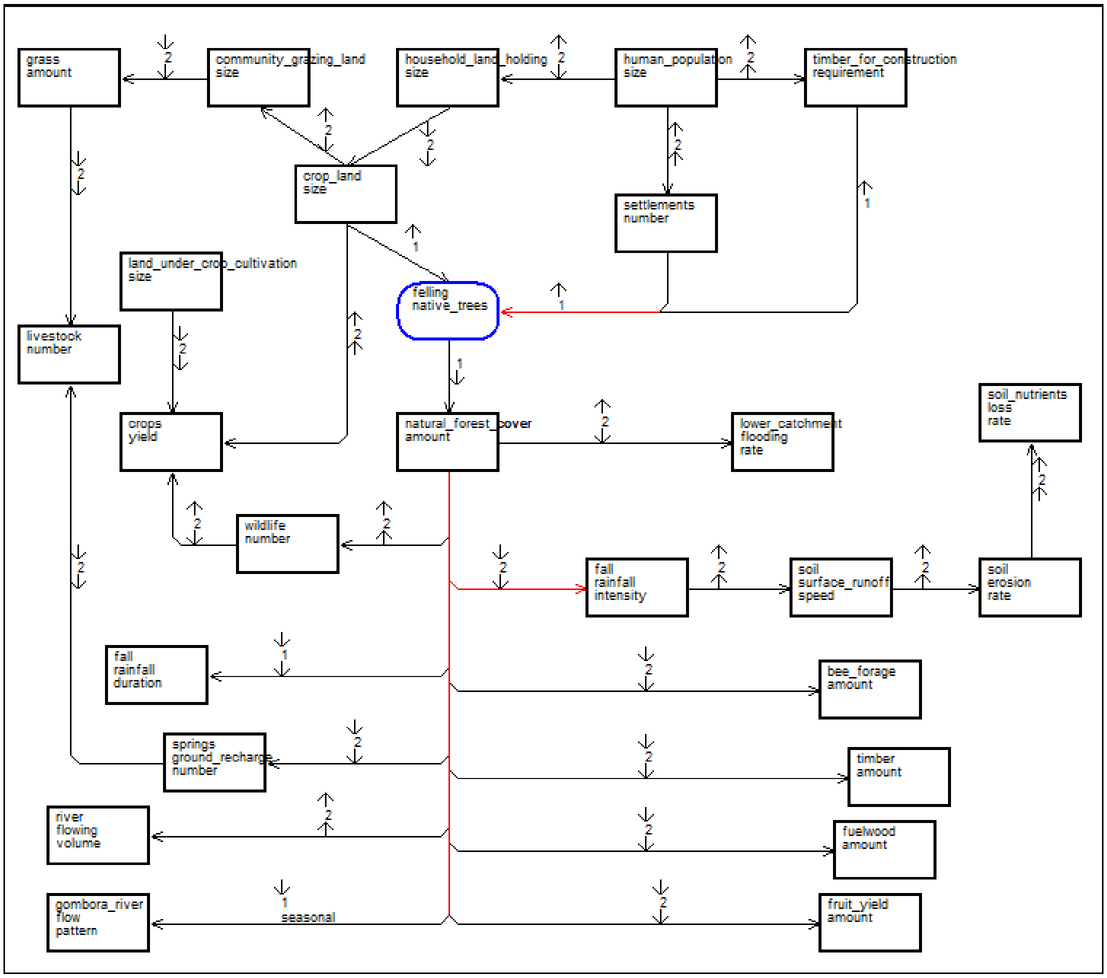

Figure 21: AKT diagram on drivers of land use change in Jawe and Upper gana kebeles
Source: Lemo_africarising.kb

KEY: Nodes represent attributes of objects, processes or actions. Arrows connecting nodes show the direction of causal influence. The upper small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the lower arrow refers to the effect node. Numbers between small arrows indicate whether the relationship is two-way (2), in which case an increase in A causing a decrease in B also implies that a decrease in A would cause an increase B, or one-way (1), where this reversibility does not apply.

These changes were visualized and presented in the diagrams below (Figure 22 and Figure 23). Red lines/ marks on the map on the right represents gullies

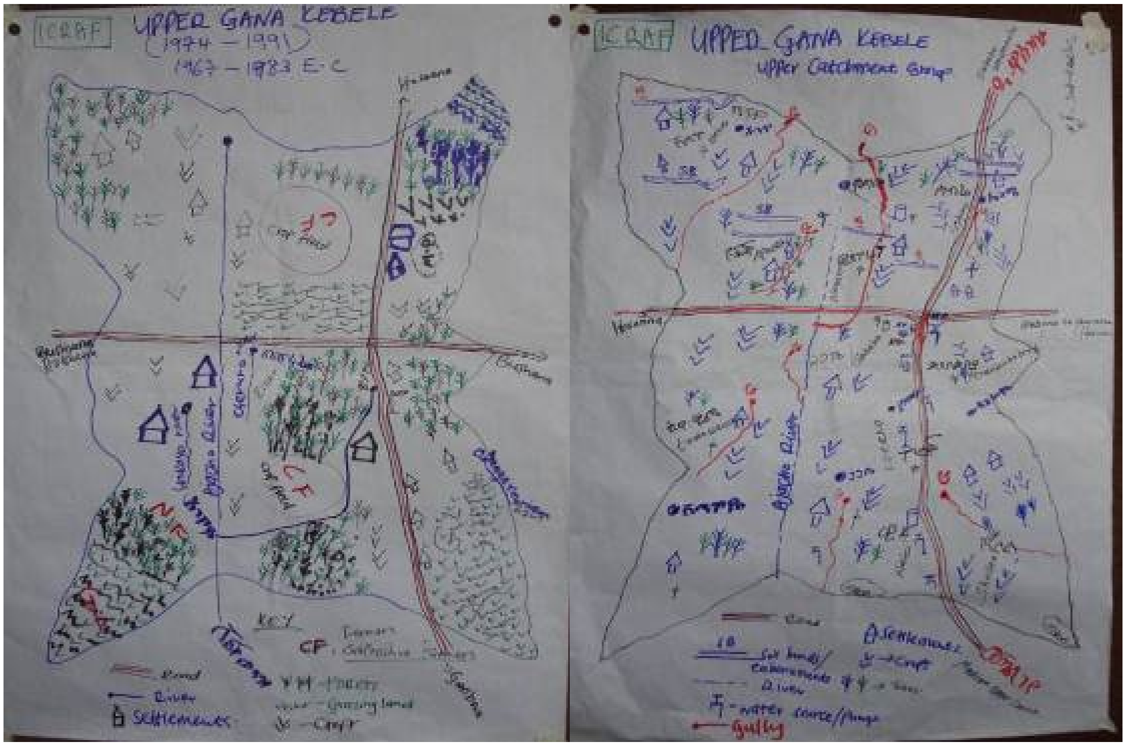

Figure 22: Upper gana kebele in Derg regime -1974-1991 and the current status (2013)   Source: farmers

Red wavy lines/ marks on the map on the right represents gullies currently existing in the kebele

Figure 23: Jawe kebele in Derg regime -1974-1991 and the current status (2013)   Source: farmers
Red broad lines/ marks on the map on the right represents gullies currently existing

3.10 Trees and Management

3.10.1 Tree diversity and utilities

There were no natural forests left found in both kebeles. However, there were native tree species remnants onfarm, and some farmers had planted woodlots on their farm compound, where they derived tree-based benefits. Unique tree species, which are endemic to Ethiopia were encountered namely: *Millettia ferruginea, Erythrina brucei* and *Vepris dainelli.* A total of 56 species were encountered (52 were identified upto botanical species name while 4 were unidentified). In Upper gana, the average tree species per farm was 12 species (ranging from 4 to 20 species per household) while that of Jawe had 11 tree species (ranging from 6 to 21 species per household). The most dominant tree species in Jawe were: *Eucalyptus species (Eucalyptus globulus and Eucalyptus camaldulensis), Croton macrostachyus, Cordia africana, Adhatoda schimperiana, Vernonia auriculifera, Vernonia amygdalina, Erythrina abyssinica, Senna siamea,* and *Cupressus lusitanica.* The most dominant species in Upper gana were *Eucalyptus species (E. globulus and E. camaldulensis), Croton macrostachyus, Cordia africana, Adhatoda schimperiana, Vernonia auriculifera, Vernonia amygdalina, Podocarpus falcatus, Erythrina abyssinica, Juniperus procera,* and *Polyscias fulva.* However, majority of native tree species had low abundance. Unidentified tree species were: fruits (sego'o, atura, and gora.) and kowada (fodder and making utensils). Newly introduced species included *Grevillea robusta* and *Sesbania sesban*.

Farmers acknowledged the great role played by trees in improving and enriching their livelihoods through provision of products and ecological services. In Lemo woreda, trees contributed to farmers' food security through: provision of fruits and other edible foods, soil fertility improvement, and fodder for livestock, and through income from sale of products such as fruits, other foods, timber and poles. Income oriented tree species included: *Enset ventricosum, Catha edulis, Eucalyptus globulus, Eucalyptus camaldulensis Juniperus procera, Cordia africana, Arundo donax, Annona senegalensis, Persea americana, Malus domestica, Rhamnus prinoides*. Trees were also reported to promote a healthy environment such as through erosion control and water table stabilization.

Fodder tree species

As mentioned earlier, trees play a key role in fodder provision during the most critical (dry) period in January and February. *Vernonia amygdalina* (Figure 24b) and *Adhatoda schimperiana* were the most commonly utilized fodder tree species due to their high palatability by livestock and their abundance across the landscape due to their wide use as live fence. *Sesbania sesban* was named as the most nutritious of all fodder species, and by was also highly palatable by livestock especially sheep. The most commonly utilized fodder tree species are shown in the AKT tree diagram below (24a).

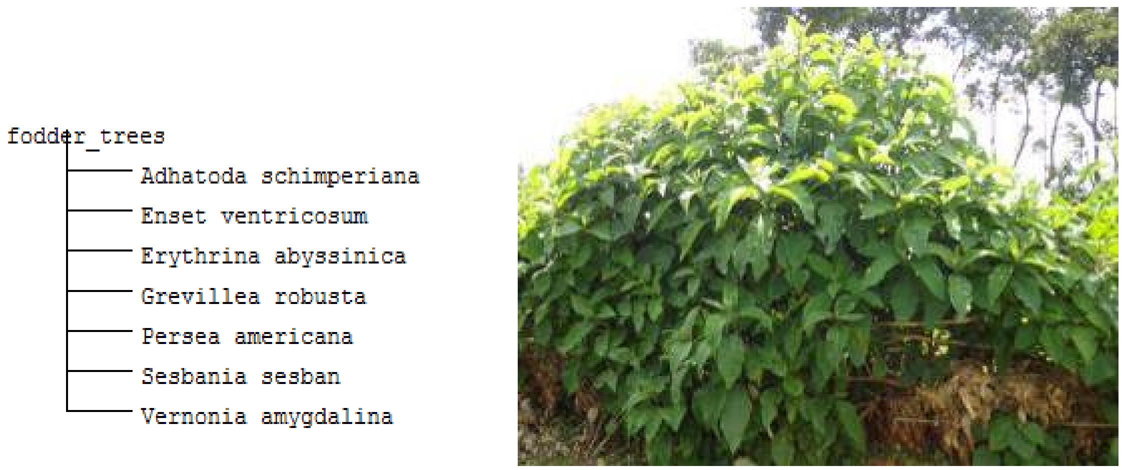

Figure 24: AKT fodder species tree diagram; Vernonia amygdalina fodder

More palatable trees named by farmers included: *Acacia melanoxylon, Acacia abyssinica, Acacia seyal, Albizia gummifera, Arundinaria alpina, Arundo donax, Cordia africana, Ekebergia capensis, Ficus thonningii, Millettia ferruginea, Olea europaea subsp. cuspidata, Polyscias fulva, Prunus africana* and *Syzygium guineense*

Timber tree species

Timber trees were viewed as key to the farmer's livelihood because they provided construction materials for houses and furniture and tools; and were a source of income for the household. Though not a timber tree, bamboo species played a key role in providing poles for thatching roofs of tukul houses (Figure 26). The most commonly used timber tree species are presented in figure 25 below:

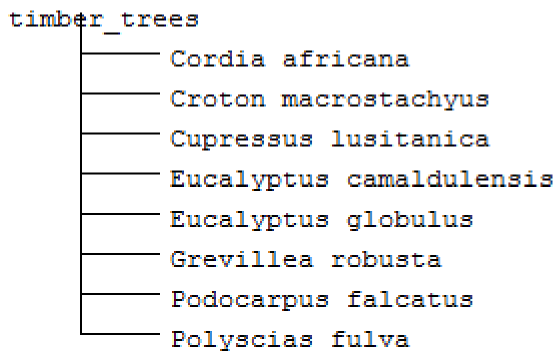

Figure 25: Most commonly utilized timber tree species in Lemo.

Figure 26:: Bamboo poles for thatching and Eucalyptus timber for house construction

Farmers went ahead to assess the attributes of some timber tree species as follows.

- Soft timber species- *Ficus thonningii, Croton macrostachyus, Polyscias fulva*
- Hard timber species*: Juniperus procera, Cordia africana,*
- Durable timber: *Cordia africana, Podocarpus falcatus, Ekebergia capensis, Syzygium guineensee*
- Termite resistant timber species- *Juniperus procera, Cordia africana, Syzygium guineensee*
- Few knots: *Cupressus lusitanica, Cordia africana*

- Straight timber grain: *Podocarpus falcatus*
- Multi-purpose timber- *Cordia africana, Grevillea robusta,*
- Attractive physical appearance- *Cordia africana*
- Timber that easily splits, especially when nailing- *Olea europaea subsp. cuspidata, Eucalyptus globulus, Croton macrostachyus*

Firewood tree species

Although it was almost becoming extinct, the most preferred and sought after firewood species was *Olea europaea subsp. cuspidata*. But based on the currently available tree species, *Eucalyptus* species was the most preferred firewood by women due to its superior attributes as listed below. Farmers, mostly women were able to analyze some important fuelwood attributes, with the order of appearance of species representing degree of possession of the stated attribute.

- Fast combustibility: - *Eucalyptus globulus, Eucalyptus camaldulensis*
- Green wood combustibility- *Olea europaea subsp. cuspidata, Eucalyptus globulus*
- Long burn length- *Olea europaea subsp. cuspidata, Eucalyptus globulus, Croton macrostachyus*
- High calorific value:- *Olea europaea subsp. cuspidata, Eucalyptus globulus*
- Fast growth rate:- *Eucalyptus globulus*
- *Olea europaea subsp. cuspidata* fuelwood smell is sweet.
- *Cupressus lusitanica* firewood produces sparks when burning, hence was not preferred Majority of farmers mentioned that they experienced fuelwood shortage during the rainy season from June to September. In such periods, farmers used crop residues, kubet (cow dung) and green Eucalyptus globulus wood and leaves (due to its green combustibility ability).

Charcoal trees

Charcoal tree species identified by farmers were: *Acacia abyssinica, Acacia seyal, Albizia gummifera, Croton macrostachyus, Milletia ferruginea* and *Prunus africana. Charcoal was also sold for income.*

Fruit trees

Fruits were seen as an important source of household nutrition/ food and income. The most common fruit trees found were exotic namely: *Persea americana, Malus domestica, Casimiroa edulis, Annona senegalensis, Prunus persica, Mangifera indica* and *Citrus sinensis.* However, there was low density of these fruits onfarm. Furthermore, majority of farmers in both kebeles noted with concern the very slow maturity rate of these exotic fruit tree species, especially mangoes, avocado and oranges; which discouraged them from planting more on their homesteads. For instance, at eight years of age, avocado trees had not begun flowering and fruiting. Therefore, intensified fruit production would require ecologically suitable fruit trees to be introduced into Lemo area; and also investment on improved fruit varieties in these highland areas. *Dovyalis abyssinica* (commonly used as live fence) was also a source of fruits, though had no market/ income potential. Others native fruit species, though low in diversity and density were: *Syzygium guineensee,* and unidentified species namely: *sego'o, atura*, and *gora.*

Bee forage

Bee products such as honey were named as a source of improved household nutrition and income. However, only afew farmers were practicing apiculture due to lack of market for honey and lack of raw materials to construct improved beehives. Numerous species were named as having good bee forage namely: *Eucalyptus globulus, Grevillea robusta, Persea americana, Senna didymobotrya, Sesbania sesban, Acacia abyssinica, Acacia seyal, Cordia africana, Croton macrostachyus, Dovyalis abyssinica, Ekebergia capensis, Erythrina abyssinica, Olea europaea subsp. cuspidata, Polyscias fulva, Senna siamea,* and *Syzygium guineensee.* Hence there is

Soil fertility improvement tree species

Farmers retainedseveral native trees in the crop fields, which they had observed were friendly to crops. Attributes which qualified these speciesfor this niche was that they were termed as compatible with crops because they had a shallow root system, and they did not compete for moisture or nutrients, hence crops tolerated them. Further, their leaves, which were described as fast decomposing were normally utilized in June as mulch for the crops after pollarding, just ahead of the crop planting activities in July. Species most commonly retained in the crop land, which improved soil fertility are presented in figure 27:

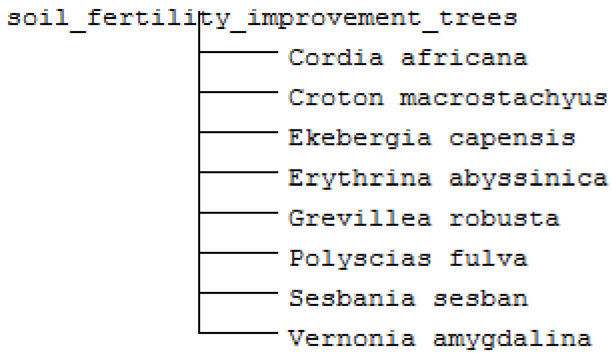

Figure 27: Tree species retained in the cropland

Podocarpus falcatus and *Olea europaea subsp. cuspidata* leaves were mentioned to be very slow decomposers, hence their presence in cropland inhibited proper crop growth and their leaves were never used as mulch. Tree species that competed for water with crops named were: *Eucalyptus globulus, Eucalyptus camaldulensis, Cupressus lusitanica* and *Syzygium guineensee, with farmers reporting that they hardened the soil around the making it impossible for crops to grow*

Soil erosion control tree species

Majority of farmers interviewed believed that all trees found on their landscape served the function of controlling soil erosion. This they attributed to the ability of tree roots to hold and bind together soil particles; and to reduce the speed of surface runoff and enhance the process of water infiltration. The degree to which every species serves these functions is what farmers said differed from one species to another. One farmer further stated that trees, if planted or retained in an organized manner across the slope were very effective in controlling surface runoff and thereby preventing soil erosion. Four species were commonly being planted along soil and water conservation structures such as soil bunds and trenches namely: *C. macrostachyus* (Figure 31)*, A. abyssinica, S. sesban* and *V. amygdalina.*

Table 8: Tree utilities table for Lemo woreda

				Provisioning Services/ Products														Regulating Services					Common Niches onfarm				
Botanical Name	Hadiyya Language	Amharic Language	Origin	Income	Fruit	Other foods	Fuelwood	Charcoal	Timber for Furniture	Poles/Timber for Construction	Timber for tool handles, utensils	Medicine	Livestock Fodder	Bee Forage	Live Fence	Dead Fence	Fibre	Shade	Soil Erosion Control	Soil Fertility Improvement-Roots	Soil Fertility Improvement-Leaves	Streambank Stabilization	Boundaries	Home compound	Woodlot	Cropland	Open or grazing land
Acacia abyssinica	Grara	Girar	N				x	x					x	x		x		x	x	x	x		x			x	
Acacia decurrens	Grara	Girar	E				x			x						x								x			
Acacia melanoxylon	Omendila	Girar	E				x			x			x			x								x			
Acacia seyal	Waccu grara	Girar	N				x	x					x	x		x				x	x		x				
Adhatoda schimperiana	Tumunga	Sensel	N				x						x		x						x			x			
Albizia gummifera	Mande’e	Sasa	N				x	x		x	x	x	x					x		x	x					x	
Annona senegalensis	Gishita’a	Gishita	E	x	x																			x			
Arundinaria alpina	Lema	Kerkha	N	x						x	x		x												x		
Arundo donax	Shamboko’o	Kerkha	N	x						x	x		x												x		
Azadiracta indica	Niima	Neem	E																					x			
Bersama abyssinica	Kor’haka	Azamir	N				x				x	x									x			x		x	
Casimiroa edulis	Kazmira	Kazimir	E	x	x																			x			
Catha edulis	Chata	Chat	N	x																				x		x	
Celtis africana	Kema’lhaka	Kawot	N				x									x							x			x	
Cinnamomum cassia	Wato’o		N									x			x												
Citrus sinensis	Birtukana	Birtukan	E	x	x																			x			
Coffea arabica	Buna	Bunna	N																					x			
Cordia africana	Wedesha	Wanza	N	x					x		x		x	x		x		x			x			x		x	x
Croton macrostachyus	Masana	Bisana	N				x	x	x		x	x		x		x			x		x		x	x		x	x
Cupressus lusitanica	Ferenj homa	Yeferenj tid	E	x			x		x		x				x								x	x			
Dovyalis abyssinica	Koshima	Koshim	N		x									x	x												
Ekebergia capensis	Ollola	Lol	N				x		x		x		x	x							x		x			x	x
Enset ventricosum	Wesa	Enset	N	x		x							x				x							x			
Erythrina abyssinica	Wora’a	Korch	N								x		x	x						x	x		x			x	x
Eucalyptus camaldulensis	Kashar Bahir’zafa	Key Bahir zaf	E	x			x			x				x		x			x				x	x	x		
Eucalyptus globulus	Kedal Bahir’zafa	Nech Bahir zaf	E	x			x			x				x		x								x	x		

				Provisioning Services/ Products														Regulating Services					Common Niches onfarm				
Botanical Name	Hadiyya Language	Amharic Language	Origin	Income	Fruit	Other foods	Fuelwood	Charcoal	Timber for Furniture	Poles/Timber for Construction	Timber for tool handles, utensils	Medicine	Livestock Fodder	Bee Forage	Live Fence	Dead Fence	Fibre	Shade	Soil Erosion Control	Soil Fertility Improvement-Roots	Soil Fertility Improvement-Leaves	Streambank Stabilization	Boundaries	Home compound	Woodlot	Cropland	Open or grazing land
Euphorbia candelabrum	Ad'ama	Kurkual	N								x													x			
Ficus thonningii	Oda'a	Sholla	N		x				x		x		x										x	x		x	
Grevillea robusta	Grevila	Ytemenja zaf	E				x			x			x	x		x		x			x			x			
Jacaranda mimosifolia	Jacaranda	Jacaranda	E				x									x								x			
Juniperus procera	Habeshich homa	Yehabesha tid	N	x			x		x	x	x													x			
Malus domestica	Appla	Apple/ Pome	E	x	x																			x			
Mangifera indica	Mango'o	Mango	E	x	x																			x			
Millettia ferruginea	Hangeda/ Bilaw'ha	Birbira	N				x	x				x	x								x			x			
Moringa oleifera	Shifera	Shiferaw	E																					x			
Olea europaea subsp. cuspidata	Wera	Weira	N	x			x			x	x		x	x		x		x					x	x			
Persea americana	Avocado'o	Avocado	E	x	x		x		x				x	x		x								x			
Phoenix reclinata	Dimbaba	Zimbaba	N								x															x	
Podocarpus falcatus	Digba	Zigba	N				x		x		x					x		x						x		x	x
Polyscias fulva	Bolfe'e	Yezinjero wonbe	N				x		x		x		x	x		x					x			x		x	x
Prunus africana	Arara	Tikur inchet	N				x	x		x	x	x	x			x							x			x	
Prunus persica	Koka	Kok	E	x	x																			x			
Pterolobium stellatum	Chergosa	Kontir	N													x							x				
Rhamnus prinoides	Gesho'o	Gesho	N	x		x									x								x	x			
Ricinus communis	Kobo'o	Gulo	N	x																	x			x			
Senna didymobotrya	Meka	Yeferenj digita	E											x											x		
Senna siamea	Senna	Digita	N				x				x	x		x	x								x				
Sesbania sesban	Sesbana'a	Sesbania	E				x						x	x				x	x	x	x			x		x	
Syzygium guineense	Dubana	Dokma	N		x		x			x			x	x		x					x		x			x	
Vepris dainelli	Ta'a		N								x	x											x	x		x	
Vernonia amygdalina	Heba	Girawa	N				x						x	x	x				x		x		x				
Vernonia auriculifera	Barawa		N				x					x	x		x						x		x				

3.10.2 Tree Management and Phenology

The most common tree management practice was pollarding. Coppicing was also practiced, but mainly on *Eucalyptus* species for timber and poles. Pollarding (practice and frequency) was influenced by various factors namely: tree utility, niche where trees were found, need for products and land ownership type.

Tree utility: As mentioned earlier, majority of trees retained in the crop land were mainly pollarded in June before planting crops to reduce shade and also provide mulch (leaves) and dead fence (branches) to protect crops from livestock browsing. Timber, firewood and fodder trees were only pollarded or coppiced on needs basis when such products were required.Fruit trees were never pollarded since farmers felt pruning would reduce fruit potential.

- **Niche found:** Trees found away from the crop land were rarely pollarded, especially those in the home compound, except when products were required. Also, trees purposively retained for shade in the home compound such as *Podocarpus falcatus* were never pollarded.

- **Land ownership type:** Farmers who had rented land were not allowed to manage trees therein, even though such trees could have dense shade which would affect crop's ability to access sunlight. This eventually affected crop productivity.

- Farmers had observed knowledge about canopy spread and density of a few trees retained in their cropland, and how this eventually interacted with crops such as influence on shade access to sunlight.

Key timber tree species such as *Eucalyptus* were coppiced during the dry season. Some farmers observed and others overheard that trees coppiced during the rainy season did not sprout back, and instead died from attack by pests.

Although some farmers had some knowledge about tree phenology (leaf fall, flowering, fruiting), there was no consistency in their observations. Only fruiting period of edible fruit tree species were consistently described. Women had far lower knowledge about tree phenology than men. One of the women farmers interviewed in Upper gana- mentioned that *"women look down, men look up"* meaning that women are mostly concerned with crop production while it is men's work to look after and manage trees and sell tree products.

3.10.3 Opportunities and Challenges for tree integration in Lemo woreda

Farmers appreciated the important role trees play on the landscape, and expressed their interest in planting more of the following species:

Jawe kebele:

- Fruit (food and income): avocadoes, mangoes, oranges
- Timber: *Cordia africana, Eucalyptus globulus, Juniperus procera, Cupressus lusitanica, Grevillea robusta*
- Income: *Coffea arabica, Catha edulis, Cordia africana, Eucalyptus globulus, Juniperus procera*, and fruits,
- Multi-purpose trees- *Cordia africana, Eucalyptus, Grevillea robusta,*
- Soil fertility
- Fodder- *Sesbania sesban, Vernonia amygdalina*

Upper Gana kebele:

- Fruits (food and income)- avocadoes, apple, pawpaw, peach, mango, orange
- Income-*C. africana, G. robusta*, *Enset ventricosum, Catha edulis*
- Timber-*C. africana, Eucalyptus spp, P. falcatus, G. robusta*
- Firewood: *O. europaea, P. falcatus* , Shade- *P. falcatus*
- Multipurpose trees- *Eucalyptus spp, C. macrostachyus, C. africana*

However, farmers expressed constraints which inhibited tree integration namely:

1. Lack of seedlings/ propagative materials: In both Jawe and upper Gana kebele, there was no government or community owned tree nursery. Only private onfarm nurseries where *Eucalyptus spp, Sesbania sesban,* and *Grevillea robusta* seedlings being raised.
2. Water scarcity (DAs said this discouraged them from establishing government nurseries), and some of the farmers too had a similar response
3. Farmers lacked adequate knowledge about some tree utilities and tree-crop interactions, hence they were cautious about planting certain less-familiar trees.
4. Scarcity of land discourages farmers from planting more trees due to competition of space with other landuses such as crops.
5. Slow maturity of fruit trees discouraged farmers from planting more. This could be ecological unsuitability of such tree species, hence need for matching this highland area with appropriate trees

4. Discussions

4.1 Understanding drivers of land use change

Various factors were identified as causing land-use change in Lemo woreda. Population pressure is a major driving force to land use change (Ningal, Hartemink, & Bregt, 2008), with extensification as a result of agricultural expansion coming largely at the cost of reduction in both woodlands and riparian forest, hence agricultural expansion is one of the drivers of land-use change (Wood, Tappan, & Hadj, 2004). Further, land fragmentation (Nagendra, Munroe, & Southworth, 2004) leads to fragmented and unsustainable land use practices. Given, however, the some-times large erosion-induced reductions in crop yields, it appears likely that erosion has a strong impact on land-use. Abandonment of arable land due to declining productivity is a landuse change that may result from soil erosion (Bakker et al., 2005).

Other drivers of landuse include changes in policies as experienced from the transition from Derg regime to EPDRF regime in Ethipopia; a factor that was also observed in Ghana, where national policies formulated led to changes in use of land (Braimoh, 2009). Further, change in climate, dating back from early 1980's in the study areas had a negative impact on crop productivity through changing rainfall patterns from bimodal to unimodal. The increasing surface temperature influences factors very relevant for food security such as precipitation, water availability, and weather extremes (Christoph Bals, Sven Harmeling, 2008). Adaptation to climate change requires substantive investments in infrastructure such as dams, flood-resistant storage facilities, and techniques for reducing water loss in distribution systems including the farm/crop system.

4.2 Different approaches to sustainable intensification

Sustainable agricultural intensification is defined as producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services (Pretty, 2009). A sustainable production system would thus exhibit most or all of the following attributes: utilising crop varieties and livestock breeds with a high ratio of productivity to use of externally- and internally-derived inputs; avoiding the unnecessary use of external inputs; harnessing agro-ecological processes such as nutrient cycling, biological nitrogen fixation, allelopathy, predation and parasitism; minimising use of technologies or practices that have adverse impacts on the environment and human health; making productive use of human capital in the form of knowledge and capacity to adapt and innovate and social capital to resolve common landscape-scale problems; and quantifying and minimising the impacts of system management on externalities such as greenhouse gas emissions, clean water, carbon sequestration, biodiversity, and dispersal of pests, pathogens and weeds.

Traditionally agricultural intensification has been defined in three different ways: increasing yields per hectare, increasing cropping intensity (i.e. two or more crops) per unit of land or other inputs (water), and changing land use from low- value crops or commodities to those that receive higher market prices (Pretty et al., 2011).

4.2.1 Increasing yields per hectare while promoting environmental protection

Increasing yields per hectare of land is essential in order to optimize on the limited land resource in achieving food sufficiency. Agricultural technology has played a central role in overcoming food insecurity in this regard. Though many technologies and practices have been used in success project, the following three types of technological improvements have probably played substantial roles in food production increases: more efficient water use; improvement in organic matter accumulation and carbon sequestration; and reduced pesticide use (European Commission, 2006).

Presently, the world's population continues to increase, although at lower growth rates. On the other hand global food production is confronting issues such as climate change and the scarcity of water, land and energy resources. Fortunately, there are existing improved and promising technologies that could be employed to boost farmers' production and to increase their incomes, while ensuring environmental conservation. These are: genetic improvement; minimizing the effects of the scarcity of water, land, and labour resources; confronting the declining soil fertility, increased pressure from pests and diseases, and the degradation and pollution of environment and integrated crop management to close the yield gap and to increase farmer's income (Van Nguyen, 2006). For example, through adoption of good agronomic practices such as mulching and use of organic manure, sequestered carbon can be stored in the longer term as soil organic matter, which is a much larger and more stable pool of carbon. At the same time, it would contribute to more sustainable agriculture by increasing resistance to erosion, add to water and nutrient reserves in the soil, and increase infiltration capacity (Schlesinger 1999). Low capital input farming systems may have a higher potential for net carbon accumulation than intensive forms of agriculture, where the inputs (such as fertilizer and energy) are associated with high carbon costs. Crop rotations can break insect and disease cycles, reduce weeds, curb erosion, supplement soil nutrients, improve soil structure and conserve soil moisture ((Sustainable Agriculture Networks, 2006)

While aiming at maximizing crop yields, unsustainable cropping methods such as continuous cropping, lack of fallows, excessive tillage and lack of water and soil conservation measures many result into land degradation including depletion of soil nutrients. Land degradation is a long-term loss of ecosystem function and services, caused by disturbances from which the system cannot recover unaided (UNEP, 2007). This occurs as a result of various factors such as soil erosion. Soil erosion becomes a problem when the natural process is accelerated by inappropriate land management, such as clearance of forest and grasslands followed by cropping which results in inadequate ground cover, inappropriate tillage and overgrazing. Nutrient depletion is a decline in the levels of plant nutrients, such as nitrogen, phosphorous and potassium, and in soil organic matter, resulting in declining soil fertility. The removal of the harvest and crop residues depletes the soil, unless the nutrients are replenished by manure or inorganic fertilizers. Deficiency of plant nutrients in the soil is the most significant biophysical factor limiting crop production across very large areas in the tropics, where soils are inherently poor, Further, water scarcity is also a limiting factor to increasing crop productivity, hence there is need to employ risk management practices such as: water harvesting, soil and water conservation, and supplementary irrigation (ibid).

4.2.2 Increasing system resilience through diversification

Ecological resilience is the ability of a system to absorb impacts before a threshold is reached where the system changes into a different state (Gunderson 2000). Diversity in various system components such as crops, trees and livestock is what brings about resilience. Agroforestry is one of several promising multifunctional landscape developments that can create resilience through simultaneously generating livelihoods and preserving environmental quality (UNEP, 2007). Diversity is not only intrinsic to agriculture; it can be considered also as one of its main assets as it provides a wide range of responses that can help to face uncertain futures (van der Ploeg, Laurent, Blondeau, & Bonnafous, 2009).

For instance, in Lemo, there is need to increase diversity and density of native fruit tree species, because some of the exotic fruit trees were poorly performing. Biodiversity conservation in forestry and agricultural landscapes is important because: reserves alone will not protect biodiversity; commodity production relies on vital services provided by biodiversity; and biodiversity enhances resilience, or a system's capacity to recover from external pressures such as droughts or management mistakes (Fischer et al, 2006). Farms in Lemo area were found to host unique tree species , which are endemic to Ethiopia namely: *Millettia ferruginea (Hailu, Negash, & Olsson, 2000)* , *Erythrina brucei* and*Vepris dainelli* (Vivero & Kelbessa, n.d.)

Likewise, crop diversification, meaning farming two or more crops per unit of land or other inputs (water), is a fundamental approach for improving yield stability and crop resilience under changing climatic conditions (Mugendi, 2013). Conventional agriculture is dependent on the use of specific crop varieties or hybrids that have been bred specifically to exploit high-input conditions. Conversely, crop varieties used in high-input systems are not often adapted to low-input farming, a key element of many smallholder farming systems. Hence the need to diversify (Sustainable Agriculture Networks, 2006). Diversification helps to soften impacts on environmental resources, spread farmers' economic risk, exploit profitable niche markets, create new industries based on agriculture, strengthening rural communities, aid the domestic economy, and enabling producers to grow crops that would otherwise be imported (Bhattacharyya, 2008) (Goletti & Division, 1999)

4.2.3 Markets and Infrastructure

Sustainable intensification also promotes the integration of small farmers into commercial markets and global food chains but it is not certain that small-scale farmers will benefit from this (Friends of the earth, 2012). One of the approaches would be to change land use from low-value crops or commodities to those that receive higher market prices. Also value addition is advantageous in ensuring farmers fetch better prices for their products and also helps prevent post-harvest losses.

4.2.4 Bridging Knowledge Gaps

Understanding local agro-ecological processes- what farmers and other resource users do not know usually limits their practices. Limits to what farmers can observe also limits their knowledge ((Sinclair & Joshi, 1999) (Sinclair, 1999). To increase production efficiently and sustainably, farmers therefore need to understand under what conditions agricultural inputs (seeds, fertilizers and pesticides) can either complement or contradict biological processes and ecosystem services that inherently support agriculture (Royal Society,2009; Settle and Hama Garba, 2011). Hence there is great need to promote intensification of knowledge, skills and management practices among farmers.

4.2.5 Ecological suitability

Farmers in Lemo woreda noted with concern about the poor performance (slow maturity rate of fruit tree species especially avocadoes, mangoes and oranges) though they did not have an explanation for this phenomenon. A tree species is suited to a site when it is physical and genetic makeup allow for it to survive and reproduce given the constraints of a site's physical environment (Almendinger, J. 2011). The choice of suitable tree species to grow, which must be adapted to the environmental conditions of a locality is one of the most important prerequisites for successful agroforestry (Gresbach, 2007). Hence the need to match species with sites local conditions and circumstances

5 Conclusions and Summary of key findings

- Both Upper Gana and Jawe kebeles were accessed through a murram/ dirt road. There was water scarcity as there were only 1 permanent river in each kebele, with afew springs. There were also 2 dams for watering livestock. There was no communal grazing land in upper Gana. There was no natural forest remaining, and no government tree nurseries, only individual nurseries with Eucalyptus seedlings. 1 Farmer Training Centers per kebele offered demonstrations on farming best practices. occasionally trained on farming best practices.
- Lemo area is characterized by highly intensified farming system within small privately owned land, with the actual average land holding of farmers interviewed in Jawe kebele being 1.2ha. while that of Upper gana was 1.5. Land is not very fragmented, with individual farmers having only one or two fields.
- Tree niches on farm varied depending on the location of the field. Farms that hosted the homestead had trees along the boundary, while those in the cropfields separate from the homestead were not fenced and had no trees / live fences along boundaries. Because cut and carry system of livestock feeding was practiced, there were no crop loses experienced from livestock browsing.
- Planting of major annual crops was done by men except teff which was done by women. Men were involved in selling the most economically valued products such as trees, coffee and khat; while women were involved in the less valuable products. Both men and women took up major chores such as harvesting crops based on the intensity / volumes of crop production, that is, men were involved in harvesting during the long-rainy season while women harvested during the short-rainy season
- Some common knowledge held by farmers varied according to kebele, upper-lower catchment, gender, age and land size.
- Crop production challenges: limited household land leading to continuous cropping leading to low of soil fertility, unreliable rainfall and water scarcity, enset bacterial wilt (alooya), coffee berry disease, irish potato diseases, soil erosion, high cost of inputs,

Lack of improved crop varieties eg disease-resistant potatoes, Market fluctuations of crop prices, labour shortage and crop pests and diseases.

- Livestock- Crops and livestock components were found to complement each other in a lot of ways, though competed in afew ways. Crop residues played a key feed role especially between November and February. Trees on the other hand played a key role in bridging the fodder gap and complementing crop residues during the most critical (dry) periods in January and February, when there was no other source of fodder. Challenges affecting livestock numbers and / or productivity included: fodder scarcity, water scarcity, inferior local breeds, livestock diseases led to death or low productivity of livestock.
- Community exchange groups played a key role in keeping farmers together and sharing information, knowledge and technologies, and community burdens
- Drivers of landuse/ tree cover change: landuse and tree cover began changing during the transition period from Haile selasie and Derg era around 1992 (1983 Ethiopian calendar). Increased human population triggered changes such as an increase in number of settlements and a decrease in average household land holding. Due to reduced land holding, there was competition among landuses, with an increase in land under cultivation leading to a decrease in the size of community grazing land, which had a direct impact on fodder and livestock numbers and productivity. Reduced natural tree cover also led to a decrease in availability of tree products such as fruit, timber, and firewood.
- Trees - A total of 56 species were encountered on farms and landscapes across Lemo woreda. There were native tree species remnants onfarm. Unique tree species, which are endemic to Ethiopia were encountered namely: *Millettia ferruginea, Erythrina brucei* and *Vepris dainelli.* Farmers acknowledged the great role played by trees in improving and enriching their livelihoods through provision of products and ecological services. Products included: provision of fruits and other edible foods, fodder for livestock and through income from sale of products, timber, firewood, bee forage, while services included: soil fertility improvement, erosion control. Farmers were able to assess the attributes of trees with regards to: timber, firewood, fodder, crown density, crown spread, root depth and spread.

- The most common tree management practice was pollarding. Coppicing was also practiced, but mainly on *Eucalyptus* species for timber and poles. Pollarding (practice and frequency) was influenced by various factors namely: tree utility, niche where trees were found, need for products and land ownership type.
- Farmers appreciated the important role trees play on the landscape, and expressed their interest in planting more of the following species: fruits, timber, income, multi-purpose, soil fertility improvement and fodder. Constraints which inhibited tree integration were: lack of seedlings/ propagative materials, water scarcity, farmers lacked adequate knowledge about some tree utilities and tree-crop interactions, hence they were cautious about planting certain less-familiar trees, scarcity of land discouraged farmers from planting more trees due to competition of space with other landuses such as crops and slow maturity/ ecological unsuitability of fruit trees discouraged farmers from planting more.

6. Opportunities for sustainable intensification in Limo

6.1 Opportunities for intervention at the landscape scale

- Soil erosion is a serious problem: erosion structures with grass and tree strips, also water harvesting in the upper catchment areas to reduce the speed of surface runoff downslopes. Also important is to maintain ground/soil cover to reduce surface runoff
- For quicker upscaling, there is need to target existing community exchange groups to pass on agricultural / agroforestry technologies and knowledge
- Need for tree nursery establishment in each kebele to meet farmers needs of improved fruit trees, timber trees, multipurpose trees including fodder
- The government through DAs should work to promote tree planting culture through awareness creation on tree utilities, services and especially promote trees that are compatible with crops
- Elephant grass has been utilized and tested in similar areas- widely used in Gishwati, Rwanda for erosion control along the highland; hence this could be maximized
- In order to catalyze scaling up of agricultural best practices, the existing FTCs should be fully utilized for demonstration purposes; also monitoring of the model farmer concepts to ensure sharing of knowledge among more farmers. Interventions can also target community organizations; and also target farmers based on the various roles they play in livelihoods.
- Ecological suitability- need to match species with site characteristics/ biophysical
- Need for nursery establishment in each of the kebele

6.2 Opportunities for intervention at the farm-level scale

- Due to land scarcity, there is need to look into the economics of intensification and determine what is the carrying capacity of land in this area for intensification to be termed as sustainable.

- Due to land scarcity, retaining of more trees would require interventions to identify and maximize on those niches that farmers prefer to plant trees such as: non-competing species in the cropland – including short rotation shrubs, along boundaries (in line with the live fence), along soil and water conservation structures and in the home compound

- Controlling crop diseases requires provision of improved crop varieties, combined with good crop management practices.

- Livestock disease control requires improved livestock breeds, farmers to regularly consult with veterinary services and practicing livestock management practices that eliminate disease transmission such as not sharing livestock watering points

- Water scarcity: need for water harvesting interventions. Water availability will lead to diversified incomes through farmers planting vegetables. It will also ensure success of tree nursery initiatives

- Low soil fertility and high cost of fertilizer: incorporate short rotation fertility trees/ shrubs

- Small/no communal grazing land – need to maximize on intensify and diversity fodder sources onfarm

- There are no natural forest left- need to maximize on onfarm multi-purpose tree planting/ regeneration for tree products

- There is general need to increase tree species diversity and density in order to increase resilience and products throughout the year such as fodder, firewood, fruits

- Regeneration of native tree species

- With high cost of fertilizers, farmers should be encouraged to use organic fertilizers such as crop residues and tree mulch
- Bee keeping should be encouraged and promoted to take advantage of the numerous bee forage trees. For household nutrition and income

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List of farmers interviewed during individual home visits

Jawe Kebele

	Names of farmers	Gender
	Upper catchment	
1	Zemu Tukie	F
2	Adinaw Ayele	M
3	Mandulo Amano	M
4	Amarech Tirago	F
5	Siyoum, Mencha	M
	Lower catchment	
6	Tadelech Ersido	F
7	Aster Erbeto	F
8	Brehanu Tirkaso	M
9	Nigussie Habte	M
10	Desarech Helalo	F

Upper Gana Kebele

	Names of Farmers	Gender
	Lower catchment	
1	Koeyo degaro	F
2	Amarech Abiyo	F
3	Erkalo Lamorie	M
4	Tadelech Araba	F
5	Kassa Abera	M
	Upper catchment	
6	Abera Ulgaso	M
7	Abate Hadero	M
8	Aster Menamo	F
9	Zerihun Datta	M
10	Tseganesh Taddese	F