Local agro-ecological knowledge of sustainable intensification of the tree-crop-livestock system in the Ethiopian Highlands, Sinana Woreda, Oromo Region

Farmers weeding a wheat field in Ilu Sambitu kebele, Sinana woreda

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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.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment. http://africa-rising.net/

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Introduction

Africa faces considerable challenges overcoming food insecurity in the coming decades. The decline in the natural resource base, on which agriculture depends, is significant. More than 95 million ha of arable land, or 75% of the total in sub-Saharan Africa has degraded or highly degraded soil, and farmers lose eight million tons of soil nutrients each year estimated to be worth $4 billion (Toenniessen et al. 2008). If present trends continue African food production systems will only be able to meet 13% of the continent's food needs by 2050 (Global Harvest Initiative, 2012; Montpellier Panel Report, 2013). One response to this challenge is sustainable intensification (SI). There are a number of definitions of SI but perhaps the most widely accepted definition comes from Pretty et al. (2011) which describes SI 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'. Not surprisingly there are a number of challenges associated with moving SI from theory into practice within Africa – not least the considerable heterogeneity of African farming systems. Acknowledging this there remain questions about how SI will look like on the ground, and how it might differ amongst production systems, in different places, and given different demand trajectories.

SI is being developed as a 'systems' oriented approach to decision making which accommodates a mix of strategies required for different biophysical, social, cultural and economic contexts (McDermott et al. 2010). Given the high vulnerability of many African farming systems, it is important to recognise that capacity for SI will vary from shoring up resilience to enhancing productivity (Ginkel et al. 2013). SI strategies are only likely to be successful in areas were vulnerability has been addressed through resilience strategies.

Successful implementation of SI strategies needs to be implemented across a range of scales. One of the key constraints to implementation of SI in sub-saharan Africa is insufficient data at a local landscape scale. Prioritising where to implement SI interventions will require a sufficient characterisation of the variability in capacity of farming systems across these landscapes. Local ecological knowledge (LEK) is one tool for rapid characterisation of spatial and temporal variation within a landscape. LEK can also be used to identify trends and spatial patterns of land use and land cover change, observed by local people over many years, and the impact that these changes have wrought on ecosystem service provision (Pagella and Sinclair, 2014).

This study was focussed on identifying existing sustainable intensive agricultural methods in Sinana woreda, Oromo region. The study also collected local knowledge on agricultural methods so as to assist in the development and implementation of appropriately adapted technologies to intensify production of crops, livelihood and household production without extending the areas subject to cultivation.

Research Objectives

The research objectives of the study were:

- To characterize agro-ecological knowledge of farmers in the Africa RISING project sites
- To identify and map out community resources
- To assess land use and livelihood strategies at the household level
- To characterise existing tree cover and assess the drivers of tree cover change
- To determine temporal variation in availability of provisioning services (income, fuel, livestock feed, crops, labour.)

Research Questions

The research questions posed were:

1. What is the range of land use and livelihood systems in the area?
2. What are the main resources farmers utilize and when in the year are they available?
3. What functions and services do trees provide in these sites?
4. How have the tree cover and the land use systems changed over time?
5. What constraints are there to agricultural production and what agro-ecological knowledge do farmers have about them and their solutions?

Methods

Study site selection

The sites in this study were pre-selected for the Africa RISING project based on a specific set of criteria. The study sites were delineated based on political/administrative boundaries. Four ‘woredas’ (districts) were therefore chosen as the size of woredas is large enough to encompass a range of bio-physically defined areas with contrasting farming systems and a range of social institutions. The selection of target woredas was done based on the following criteria:

- It has 25% or more area dedicated to wheat production
- It is one of the government selected AGP (Agricultural Growth Plan) woredas
- It has an annual rainfall of more than 600mm and an elevation greater than 1700 m.a.s.l

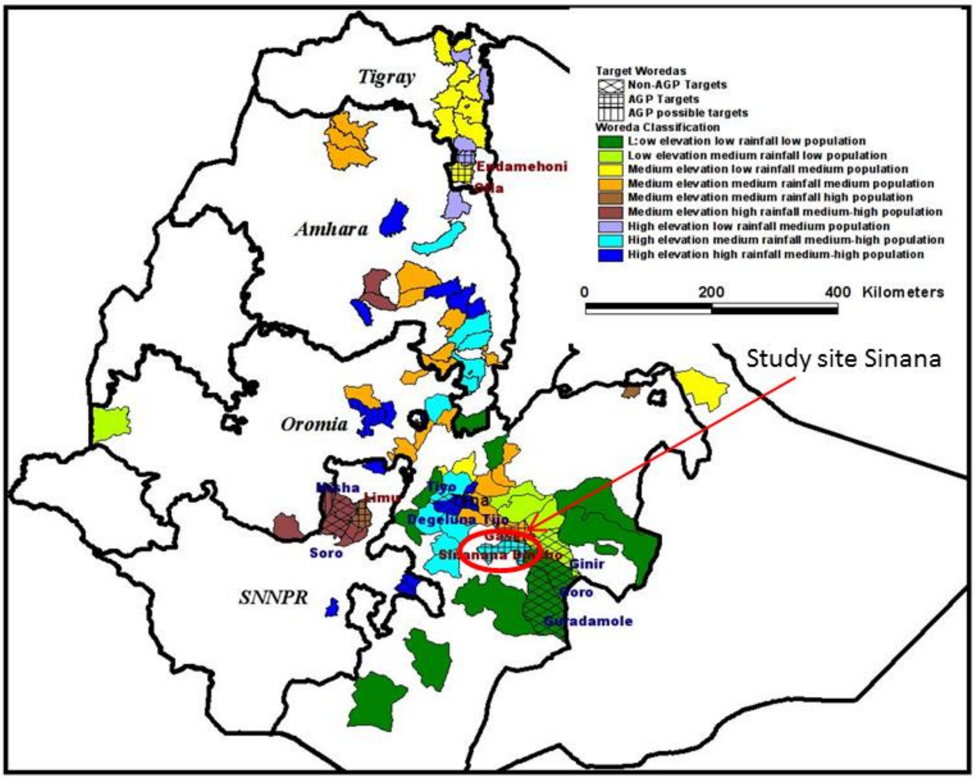

Figure 1 Classification of woredas and recommended target sites for Africa RISING Source: Legg, C. 2012 ‘Africa RISING the Ethiopian highlands mega-site selection of project implementation sites’ *Internal project report*

The chosen sites were known to exhibit large variations in existing levels of intensification including cereal-legume rotations and other crop-combinations and crop-livestock integration. Furthermore, the factors driving intensification such as agricultural potential, access to available technologies, demand for livestock products, and integration with markets were also known to vary. The sites were chosen to represent contrasting levels of intensification to enable the characterization of different trajectories and identification of technology combinations that lead to sustainable development pathways. The local knowledge research was conducted in order to better understand this variation and provide a richer characterization of the study sites at different scales.

The two target kebeles selected in Sinana woreda were Ilu Sambitu kebele and Selka kebele. Data was collected from the kebele government offices to help with characterisation, some was sourced by the development agents themselves, some was compiled by woreda office or Ethiopian statistics agency (Table1).

Table 1 Table of land data taken from the DA offices in Ilu Sambitu and Selka kebele (source: Woreda office 2005 E.C)

Characterisation data	Ilu Sambitu kebele	Selka kebele
Area of kebele	5350 ha	10994 ha
Total area of cultivated land	95.7%	64.7%
Area of irrigated land (part of total)	0.5%	0%
Area of grazing land	0.5%	0.2%
Area of plantation eucalyptus	0.4%	2.3% (also includes natural tree cover)
Residential land	3.4%	29.4%
Roads	Unknown	1.6%
Mountainous land	unknown	1.8%
Total population	9481	10897
Human population density	1.8 p/per/ha	1.0 p/per/ha
Male population	4582	5025
Female population	4899	5872
Total MHH	1080	1417
Total FHH	174	185
Average landholding	4.3 ha per household	6.8 ha per household
No. of cattle	9447	15801
Cattle population density	196.8 c/per/ha (grazing land + eucalyptus)	33.5 c/per/ha (grazing land + eucalyptus + mountainous)
Number of farmers involved in livestock fattening	100	unknown

One of the main objectives of the local knowledge study was identification of gaps in initial data (from project and from secondary sources), which was achieved mainly a course resolution characterization (for example no agroforestry systems were visible).

The existing woreda level data had ambiguous and inconsistent definitions for land types and methods for characterizing land cover (at a kebele level) for example: extra categories for 'roads' or 'uncultivable land' (Figure 2). Cultivated land size is not a measurement based on area of land. Fields are counted more than once to accommodate for multiple annual cropping seasons.

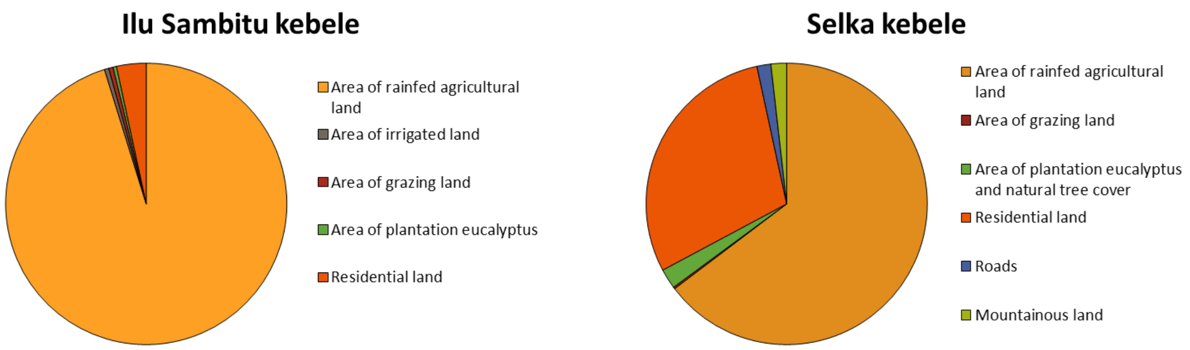

Figure 2 Land use data taken from the DA offices in Ilu Sambitu and Selka kebele (source: Woreda office 2005 E.C)

In this study the local knowledge of farmers and extension workers was acquired using the Agro-ecological Knowledge Toolkit (AKT5) knowledge-based systems methodology and software (Sinclair and Walker 1998; Walker and Sinclair, 1998; Dixon et al., 2001). The major focus of knowledge collection comprises an iterative cycle – that is eliciting knowledge from a small purposive sample of farmers, through semi-structured interviews, and the representation and evaluation of the local knowledge obtained using an explicit knowledge-based systems approach. Each new round of interviews is informed by the previous evaluation cycle and the process is complete when further interviews do not result in a change to the knowledge base. The knowledge base remains a durable and accessible record of the knowledge acquired and can be subjected to validation in a generalization phase where key results are tested with a large random sample of informants to explore the occurrence and consistency of knowledge amongst the wider populations of the research communities (Walker and Sinclair, 1998).

Table 2 Activities in performed in the field to complement the AKT methodology

Activity	Ilu Sambitu	Selka
Landscape characterisation	Walks/ photographs	Walks/ photographs
Interview NRM Development Agent	1 SSI	1 SSI
Participatory resource mapping	1 FGD (m/f)	1 FGD (m/f)
Historical timeline	1 FGD (m)	1 FGD (m)
First interviews farmers	10 SSI (m/f)	6 SSI (m/f)
Second interviews farmers		2 SSI (m)
Seasonal cropping calendar	10 SSI (m/f)	6 SSI (m/f)
Livestock feed calendar	10 SSI (m/f)	6 SSI (m/f)
Land use and livelihood	10 SSI (3FHH, 7MHH)	6 SSI (1FHH, 5MHH)
Nursery survey	Record species list	
Other stakeholder interviews	1 FGD on flooding in Ilu	
Feedback discussion	1 FGD (m/f)	1 FGD (m)

Field activities included transect walks, focus group discussions and a range of participatory methods used to complement the AKT methodology (Table 2). Farmers were selected across two kebeles in the Sinana woreda. Mapping exercises were carried out with groups of farmers as well as individual farmers of both genders (Plate 2).

Plate 1 Participatory resource mapping in Ilu Sambitu and Selka kebeles. Photographs taken by M. Cronin, August-September 2013.

Stratification

The following stratification categories were used to sample farmers for participation in both individual interviews and focus group discussions.

- Gender of informant
- Gender of household head
- Location in landscape
- Age (for historical timeline exercise only)

In Sinana a total of 71 farmers were involved in the study with 15 farmers involved in individual interviews and the remaining 56 farmers involved in five focus group discussions (Table 3). Location was an important consideration to account for variation in topography and soil types in sloped land compared to flat land; as well as the increased access to kebele assets that farmers had living in the kebele village centres (where the majority of community assets are located) in Sinana woreda. Gender was another consideration because of the different roles and responsibilities held by male and female farmers. Gender roles were found to be quite distinct and uniform in agricultural production, with men involved more heavily in ploughing and women in sowing, both were involved in weeding and harvesting. Gender of the household head was considered because of general trends in access to training and knowledge as well as the wealth status of the household. Some of these trends included the tendency for female headed households to enter into plough or labour sharing agreements because of insufficient labour in the household.

Table 3 Breakdown of stratification categories for local knowledge research from Sinana woreda

	Location	M	F	MHH	FHH	> 45
Sinana	Village centre	20	11	23	8	10
	flatland	13	3	13	3	2
	Sloped land	7	3	7	3	2
	Totals	**40**	**17**	**43**	**14**	**14**
Village centre	**41**					
flatland	**18**					
Sloped land	**12**					

Feedback sessions were held in each of the two kebeles where the main findings of the research were reported back to the community. This was done for validation and clarification of the results and to maintain transparency and full stakeholder participation in the field work. Participants from the focus groups and individual interviews were invited to participate.

Results from Sinana woreda

Summary

In this site knowledge was elicited from a purposive sample of local stakeholders and compiled into statements. Statements are expressions of single pieces of qualitative information which can be linked together. They were processed in this knowledge base in three main types; attribute statements, causal statements and comparison statements (Table 4). Statements may have conditions attached – which in this knowledge base provided spatial or temporal circumstances in which the statement was true. Statements were then categorized into topics of knowledge (Table 5).

Table 4 Output from the sinana kb showing number of statements of each type and number of statements with conditions attached.

TYPE	Number of statements	Conditions attached
all	227	102
attribute	35	12
causal	182	85
comparison	10	5

There is a total number of 227 statements in the Sinana knowledge base, 102 of which had conditions attached to them. Topics in the knowledge base ranged from crop management, livestock management, tree utilities, water security and soil types.

Table 5 Output from the sinana kb showing the topics and the number of statements in each topic.

Topic	Statements
knowledge about crop managment	25
knowledge about fuel sources	15
knowledge about livestock management	27
knowledge about soil managemnt	21
knowledge about tree utilities	13
knowledge about water movement and security	21
knowledge of soil types and their attributes	46

Resource Mapping

Sinana woreda is located in Bale region, it is on a high mountain plateau surrounded by the Bale mountain chain. Sinana woreda is characteristically flat land with some slight topographical undulation. The household land size is typically above average for Ethiopia (4.2 ha) and so farmer incomes are correspondingly higher. The larger field sizes meand farmer reliance on chemical herbicides and mechanised agriculture is also greater. Sinana is situated in Ethiopia's wheat belt and produces surplus wheat for the rest of Ethiopia. The research in Sinana woreda was conducted in two kebeles – namely Ilu Sambitu and Selka.

Ilu Sambitu kebele was mostly flatland with very little tree cover. It had a good dirt road running through it from Robe town to the village centre and some seasonal dirt roads linking smaller zones within the kebele. The Kebele is made up of 4 main zones. The zones are Sambitu zones 1 and 2 which form the village centre where the majority of the population live, Ilu zone and Zula zone. Zula is the region with most topographical and soil variability within the kebele, it is also not easily accessed from the good dirt road. Ilu is a small settlement of around 40 households which is parallel to Shaya river and suffers from perennial flooding. Sambitu zones 1 and 2 are where the majority of community resources are located (such as a local market, FTC and health centre).

Selka kebele had a good dirt road running from Robe town through some of the settlement zones. It also had lesser roads connecting these to the central zone of Selka Bakaye. Selka Bakaye zone is where the majority of community resources were located (such as a local market, FTC and health centre).

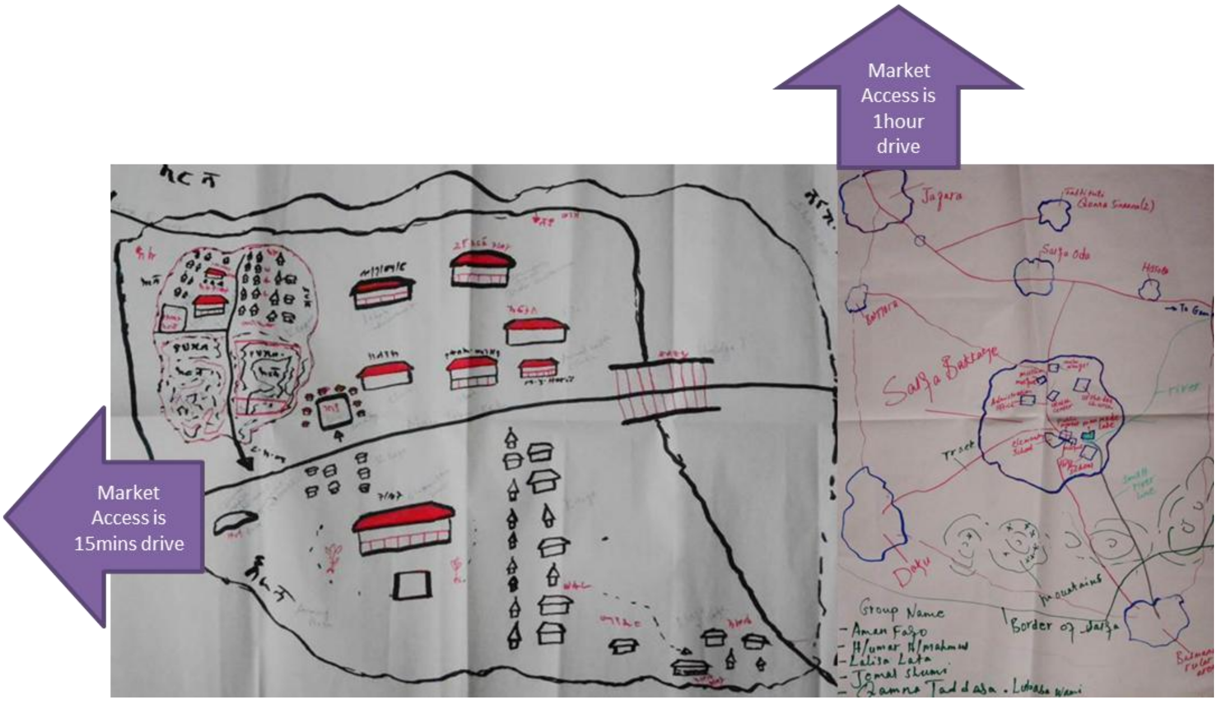

Figure 3 (left) Participatory resource map drawn by the community in Ilu Sambitu kebele. The map depicts the placement of settlements, roads and the river Shaya as well as community buildings and physical assets. (right) Participatory resource map drawn by the community in Selka kebele. The map depicts the different zones of the kebeles and their physical assets, road and river networks and mountainous areas/ tree cover.

The main comparisons to be drawn between the two kebeles are that population was less dispersed in Ilu Sambitu kebele as the populations were considerably smaller in Ilu and Zula zones compared to Sambitu 1 and 2 (which form the main commercial centre). Selka, in contrast was characterised by a sprawling residential areas punctuated by cropland. Selka had more undulating topography and was generally slightly higher in altitude than Ilu Sambitu, which delayed Selka's planting season by 2 weeks. Ilu Sambitu was predominantly flatland with a small hill in Zula zone.

Both kebeles depended primarily on piped water which travelled through a network of underground pipes and had its origins in the Bale mountain chain/ National Park. Ilu Sambitu also had Shaya river to provide extra water especially when pipes were damaged. Selka kebele had one large man made pond in the village centre which supplied surplus water though was seen as unreliable.

Soil types and quality differed because of the difference in topography. Ilu Sambitu had more stable soils (being flatland) with some floodplains where nutrient rich sediment was deposited annually. Selka had more evidence of degradation and erosion on the high slopes; and more problems of deposition of sandy sub-soils on the fields beyond the slopes making its quality generally poorer. Both Kebeles relied predominantly on the large market in Robe town to sell surplus cereal crops. The local market located in the village centre attracted only local buyers and so large quantities of wheat and barley and fava bean were transported to Robe as a main source of income. Distance to Robe town was less in Ilu Sambitu (around 15 minuites drive, by car - from the village centre) compared to Selka (around one hours drive, by car - from the village centre).

Land Use and Livelihood strategies

There was found to be a mostly heterogeneous land use and livelihood system in Ilu Sambitu kebele, with similar land types and resource bases across the community (Figure 4). Farmers main source of income was through the sale of wheat and barley, so the majority of cropland was given to growing cereals. Farmers would also grow small amounts of fodder (maize and oats) for their livestock, and some subsistence crops around the home compound – often with water support from piped water.

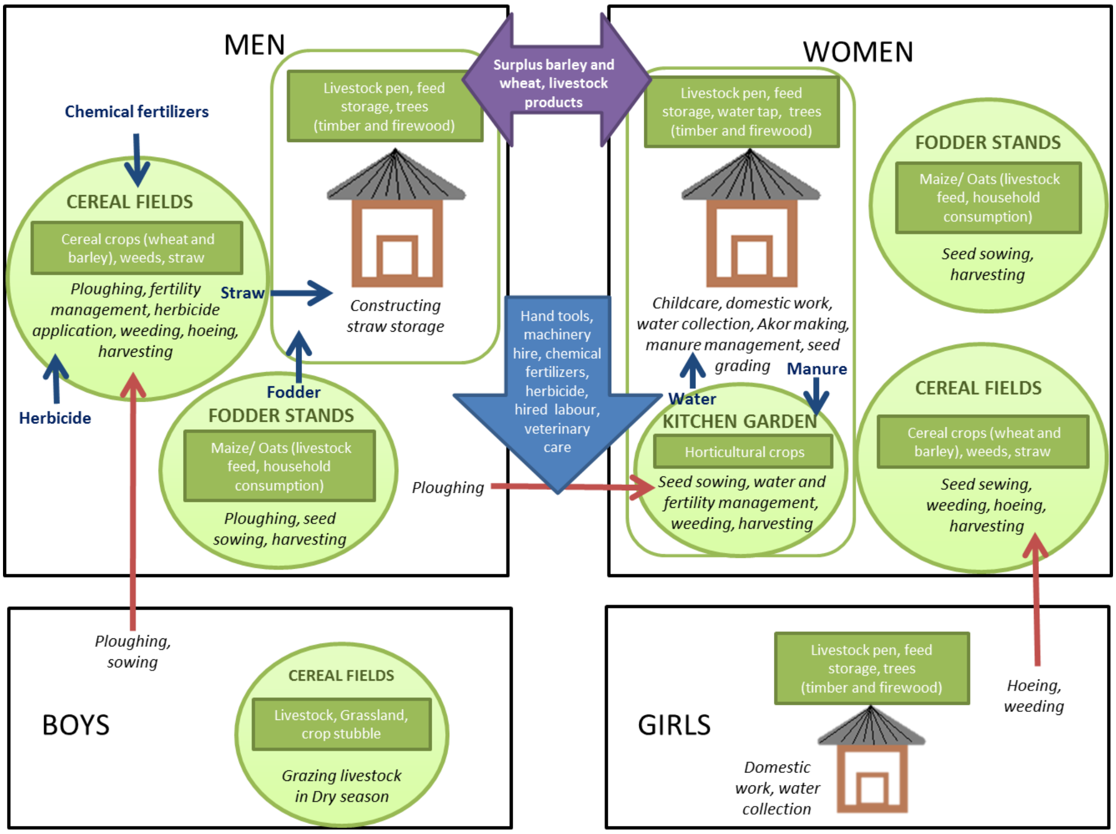

Figure 4 Land use and livelihood diagram of 'typical' household across the two kebeles. Data taken from farm scale resource maps and semi-structured interviews.

Idiosyncratic differences occurred in areas such as Ilu Zone; where perennial flooding reduced the capacity of farmers to exploit both annual cropping seasons. Differences also occurred in Zula zone, whose lack of direct access to the village centre made access to training and information from the Development agents more challenging. Zula zone also had difficult access to Robe town during peak rain season which hindered transportation of goods.

Labour flows

Regardless of wealth and family size, labour scarcity was found to be a common problem amongst all farmers interviewed. The issue was mainly that mechanization was limited whilst average landholdings were extensive. Ploughing was mostly done by oxen (although there were some farmers hiring tractors), and a single field would be ploughed multiple times (the frequency depending on the soil type see Table 6). Seed sowing was done by hand and some farmers were moving away from the traditional practice of broadcasting seeds, to the more labour intensive practice of rowplanting. Herbicide and fertilizers were routinely applied but only those farmers beginning to rowplant their crops were engaged in hand weeding (another labour intensive task).

Table 6 Table showing the duration of time spent on different agricultural tasks based on farmer interviews

					BONA SEASON													
	April		May		June		July		August		September		October		November		December	
Ploughing	■	■	■	■	■	■	■											
Seed sowing								■										
Herbicide application										■		■						
UREA application										■								
DaP application								■										
hand weeding										■								

Labour sharing systems

Numerous strategies of labour sharing were practiced by households in the site to cope with large landholdings and minimal mechanization. The main types discussed with farmers are listed below:

- Family labour: in which members of immediate and extended family assist in agricultural activities for no profit.
- Hired labour: in which landless youth or seasonal labourers from the lowlands are employed by the farmer for cash or a percentage of the agricultural returns.
- Plough sharing: in which ox owners will assist in ploughing fields (normally of female headed households) in exchange for a percentage of the agricultural returns.
- Community labour sharing: in which neighbors with adjacent fields share labour and synchronize field activities like ploughing, sowing and weeding in order to increase the number of workers and reduce the time taken.
- Leasing: in which and owners (normally town dwellers) give land over to be cultivated by landless farmers (who are responsible for the cost of inputs) for half of the agricultural returns- not a common practice.

Main difference between female headed household and male is in the labour capacity and the labour sharing strategies taken – Female headed households tended to turn rely more on plough sharing and community labour sharing to cope with labour insufficiency whereas male headed households more commonly had hired labour. Both would use family labour with members of working age (typically aged 8 to 50).

Agricultural Cropping System

The soil that was dominant in both sites was ‘Delacha’ a clay-loam vertisol with high productivity and some waterlogging issues. Only small areas of different soil varieties (‘Dima’ and ‘Guracha’) were found in areas with undulating topography (Table 7). Farmers equate soil fertility with frequency of ploughing per cropping season with a higher frequency of ploughing causing higher soil fertility (statements 166 and 208).

Table 7 Soil types and known attributes in Sinana Woreda, evidence taken from sources in the Sinana knowledge base.

	Distribution	Location	Colour	Texture	Weight	Dry texture	Fertility	Soil water inflitration
Delacha	dominant	on flat land	grey	clay loam	mid	some cracking	high	ideal water holding
Guracha	mid	on flat land	black	clay	heavy	cracking	mid	prone to waterlogging
Dima	mid	on mountainous areas	red	sand	light	soft	low	high drainage
Bojji	minor	on mountainous areas	white to black	silt	light	soft	low	high drainage
Cirracha	minor	on mountainous areas	white to black	silt	light	soft	low	high drainage

There are two cropping seasons which overlap (Table 8). Gana is the short season from March till mid-July and Bona is the long season from early June to late December. Wheat is typically grown in Bona season and Barley and Pulse crops in Gana season. Because of large average landholding many farmers have separate plots of land planted in either Gana or Bona and a few plant one plot in both seasons.

Table 8 Cropping calendar showing the dominant rain-fed crops for human consumption and livestock consumption taken from sources in the Sinana knowledge base

	January	February	March	April	May	June	July	August	September	October	November	December
						BONA SEASON						
			GANA SEASON									
Wheat (Gana)			P S				H					
Wheat						P	S					H
Barley			P S			H		P	S		H	
Fava Bean			P S/W			H		P S/W			H	
Field Pea			P S/W			H		P S/W			H	
Maize			P	W							H	
Oats			P			H	P			H		

KEY: P = Planting, S = Spraying, W = Weeding and H = Harvesting.

Wheat rust is a seasonal problem in this region and was known to attack some wheat varieties more aggressively than others (Figure 5). Farmers attribute the rust to waterlogging and frost forming on flat land.

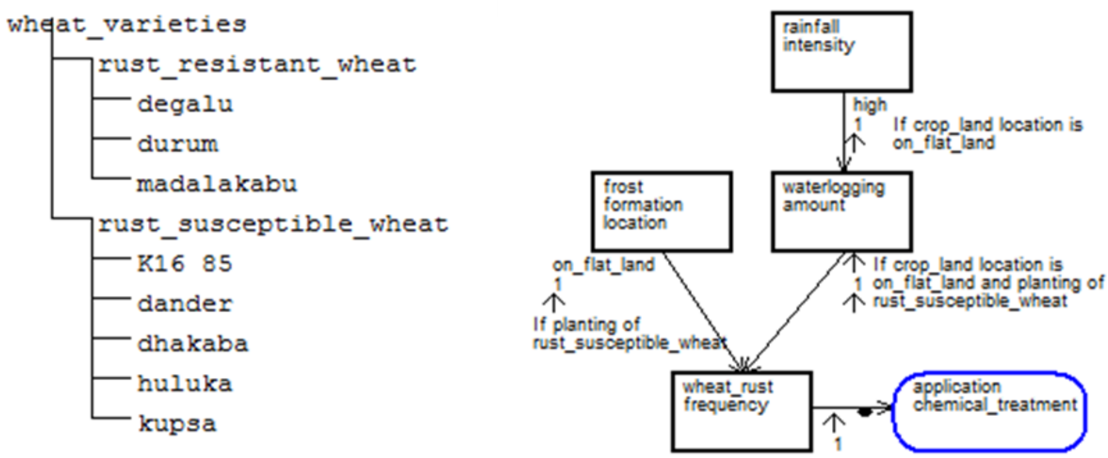

Figure 5 Object hierarchy of local wheat varieties known to be susceptible to and resistant to wheat rust (left). Causal diagram on the known environmental causes of wheat rust (right).

Row planting is a new technique introduced to the area 3 years ago – there has been widespread adoption by farmers but most only have sufficient labour to practice row planting on a fraction of their lands (Plate 3). The increase in yield/ decrease in expenditure on fertilizer is well known however the labour involved is a major constraint and farmers are interested in a mechanized technique for row planting. Weeding by hand is practiced when row planting and again is known to be labour intensive. There are a number of weed varieties known to be resistant to herbicides, some of which are foreign invasive species to the area (Table 10), and these can therefore only be controlled by hand weeding.

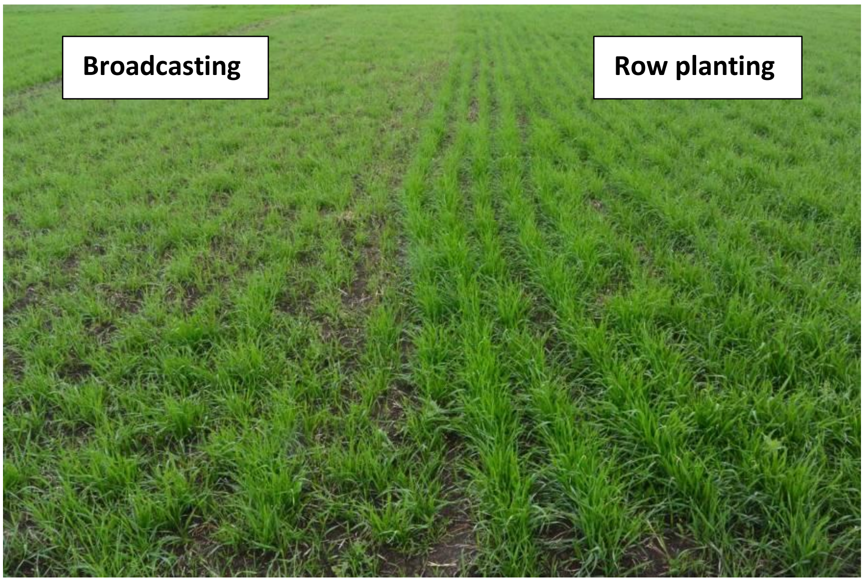

Plate 2 Model farmer and member of the Africa RISING participatory trials for varieties of wheat and fava bean has been running his own experiment of the productivity of broadcasted wheat versus row planted wheat.

Soil and water interactions

In Ilu Sambitu kebele the main source of water is Shaya river which flows along the border of the kebele. Farmers use Shaya river for small-scale irrigation, domestic use and livestock watering. Farmers living in Sambitu town (which are the majority in the kebele) also have access to piped groundwater which connects into their home compounds.

Plate 3 Flood damage in Ilu zone of Ilu Sambitu kebele. Photographs taken by M. Cronin, August 2013.

Flooding is an issue which affects a small settlement called Ilu in the kebele. There are around 40 households which are affected by seasonal flooding during August and September. Flash flooding occurrence has increased over the last 3 years and is believed to be caused by excess surface runoff from the asphalt road which enters Shaya river on the outskirts of Robe town (statements 35-37 and 187). Shaya river bursts its banks around Ilu settlement and the slight downward slope allows water to encroach on crop fields, dirt roads and residential areas (statements 38-41) (Plate 4). The unpredictable and early floods this year caused un-threshed wheat (left on the field in preparation for threshing) to suffer water damage and become inedible so it could not be sold. In addition crop residue (if it wasn't propped on a platform), decomposed which made it inedible for livestock (statements 46-54) (Plate 5). Houses have suffered water damage and strong flows have washed away property (statement 43). Because of high levels of waterlogging after flooding occurs the farmers were only able to grow crops in the first ('Gana') cropping season (March to late June) (statement 44 and 249 and 255). Wheat and maize as they have the longest cropping season are most affected by floods (statements 55-58). Maize is only grown for livestock feed and as a subsistence food crop, so it is not the dominant crop in the area (statement 105). Wheat is dominant. The alternative crop - barley –has other problems – in particular barley is prone to lodging on these fields due to excess soil fertility (statement 172). The high soil fertility is caused by sediment delivery from River Shaya making this a high potential but high risk area of the kebele.

Plate 4 Un-threshed wheat stored on a platform to protect from flooding damage (left). Un-threshed wheat seeds volunteer germinating due to water damage (right). Photographs taken by M. Cronin, August 2013.

The current situation on the stretch of river where flooding occurs is that there is no riparian cover (the other side has a strip of Eucalyptus trees but the side where water travels is bare), and no bank protection of any kind. Farmers believe the flooding issue is beyond their capacity to deal with and riparian cover alone could not solve the issue, they think constructing a gabion may reduce the flooding. The farmers in this area are mainly new settlers to the kebele (land has not been cultivated for long) or youth from the kebele who have been given a grant of land. They are a distinct low-income group in this area.

Plate 5 Selka kebele surface run off is channelled into a hand dug pond for livestock watering and domestic use when piped water sources are not working (left); natural regeneration on watershed area in Selka kebele (right). Photographs taken by M. Cronin, August and September 2013.

In Selka kebele the main water sources were piped water sourced from the upper watershed in Bale national park and a hand dug pond which collected rainwater and surface runoff (Plate 5). The pond was mainly used to water livestock and for washing but it could be used for drinking water when the pipes were damaged or not functioning. The community did not use chemical purification methods.

Soil erosion and surface runoff occured on sloped land due to insufficient tree coverage on mountain tops (statements 64, 85 and 86) (Plate 5). Sedimentation was a result of surface runoff and affected the productivity of flat crop land around the mountains (statements 73 and 75). Older farmers recognised a noticeable decline in groundwater recharge which they attributed to deforestation of the upper slopes and mountains (statements 63-66). The low tree density had reduced available groundwater and over time had dried all the natural springs (statements 66 and 94). Attempts to reforest the mountain tops to reduce runoff had been made in 2012 however without adequate exclusion of livestock the planted seedlings had not survived (statements 95 to 99).

Information from farmers in both kebeles on the impacts of land use change on soil and water resources was compiled into a causal diagram using the AKT software programme (Figure 1). Much of the information was elicited during FGDs and historical timeline exercises carried out with farmers over the age of 45. These farmers linked the loss of indigenous tree coverage with the reduction in groundwater surface recharge which is affects community water security; they also linked the asphalt road expansion through Bale region with concentrated surface runoff in the river Shaya and the consequential flash floods which cause property damage, community displacement and a loss in cereal productivity. Farmers in both kebeles linked historic loss of fallow rotation system to cropland exhaustion and increased reliance on chemical fertilizer.

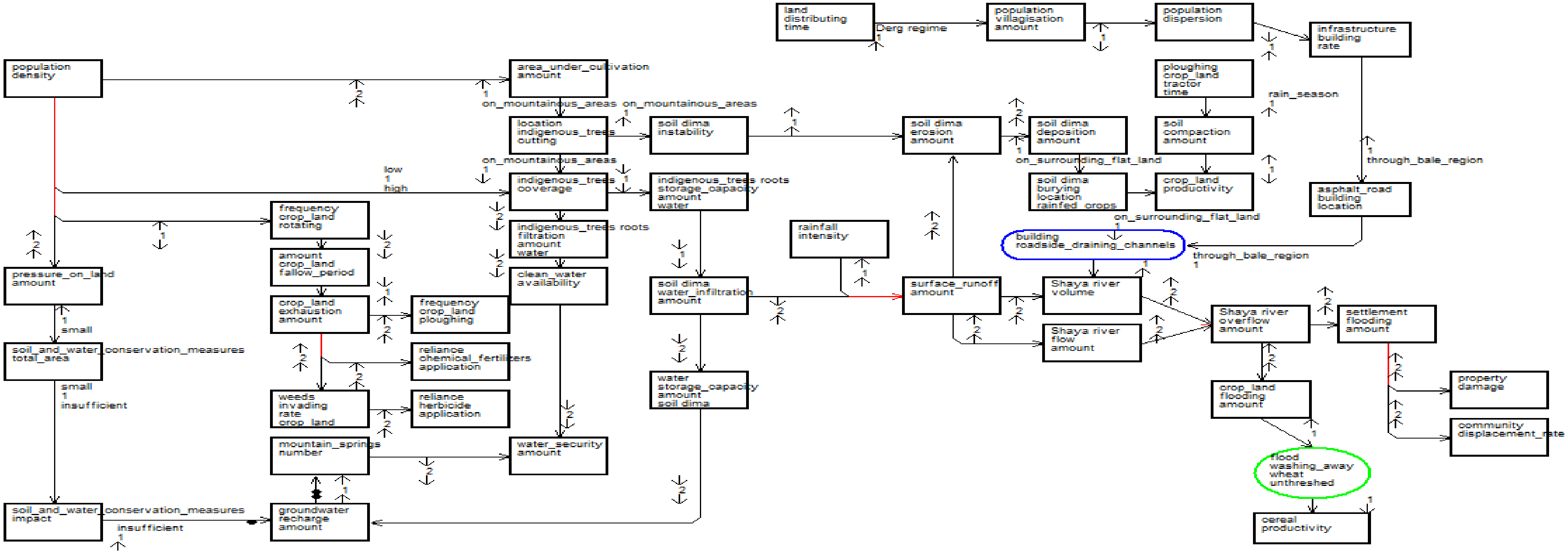

Figure 6 Causal diagram on the impacts of land use change on soil and water resources in Sinana Woreda.

KEY: Nodes represent natural processes (ovals), or attributes of objects, processes or actions. Arrows connecting nodes show the direction of causal influence. The first small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the second 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

Tree nursery survey

Plate 6 The tree nursery in Robe town with left-over seedlings of *Sesbania sesban* left to overgrow. Photographs taken by M. Cronin September 2013.

The only known tree nursery used by farmers and Development agents in the area was located in Robe town. A visit to the nursery revealed that the management was quite poor, with much of the site overgrown by grass and surplus seedlings left untended (Plate 6). The nursery was privately run but reportedly fulfilled orders from the Woreda office in Robe and sold directly to individual farmers. The following species were observed at the nursery site:

- *Acacia decurrens*
- *Casaurina equisifolia*
- *Cupressus lusitanica*
- *Leucaena leucocephala*
- *Pinus patula*
- *Scinus molle*
- *Eucalyptus globulus*
- *Grevillea robusta*
- *Sesbania sesban*

Farmer preferences were for *Eucalyptus globulus* and other fuel and timber trees like *Cupressus lusitanica*. The other species were mostly used by the government in soil and water conservation activities. In Selka kebele 3,000 seedlings were planted in 2012 to reduce erosion run-off on an overgrazed hillside. The tree species planted in the soil and water conservation site in Selka kebele were: *Sesbania sesban, Grevillea robusta, Pinus patula* and *Casaurina equisifolia*. Most of the seedlings did not survive due to insufficient management over the dry period and damage by free roaming livestock (Figure 7).

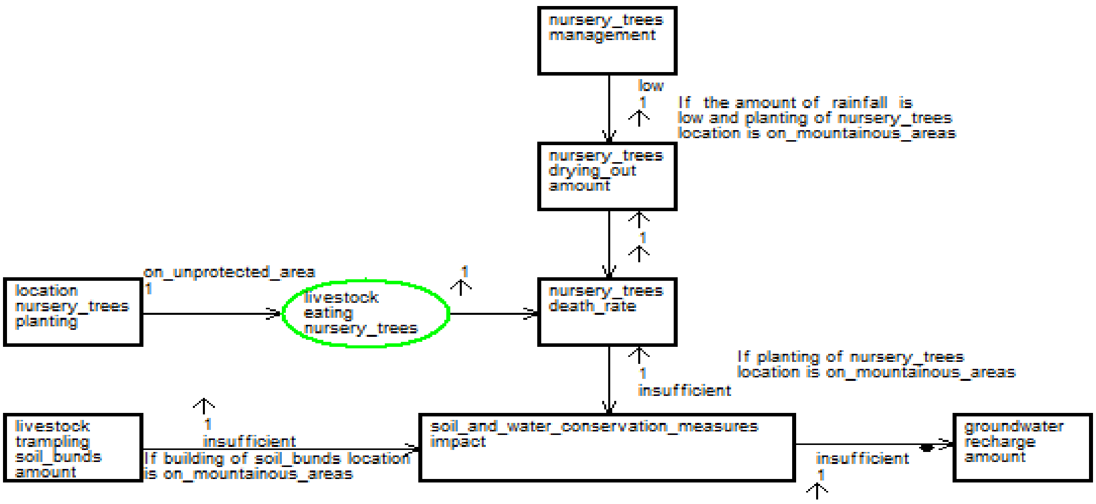

Figure 7 Causal diagram on the management of nursery trees in a soil and water conservation site in Selka kebele. (see figure 6 for key)

Table 9 Output from sinan kb hierarchic object usage tool - table on the services, location and abundance of tree species in Sinana woreda.

				Provisioning services				Regulating services			Common position in landscape							Abundance			
	Local name	***Scientific name***	***indigenous/ exotic***	Fuelwood	Timber	Livestock fodder	Live fence	Soil conservation	Soil fertility	Shade/ shelter on field	Mountain tops	Field boundaries	Roadsides	Home compound	Scattered on cropland	Riparian	Historical forest	Naturally regenerating (browsing resistance)	Threatened	Common	Propagated
Trees	acacha	*Acacia decurrens*	E			x		x			x			x							x
		Capparis tomentosa	I				x							x							
		Casuarina equisetifolia	E			x		x			x										x
	yeferejii tid	*Cupressus lusitanica*	E					x						x						x	x
	etacha	*Dodonaea angustifolia*	I			x					x						x		x		
	bargamo	*Eucalyptus globulus*	E	x	x							x	x	x		x				x	x
	adami	*Euphorbia abyssinica*	I	x	x		x	x		x		x	x	x	x		x			x	x
	grevilea	*Grevillea robusta*	E					x			x			x							x
	heto	*Hagenia abyssinica*	I														x		x		
	gatira	*Juniperus procera*	I	x	x			x	x	x	x	x		x	x	x	x	x		x	
	lusina	*Leucaena leucocephala*	E			x		x			x										x
	kombolcha	*Maytenus senegalensis*	I			x					x						x		x		
	ejersa	*Olea europaea subsp cuspidata*	I		x	x					x						x		x		
	shonka	*Opuntia ficus indica*	E				x	x				x	x	x						x	x
		Pinus patula	E					x			x										x
	gesho	*Rhammus prinoides*	I											x							x
		Schinus molle	E										x	x							x
		Senna didymobotrya	I			x	x				x			x				x			
	sesbania	*Sesbania sesban*	I			x		x													x
	koshimo		I			x					x						x		x		
	habru	*Ficus sur*	I							x					x	x	x		x		
	koba	*c.f. Ensete gilletii*	I			x								x							x

Tree crop interaction

Only Selka kebele had scattered trees commonly retained on cropland. In Ilu Sambitu kebele the practice was very rare and only *Ficus sur* was found in Ilu zone where fields were adjacent to the river Shaya. In Selka kebele the tree species found on cropland were mostly *Juniperus procera* and *Euphorbia abyssinica* (Plate 7) and were managed to reduce shading competition with irregular pruning to accommodate the slow growth of these trees (statements 127, 145, 147 and 150). The scattered trees were retained for shade for people and animals and shelter during the rainy season. Trees occurring in rows on sloping land were retained to help reduce erosion and stop soil deposition (Table 9).

Farmers in both kebeles were found to have common agro-ecological knowledge on the negative impacts of Eucalyptus on cropland through its shading effects and the allopathic effect of leaves (statements 125 and 128). Lack of awareness of tree/crop interaction (beyond knowledge of negative effects of Eucalyptus) was thought by farmers to be the main reason for the lack of trees on fields in Ilu Sambitu kebele.

Plate 7 Scattered Juniperus procera and Euphorbia abyssinica on crop land retained for shelter and soil conservation. Photographs taken by M. Cronin, August and September 2013.

Livestock feed sources

The main source of livestock feed in both kebeles is straw (of varying palatability) from cereal and pulse crops (Table 10). Wheat straw dominates but needs to be mixed with salt, water and barley flour to increase palatability (statements 260 and 261). All straw is stored after threshing in home compounds and fed to livestock throughout the year (statement 262).

Farmers keep small blocks of maize in cropland or in home compounds for livestock feed provision (maize is used in household but cobs are small and yield is low) (statements 57, 58, 105). Maize is grown from mid-March till mid-November (statement 55). Oats are also quite commonly grown for livestock feed in cropland or in home compounds and is known to be highly palatable (statements 256 and 257). *Ensete gilletii* is found in home compounds and can only be fed to Holstein Frisian cows (Plate 8).

Farmers recognise the nutritive value of some of the natural weeds however farmers were found to manage weeds on cropland using herbicides and therefore did not utilize them for livestock feed unless they grew in grazing land (Table 11). The most nutritious grass species (gargara and sidisa) have become less common due to cropland expansion (statements 33, 34, 190 and 191).

Table 10 Table on the attributes, location and abundance of grass and broadleaf weed species in Sinana woreda.

	Local name (Afaan Oromo)	***Scientific name***	***indigenous/ exotic***	Livestock forage					Weeds				Common locations				Abundance		
				Highly palatable	Low palatability	Causes bloat	Increases milk yield	Improved forage	Herbicide resistant	Causes injury	Controlled by Pallas	Roofing grasses	Near watercourses	Wheat pasture	Pulse pasture	Natural grassland	Common	Threatened	Spread through mechanisation
Grasses	ginchi								x					x	x		x		
	bokoka					x								x			x		
	goonde					x							x	x			x		
	lalunca	*Urochloa panicoides*	I			x					x			x			x		
	muja	*Snowdenia polystachya*	I			x								x			x		
	gargara			x			x									x		x	
	sidisa	*Trifolium semipilosum*	I	x			x					x				x		x	
	oats	*Avena spp.*	E	x				x									x		
	wheat	*Triticum spp.*	E		x												x		
	barley	*Hordeum vulgare L.*	E	x													x		
	serena dhera	*Avena abyssinica*	I	x					x					x					x
	mata											x				x		x	
	wita											x				x		x	
	sandaabuu	may be noug	I								x								
	batula										x								
	sambaleta	*Hyparrhenia hirta or H. rufa*	I									x				x		x	
Broadleaf	bangee								x					x			x		
	gale	Cynodon aethiopicus							x					x			x		
	kumundo								x	x				x	x		x		x
	matane								x					x	x		x		
	qoree	Argemone mexicana	E						x	x				x			x		x

Table 11 Livestock feed source calendar taken from interviews with farmers.

Feed varieties	Niche	Zero Grazing											
		January	February	March	April	May	June	July	August	September	October	November	December
Straw	F												
Frushika	M												
Maize residue	FF, HC												
Oats	FF												
		Free Grazing											
		January	February	March	April	May	June	July	August	September	October	November	December
Crop stubble	F												
Grass	HC, PGL, CGL												

	15 - 20
	10 - 15
	5 - 10
	2 - 5
	1
	0

KEY. F = Field, M = Market, FF = Fodder Field, HC = Home Compound, PGL = Public Grazing Land, CGL = Community Grazing Land. Shade of green indicates number of times answer was replicated in individual interviews.

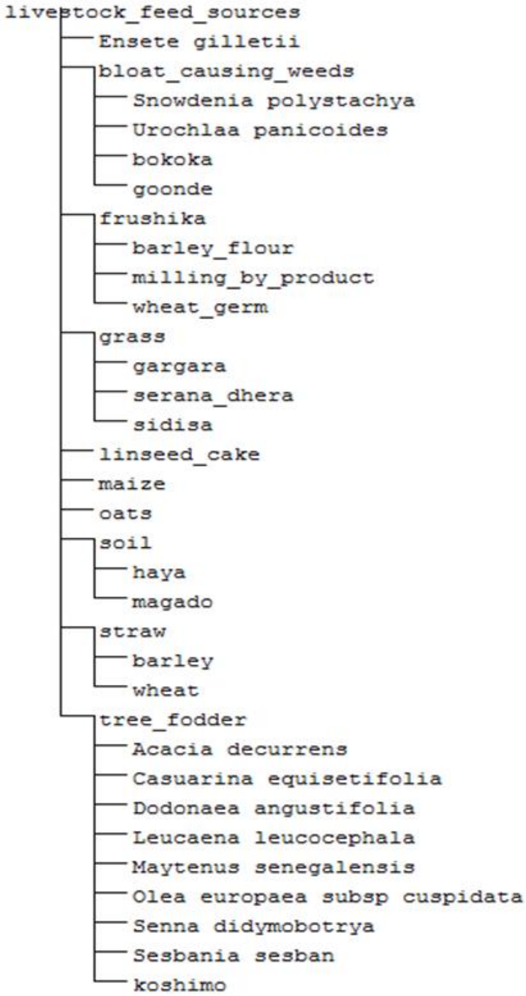

Plate 8 Improved dairy cow (mixed Holstein Fresian) being fed wheat straw and *Ensete gilettii*; various types of straw stored as livestock feed. Photographs taken by M. Cronin August 2013.
Figure 8 Object Hierarchy tree for Livestock feed sources taken from the AKT5 knowledge base on Sinana.

Grazing sources

The main source of grazing land is cropland after harvest (January to February) where livestock are tethered to reduce encroachment on others property. Farmers with in-sufficient feed may graze their livestock in a neighboring kebele called Shanaka which has a large area of unproductive grazing land that used to be a state farm during the Derg regime. The distance from Sambitu town is 1 hour walking distance. There is an un-official collective grazing regime where farmers combine their herds to take to Shanaka to graze (and take turns bringing them).

The amount of official grazing land makes up 0.4% of total land in the Ilu Sambitu kebele. Some farmers also keep small grazing fields. Some of these farmers plant their grazing land with Eucalyptus which causes grass production to be low (statements 128 and 129). Farmers may also allow their cattle to graze in the home compound if it is large enough. In Selka kebele children would typically take the household livestock to graze on the upper slopes beyond the agricultural land. The practice was known to cause land degradation and soil erosion, as well as browsing pressure on naturally occurring tree species (Plate 9).

Plate 9 Goats grazing on trees and the evidence of browsing pressure in the watershed conservation site, Selka kebele. Photographs taken by M. Cronin, September 2013.

Conclusions for Sinana Woreda

Fine scale variation

The participatory resource mapping showed a variation in access to resources, and subsequent variation in land use and livelihood systems between the two kebeles.

Ilu Sambitu kebele is mostly flatland and therefore quite uniform, which meant that it had limited internal geographic differences. Locations on the margins, outside the village centres, had higher variation. Some differences in soil types occur in Zula zone because of its slight undulating topography. Perennial flooding of Shaya river affect only households in in Ilu zone because of the placement of the settlement on a floodplain near to river Shaya.

Selka kebele was mostly undulated topography so there was a greater level of internal variation than Ilu Sambitu in soil types across its zones. Farmers in the higher zones suffered from soil erosion and those with fields in the surrounding flatlands suffered soil deposition.

There was variation between the two kebeles in Hydrological issues. In Ilu Sambitu the river Shaya provided a year round water supply and the potential for irrigation. However this river also flooded –causing loss of property and limitations to annual productivity on crop land. Selka kebele had only a hand dug community pond occurring in the kebele. The natural springs and groundwater had dried up after deforestation. In both areas the farmers depend on the piped water network servicing Bale region and farmers in both kebeles mentioned instances of lost water supply due to damaged pipes.

Function and services of natural vegetation

There was a difference between the two kebeles in their relative historic and current tree cover. During the historical timeline exercises farmers in Ilu Sambitu stated that the historic vegetation of their kebele was open grassland and that trees did not naturally occur. In Selka the area was historic forest and so remnant Juniper trees still occurred. The difference in tree cover changed the opinion on the compatibility of trees with crops as well as their ecological functions and advantages. Farmers in Selka were able to link the diminishing groundwater sources with the lack of indigenous tree cover on the higher slopes.

Key constraints to productivity across the site

- Wheat rust
- Labour constraints on row planting
- Continuous cultivation of fields with no fallows
- Monocropping and lack of crop rotations because of strong wheat market and comparably weak alternative crop markets
- Insufficient livestock manure to cope with fuel/fertility trade off
- Heavy reliance on chemical fertilizers which fluctuate in cost
- Soil erosion and deposition
- Insufficient quality and quantity of livestock feed

Recommendations for Sinana woreda

Community knowledge exchange and transferability of Sustainable Intensification technologies

- There were farmer knowledge gaps in effective management of mixed cropping systems for provision of fodder and the use of multi-purpose trees recognised by the community – Arsi valley provides a useful location for farmer exchange (similar intensive system with leguminous tree intercropping)
- Crop rotation is practiced by small numbers of model farmers – to be widely adopted farmers need community knowledge exchange
- Livestock fattening and small scale irrigation are also uncommon practices – irrigation has technical limitations which may hinder increasing uptake
- 1 to 5 grouping and media sources already a successful way of disseminating information and training to the community
- Strengthening co-operatives and irrigation committee to provide

Many of the traditional sustainable intensification techniques found in this study arise through the interaction of trees, crops, water and livestock within the mixed farming system which farmers have important and relevant knowledge about. Other intensification techniques such as row planting, crop rotation and manure application are only partially disseminated within the community and are heavily dependent on excess labour making labour a key consideration when addressing uptake.
Successful uptake of sustainable intensification technologies and management practices must be compatible with and build on existing local perceptions of sustainability. During the feedback sessions with the farmers discussions revolved around the local perceptions of sustainability. Farmers identified the following requirements needed to achieve food and water security and then to sustainably intensify their farming system.

Community requirements:

- Riparian coverage needed along River Shaya along with gabion structures built to reduce flood risk in Ilu zone
- Implementation of livestock exclusion on the tops of mountains to enable reforestation for watershed management
- Expansion of soil bund and trees along contours to reduce erosion
- Improved market access for less dominant crops such as pulses to encourage crop diversification
- More efficient use of niches for growing livestock feed and more livestock feed varieties

Ideas for household level interventions:

- Mobilisation of community over free-grazing on cropland with pilot exclusion zones for soil and water conservation/ improved feed planting
- Piloting intercropping techniques with compatible and multi-purpose tree species on land with erosion issues and land adjacent to riverbanks – fast biomass producers for fuel and fodder would be ideal
- Increasing niche utilization (such as home compound) for fuel and fodder sources
- Increasing crop diversity and crop rotation methods with training and improved seed to avoid field exhaustion
- Address labour issue to increase uptake of row planting with a mechanized or efficient method of sowing the seed and/or weeding
- Increasing compost utilization through training on proper storage