Feed the Future Innovation Lab on Small Scale Irrigation (ILSSI): Ethiopia, Ghana, and Tanzania

ILRI Final Report

Reporting Period: 2013 - 2018

Date of Report:

Report prepared by: Michael Blümmel, Melkamu Derseh, Aberra Adie, Tunde Amole

1. Introduction

The International Livestock Research Institute (ILRI) partnered in the Feed the Future Innovation Lab for Small Scale Irrigation in sub-Saharan Africa project (Ethiopia, Tanzania, and Ghana) with three major objectives in mind. First, to improve on meat and milk production for improved nutrition though better feeding. Second, to evaluate forages as cash crop to improve income and employment opportunities. Third, to employ irrigated forage production to support diversification, intensification and sustainability. Specifically explored were:

1. Opportunities for using small irrigation for annual and perennial forage production
2. Management options for optimizing irrigated forage integration and production from mixed crop livestock small holdings
3. Irrigated forages for multiple beneficial impact on soil improvement and water management
4. Use of irrigated forages for improved on farm feeding and as cash crop

Allocation of scare resources such as arable land and water to irrigated forage production by small holders was a new departure when the project started and ILRI's primary role has been to lead and implement field level studies to 1) assess and target areas where irrigated forage may play a role because of high feed demand using interactive and demand driven feed assessments tools (FEAST), 2) test key annual and perennial grass and legume forages for forage yields and fodder quality and optimize their agronomic management and depart essential training to farmers, extension officers and researchers, 3) survey fodder markets for demand for forages and forage price-quality relationships to work backwards for assessing demand and opportunities for forages as cash crop; and 4) explore multi-purpose use of forages for soil improvement, direct food production and water management. In the way the project was structured, ILRI had to work though national partners sub-contracting with national partners in all 3 countries, as follows: Ethiopia (Amhara Regional Agriculture Research Institute, Southern Agricultural Research Institute); Ghana (CSIR Animal Research Institute); Tanzania (Sokoine University of Agriculture) ILRI's general approach has included following steps: 1) Stakeholder engagements, 2) Community engagement, 3) Rapid diagnosis, 4) Pilot interventions and assessments of their impact.

2. Accomplishments: Field research results for evaluating impacts, trade-offs, and synergies of small-scale Irrigation technologies and practices

2.1. Key messages from research findings

Contrary to initial expectations, irrigated forages were shown to be attractive to farmers particularly in Ethiopia, followed by Tanzania and Ghana. The attractiveness was inversely related to farm size. In Ethiopia small landholdings had usually around 0.5 (small farmer) to 1.5 ha (large farmer). This constraint was less severe in Tanzania where small farmer owed up to 2 ha and large farmers more than 6 ha and Ghana where small holders farm up to 5 ha and large holdings farm more than 15 ha. Consequently, small scale irrigation interventions for forage production had a higher urgency in Ethiopia than in Tanzania and Ghana because access to alternative feed resources was less. Thus irrigated fodder work under ILSSI in Ethiopia started with 14 farmers in 2014/2015 and increased to 399 towards the end of the 1st phase of the project largely as a result of farmer to farmer information flow. In contrast in Tanzania and Ghana number of total famer allocating land to irrigated forges remained below 100. Anecdotal evidence exists that some farmers replaced *Khat*, a narcotic shrub, with irrigated forages (video linkage). The momentum generated in Ethiopia around irrigated forages resulted in the recommendation of the Agricultural Transformation Agency to look at irrigated forage production as a potential transformative intervention for Ethiopian small holders to increase income and fodder security.

The feed assessment tool (FEAST) was shown to be an informative and interactive yet rapid tool to assess feed resources in a farming systems context and to prioritize feed interventions. **Application of the FEAST tool afforded a structured demand driven approach for the targeting and selection of irrigated forage option**.

Broadly, two irrigated forage options were explored: annual forages that allowed integration of fodder cultivation with crop cultivation within one year of cultivation and perennial forages where land was allocated exclusively to fodder production over several years**.** In the category of annual forages oats-vetch mixes were the most preferred irrigated forage intervention**. A two cut system emerged as the preferred farmer management option with two-cut oats and two cut oats-vetch mix out-performing the one cut option by 13 (8.7 vs 7.6 ton DM/ha) and 30% (12. 2 vs 9.4 ton DM/ha).** Besides oats-vetch mixes having higher yield than pure oat stands, forage quality was substantially higher in the mixes.

Among the perennial forages, Napier that could be harvested during the course of a year between **6 and 9 times resulting relative to a 12 month growing period in a dry matter yield of a minimum of 17.9 tons/ha and a maximum of 23 t/ha** performed well in Ethiopia and Tanzania. Average dry matter yields of **Desho – indigenous to Ethiopia – as extrapolate from recorded 3 cuts and assumed 6 cuts per year was 41.9 tons per ha (range 31.4 to 92.3 tons per ha)** was even higher.

On-farm livestock productivity trials and forage quantity/quality – livestock productivity modeling showed that irrigated forages have higher returns when fed to improved livestock rather than to local animals. **In the latter case irrigated forages could have negative cost – benefit ratios (0.60) in Ethiopia.** However, fodder market and feed value chain studies in Ethiopia, Tanzania and Ghana showed that considerable demand exists for forages as cash-crop. **Small holder could sell forages likely with even higher returns from cropping irrigated forages than more commercial farmers feeding irrigated forages to their own improved livestock.**

2.2. Ethiopia results

Intervention	Emerging results / key findings
• **Feed Assessments (FEAST)** • **Annual forages** • **Perennial forages** • **Multi-purpose forages** • **Forages as cash-crops**	• **FEAST** was useful as rapid interactive tool to assess feed resources on-farm and to prioritize feed interventions • **Oats-vetch mixes** under a two cut management emerged as the preferred annual forage option in Ethiopia • **Napier and Desho grass** are promising perennial forage options with the latter preferred by farmers because of higher drought resistance • **Multi-purpose forages** contributed to increased biomass yield and quality though inter cropping of grass and legume forages, food security through intercropping of grasses with legume food feed crops and water use efficiency through intercropping of deep rooting food-feed crops • **Forages as cash crops** have potential since fodder markets exists already and sale of irrigated forages is more profitable for small holders with low producing animals than feeding

2.2.1. Feed resources and feed demand assessments (FEAST) in the context of overall farming systems

In Ethiopia the FEAST tool was applied in 2015 in the two districts of Angacha and Lemo in the Souther Region and Bahir Dar Zuria district in the Norther Region. In Angacha and Lemo FEAST was implemented in Kerekicho, Jawe and Upper Ganna kebeles by involving 45 farmers from Kerekicho, 17 from Jawe and 19 from Upper Ganna) based on representative sub-villages. Farmers were selected from different wealth categories using landholding as the main proxy as agreed by the villagers. The farmers participated in a guided focus group discussion followed by individual interviews. The two districts have generally similar faming practice and feed resource option, although landholding per household is much smaller in Angacha (0.5-0.75ha) than in Lemo (1-2ha). The agricultural practice employed in the area is traditional oxen-plough and hoe-culture practices. The main food crops grown in the districts are wheat, tef, barley, maize, field peas and broad beans. Root crops, enset, and potato are also grown in the district Among the perennial crops enset (false banana) plays an important role through its multiple uses as a source of food, fiber, animal fodder, construction material and sleeping mats. Predominant potential water sources for small scale irrigation were shallow well water and rivers and springs water. Water was lifted mostly with rope and washer pumps and sometimes with jerry can fastened to a rope and distributed to irrigation fields with human labor using watering cans. Spring and rivers water was conveyed to crop fields by traditional canals using gravity and plastic hoses. Labor was reported to be readily available when needed. Due to limited land and high population density almost 35% of the family labor per household migrated every year in search of off-farm employment. Livestock were integral part of the agricultural production system and up to 30% of the direct income was derived from sale of livestock and livestock products. This was in addition to the contribution in the form of farm power and as a source of animal protein. Enset leaves and crop residues represented the largest portion of animal feed during the entire dry period. Cattle holding per household was mostly limited to 3 heads of animals due to the limited feed resource availability. Shortage of feed quantity and quality was ranked by farmers as the main constraint for livestock production in the areas. Poor quality of available feeds was also reported to be a limiting factor especially during the long dry season. Based on FEAST findings feed technologies that showed high probability of success with small scale irrigation included fast growing short-lived annual forages such as oat-vetch fodder which do not occupy cropping land for the entire cropping period and perennial grasses which can be planted on soil bunds, backyards and farm boundaries.

In Bahir Dar Zuria district FEAST was applied in the Robit Bata kebele in the three sub-villages of Deri Gedel, Jimma Midir and Terara Gichamintola. A total of 45 farmers (15 from each sub-village) were selected for focused group discussions and subsequent individual interviews. All the farmers were selected from three wealth categories (small, medium and large landholdings) as defined by the villagers based on landholding. Farmers with land holding of less than 1ha were considered small, between 1 and 1.5 ha medium and above 1.5ha large. The study sites had two cropping seasons, the main rainy season (kiremt) when most of the major stable crops including maize, tef, and finger millet are produced, and the short rains (belg) when land preparations took place and planting of crops such as tomato, grass pea, chick pea, maize, onion, cabbage, green pepper, mango, coffee and Khat were grown by irrigation. About 90% of the households in the three sub-villages had access to irrigation mainly through shallow wells. Livestock form the backbone of the farming system and most households keep cattle, small ruminants, equids and poultry. The main feed resource options included naturally occurring and collected fodder, crop residues and grazing. Farmers in the group discussion showed strong interest for crossbred animals. Average milk yield per cow was reported to be less than 2 liters per day. Arable lands in this district were reported to be affected by hardpan formation which limited crop root growth and productivity. Shortage of feed quantity and quality was perceived by farmers as the major constraint for livestock production with the feed resource severely dwindling in the dry period. As a result, most farmers reported that they depend on purchased concentrate feeds to supplement their lactating cows and draft oxen. Supplementary forage production was generally not practiced by farmers. Forage technology options that would work well in the area were identified to be high yielding perennial grasses such specifically Napier.

2.2.2. Annual forages

In Southern Ethiopia in Lemo interventions focused on oats-vetches mixes, which the farmer preferred as a forage (oats, vetch) and management (intercropped) option. A three multi cut management of oats and vetches was introduced, following field observations in year one and two of the projects with single cut management. The three cut management had a 2.3 times higher forage yield than the single cut management. However, a two cut management emerged as the preferred options of farmer since the fields could be cleared in time for food crops, which a three cut management did not allow. Two cut management out-yielded the one-cut management besides proving forage twice over an 85-day growth period (Table 1). It became also evident that the oat-vetch mix has over sole oat cropping the added advantage of higher biomass yield and fodder quality because of the protein component of the vetch. The mean protein content of oats forage was 9.2% (range 7.3 to 12.6%) while vetch forage contained on average 20% protein (range 11.8 to 26.5%). Similarly mean *in vitro* digestibility of oats was 56.4% (range 53.5 to 61.3%) while mean vetch forage digestibility was 67.7% (range61.5 to 73.8%).

Table 1: Yields of oats and oats vetch mixtures under one and a two cut management

Treatment	N	Days of harvest	Yield (kg/ha)
Oats: One cut management	3	85	7 610
Oats: Two cut managements	3	60 + 85	8 620
Oats-Vetch: One cut managements	3	85	9 350
Oat-Vetch: Two cut managements	3	60 + 85	12 180

Oats - vetch hay supplemented at a rate of 2 kg daily increased milk yield in local cows by 1 kg (1.75 to 2.75 kg/d) and in cross bred cows by 2.33 kg (3 to 5.33 kg/d). In sheep supplementation of 200 g of oats vetch hay daily resulted in increased weight gains ranging from 52 to 110 g/d b and an estimated net benefit of 170 Ethiopia Bir. An indication of the attractiveness of oats-vetch forage cropping can be seen in the 4-fold (100 kg to 400 kg) increase in see demand on top of substantial farmer to farmer seed exchange

2.2.3. Perennial forages

Perennial forage options were Napier and Desho, initially in year one and two as single perennial crop later in various form of intercropping (see next para). Napier is the perennial option preferred by farmers in Robit Bata. Our findings show that Napier could be harvested during the course of a year between 6 and 9 times resulting relative to a 12 month growing period in a dry matter yield of a minimum of 17.9 tons/ha and a maximum of 23 t/ha. Average dry matter yields of Desho – indigenous to Ethiopia – as extrapolate from recorded 3 cuts and assumed 6 cuts per year was 41.9 tons per ha (range 31.4 to 92.3 tons per ha). A series of laboratory fodder quality trait analysis performed in the ILRI laboratory of Napier and Desho forages collected were summarized in Table 2.

Table 2: Crude protein (CP) and neutral (NDF) and acid (ADF) detergent fiber, acid detergent lignin (ADL), *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) in Napier forage samples collected in Robit Bata and Angacha

	CP (%)	NDF (%)	ADF (%)	ADL (%)	IVOMD (%)	ME (MJ/kg)
	Napier					
Mean	12.3	73.5	49.5	6.2	51.4	6.7
SD	1.9	2.8	3.5	0.9	1.5	0.16
	Desho					
Mean						
SD						

2.2.4. Multi-purpose forages

In Ethiopia small landholdings had usually around 0.5 (small farmer) to 1.5 ha (large farmer). It was therefore paramount to make optimum use of the small areas that can be allocated to irrigated forages by 1) increasing forage yield and fodder quality, 2) maintaining and where possible improving the sustainability of the cropping systems and 3) maintaining or improving direct food security. Intercropping was used to explore and achieve these objectives. Three leguminous species were used for intercropping: Desmodium is a ground covering and climbing forage species, Sesbania a multi-purpose tree and the deep rooting food-feed crop pigeon pea. Pigeon pea and Desmodium had a positive effect on Napier yield, only Sesbania depressed Napier yield (Table 3). **However total biomass yield was consistently and substantially higher in intercropped Napier then when cropped sole.** The Napier -pigeon pea combination deserves particular interest, because of the positive effect pigeon pea has on penetration of hard pans and water infiltration. This has been reported in more detail elsewhere.

Table 3: Yield of Napier, legume yield and total biomass yield when Napier was grown sole and intercropped with Pigeonpea, Desmodium and Sesbania

Treatment	**Napier yield**	**Legume yield**	**Total biomass yield**
	kg/ha		
Napier sole	2 565		2 565
Napier + Pigeonpea	4 328	987	5 315
Napier + Desmodium	3 930	1 093	5 022
Napier + Sesbania	2 101	2 068	4 169

P < F	0.12	0.38	0.04

2.2.5. Fodder market and forages as cash crop

On-farm livestock productivity trials showed, and modelling of livestock performance provided the conceptual framework, that irrigated forages benefit farmers with improved livestock breeds more than farmers with local livestock. These considerations are out-lined in Table 4 assuming dairy cattle with a genetic potential of yielding 3, 6, 9 and 12 kg of milk daily and that are fed oat-vetch mix harvested from 100 m^2 in a single cut (forage yield and quality data were obtained from our on-farm trials in Lemo).

Table 4: Conversion of oat-vetch biomass into milk in dependence of the genetic potential of the dairy animal

	Total milk produced if cow yields daily			
Oats-vetch mix from 100 m^2 supplied	3 kg	6 kg	9 kg	12 kg
	75 kg	118 kg	146 kg	166 kg
Return from milk sales assuming a farm gate price of 12 Birr/kg	732 Birr	1416 Birr	1764 Birr	2004 Birr

Thus, a farmer with a local cow yielding 3 kg of milk daily can convert oat-vetch biomass from a 100 m^2 into a cross income of 732 Birr while a farmer with a cross bred cow yielding 12 kg of milk per day can realize a cross income of 2004 Birr. These calculations are very simplified, but they pointed out a dilemma. Shall the project avoid working with farmers having low producing local livestock – which often belong to the poorer strata of small holders? **As alternative farmers with low producing livestock could still benefit from irrigated forages if there were a market for it**.

The considerations presented in Table 4 contributed also to the explanation that negative benefit: cost benefit estimates were obtained for irrigated forage production in Ethiopia, Table 5. The major contributing fact was the high labour cost for irrigated forage production, which doubled the livestock associated labour relative to livestock associated labour cost in none irrigating farms.

Table 3: Estimates of benefit-cost ratios for irrigated forage production

Farmer category	**Mean Benefit-cost Ratio (BCR)**
Irrigated forage households - Farmers participating in irrigated forage trials, i.e.	0.60
Non-project irrigation farmers	0.86

- Farmers using irrigation but not participating in irrigated fodder trials (i.e. current dominant use of irrigation)	
Pure rain-fed farmers - Farmers not using irrigation i.e.	0.95

These findings resulted in new activities within ILLSI, namely exploring opportunities from feed and fodder value chains. A rapid one-of assessments of fodder markets bear ILLSI project sites was conducted in 2015 with following findings. Informal fodder markets existed near all sites transacting mainly green forages and crop residues with women been the major players in the greed forage market. **Put differently a significant market demand for forages exists.** Samples were collected from all fodder markets and analysed for feed price quality relationships. By extrapolation the sales price of oat-vetch mix used for calculation in Table 4 would be at least 1185 Birr. Thus, farmers owning local cattle will fare better by selling irrigated quality forages to more commercialized farmer with improved livestock. Along similar lines based on on-farm yield data of Napier and Desho their estimated value at fodder markets were between 150 000 and 200 000 Birr per ha.

2.3. Ghana results

Intervention	Key findings
• **Feed Assessment (FEAST)** • **Food-feed Crops** • **Forages** • **Irrigation management:** WFD • **Sheep fattening** • **Feed and fodder value chains**	• **FEAST** was useful as rapid interactive tool to assess feed resources on-farm and to prioritize feed interventions • **Food-Feed-Crops** that provide food from the grain and fodder from the crop residues promising often preferred by farmers • **Forages such as *Sorghum almum* and *Brachiaria ruzizensis*** performed well but farmers preferred a rainfed management • **Sheep fattening** provided an attractive business opportunity but fattening on introduced forage and by natural grazing yielded similar results • **Feed and Fodder VC** Demand for off farm produced feed exists and is transacted in feed and fodder VC. The bulk of the traded feed was from crop residues

	followed by agro-industrial by-products and forage-type feeds.

2.3.1. FEAST

In Ghana the FEAST tool was implemented in Duko village in Savelugu district in the Northern Region and in Zanlerigu village in Nabdam district of the Upper East Region Twenty-six farmers (17 men and 8 women in Duko and 56 farmers (14 men and 42 women) in Zanlerigu participated in group focus discussions. For individual intervies 12 farmers were then selected representing 3 land and livestock-based wealth categories. The study sites were characterized by mixed crop-livestock production systems with the major crops being maize, rice, millet, sorghum, groundnut, soybean yam and cowpea grown during the raining season from May to October. Tomatoes, onions, okra and other vegetables were occasionally planted during the off season for consumption and income with supplemental irrigation. Only 20% of the farmers in Duko and 30% in Zanlerigu practiced irrigation using bucket and rope to draw water from the shallow wells. Livestock species in the area included cattle (dairy and draught), sheep, goat, pig, poultry and donkey. Sheep were the dominant livestock species in the Duko, mostly used as a source of cash, manure and meat, and draft were the dominant livestock holdings in Zanlerigu. About 30% of farmers in Zanlerigu rear dairy cattle. In both sites small ruminants were an immediate source of cash income. Four major livelihood activities contributed to household's income generation in the sites: crop farming, livestock rearing, of-farm labor and remittances. However, the main contributor to household income was crop farming and off-farm labor work in Duko and Zanlerigu respectively. The annual feed availability correlated strongly and positively with rainfall in all places in northern Ghana and increased from June to October. Grazing on natural pasture and crop aftermath were found to be the main source of feed for livestock. The type of feed available to livestock depended on the season. Naturally occurring forages and greens were mostly available during the rainy season. During this time, animals were restricted to graze areas where cropping activities were not taking place. However, its availability reduces from November to June which is the period of dry season. From September to December, both crop residues and few naturally occurring greens were reported to be more accessible to ruminants after crops were harvested and animals allowed to graze freely without restrictions. Legume crop residues were very important feed resource throughout the year in Duko. About 60% of the farmers in Duko collect, store and feed the residue of legumes crop to the animals. In Zanlerigu, residues of cereals and other legumes were widely collected and stored as feed for livestock. According to farmers, greater percentages of the cereal residues were left on the field and grazed along with naturally occurring forages. Improved forage cultivation was not practiced in either of the study sites. Animal disease was ranked as the main constraint for livestock production, but lack of water and dry season feed shortages were also reported to be limiting factors. FEAST identified planting of irrigated cereal forage sand of food-feed-crops as promising entry points for feed improvement.

2.3.2 Forages cultivation of under various managements options

In 2016, there was demonstration of irrigated fodder production in the project sites in Northern Ghana. Ten farmers (including 7 women) in Bihinayili and 14 farmers (including 7 women) in Zanlerigu were involved. The plot size for each farmer was 5m x 20m. Two forage grasses: *Brachiaria ruziziensis* and *Sorghum almum* (forage sorghum) were cultivated with one forage legume (Lablab purpureus). A total of 100 m^2 size plot was mapped out and divided into two (2). 50 m2 each for grass and legume. Cajanus cajan was planted as hedges on pilot farmers' plots. The irrigated method was pump and hose. There was a general willingness of the farmers towards irrigated fodder production. Small scale irrigated fodder established better at Bihinayili than Zanlerigu. Brachiaria and Sorghum regenerates well after several cutting regimes and during the dry season where there is moisture. However, there is the challenge of producing enough biomass for animal production as this requires a large area of land. The farmers tended to prefer rain fed fodder production to irrigated fodder because of the low cost of inputs. The protein content of both forages (*Brachiaria ruziziensis:* 7.6%; *Sorghum almum*: 8.3%) would suffice to provide for minimum microbial protein content in the diet (6 to 7%) but has to considered poor for a green forage. Similarly, ME contents were low (*Brachiaria ruziziensis:* 6.16 MJ/kg; *Sorghum almum:* 5.84 MJ/kg). Based on feedback from farmers the prospects of growing irrigated forages in Bihinayili and Zanlerigu for feeding of own livestock seemed less attractive than selling in fodder markets. This promoted the project to initiate fodder market surveys. Preliminary results show that legume haulms from cowpea and groundnut are strongly traded and attractively priced. Both crude proteins and ME in groundnut and cowpea haulm are superior to the one observed in *Brachiaria ruziziensis* and *Sorghum almum* raising serious questions about which fodder technology to invests in: forages or food-feed crops.

In May 2017, eight farmers in each project site (Zanlerigu and Bihinayili in Northern Ghana) established irrigated fodder plot measuring 5m x 20m each, making eight plots in each study site. To establish the irrigated fodder plots, a meeting with project farmers was held on 4/5/2017 at Bihinayili in the Savelugu district and Zanlerigu on 15 May 2017 in the Nabdam district to identify lands and project farmers that would offer lands that can be used for both irrigated and rainfed fodder production. This was necessitated by the fact that irrigated fodder was being sown in May and the rains would start in June through to September. Each of the eight fields in each location was randomly allocated to each farmer. Eight (8) farmers at each district are used rainfed forage production as control. The forage species planted were *Brachiaria ruziziensi, Sorghum almum, Cajanus cajans* and *Lablab.* Germination of all forage species (grasses and legumes) was 100% at Bihinayili. Lower percentage germination was recorded at Zanlerigu probably due to the shortage of water in the shallow wells and the adjacent pool which usually supplied project farmers with water. Germination percentage was about 60% for Brachiaria and Cajanus and 90% for Lablab and Sorghum. Agronomical and morphological data collection has been completed at Bihinayili in the Savelugu district and Zanlerigu in the Nabdam district. Fertilizer application to forage grass species seems to enhance fodder yield at Bihinayili. Cutting was done of $1m^2$ quadrat (thrown randomly).

Fodder harvesting was carried out at different plant ages: 4 weeks after planting (WAP) 8 WAP, 12 WAP and 16 WAP. At each age, regrowth after every 4 weeks was harvested till no substantial yield could be harvested. Generally, fertilizer application in 2017 could be responsible for the higher yield in 2017 as against that of 2016. Delay in harvesting irrigated fodder until 16WAP increased the dry matter yield (DMY) of both Brachiaria (24 t ha^{-1}) and sorghum (13 t ha^{-1}). Only forages harvested at both 4 and 8 WAP were able to withstand three successive cuttings. Generally, Brachiaria showed better regenerative capacity than Sorghum. Fodder harvested at 12 WAP had the maximum neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and cellulose contents with a concomitant minimum value of ash, crude protein (CP), *in vitro* organic matter digestibility (IVOMD) and ME (MJ/kg). Nutritional quality with reference to CP contents declined with age but remain same at each successive regrowth. Brachiaria and Sorghum had 21% and 19% CP content respectively at 4-week-old. This was reduced to 6.9% and 7.4% respectively in the first harvested regrowth. Only one successful harvest was achieved in Zanlerigu at 4WAP, this is due to the shortage of water for irrigation.

2.3.3 Feed and fodder value chains to bench mark market potential for irrigated fodder

Surveys on potential for irrigated fodder for producers, sellers and buyers were completed at both districts for the 1st (late dry season, May 2017), 2nd (Wet season, August/September 2017) and 3rd (early dry season, November 2017 – January 2018) quarters. Seed samples of fodder sold have been collected and analyzed in the ILRI laboratory in Addis Ababa.

Table 6: Livestock feed inventory and prices per unit at different seasons at feed markets in Northern and Eastern Ghana

Feed type	**Average price per unit of the feed (GH₵)**								**Quality**
	BOLGA				**TAMALE**				
Crop Residues	**LDS**	**ERS**	**LRS**	**EDS**	**LDS**	**ERS**	**LRS**	**EDS**	
Cowpea hay	16.2	4.5	14	-	7.8	21	15.8	21.5	3,4
Soybean haulm	-	-	10	-	7.6	16.4	4.5	9.2	3,4
Groundnut haulm or hay	6.1	8.7	8.6	7	9.4	12.1	14.3	9.7	3
Cajanus cajan Haulm	-	10	12.7	-	15	14.5	-	-	3
Maize straw	-	-	-	-	14	-	-	14	4
Rice straw	-	-	-	-	5.6	-	-	7.3	3
Sorghum straw	72	-	-	-	12.2	-	-	-	ns
Potatoes leaves	-	18	-	-	-	-	-	-	3
Round bean Pod Bran	60	-	-	-	-	-	-	-	ns
Household by-products									
Cassava peel	-	-	14.5	-	12.3	16.5	10	13.8	3,4

Yam Peel	-	35	-	-	-	-	-	-	ns
Sorghum bran	72	-	-	-	-	-	-	-	ns
Industrial by-products									
Rice bran	25	20	-	23.5	4.3	-	10	3	4
Maize bran	36.2	17.8	-	5	11.7	-	32.9	-	ns
Millet bran	-	-	-	28.6	16.7	-	80	-	ns
Wheat bran	55.9	-	-	14	-	-	15	-	ns
Maize mill waste	18.3	32.5	-	-	-	-	-	-	ns
Cotton seed cake	-	5	-	5.3	-	-	-	-	ns
Forage/Fodder									
Shrub/tree fruits	4.8	-	-	-	1	-	22.8	3	3
Shrub/tree leaves	5	1	7.5	3	10	10.5	5	-	1
Naturally grown pasture (grasses)	-	-	5	-	-	3.5	2	2	1
Rainfed fodder	-	-	-	-	-	10	-	-	3

LDS = Late dry season (February, March and April), ERS =Early rain season (May, June and July),LRS=Late Rain season (August, September and October), EDS=Early Dry season (November, December and January) Quality: 1- *Green with much leaves, 2-Green but with mainly stems, 3-Dry with much leaves, 4-Dry but with mainly stems,5-Spoilt by rain,6-Spoilt by sun*

The estimated market price of the irrigated fodder by the buyers at livestock market showed that it has market value per unit kg relative to other available feeds in the market with better quality than natural pasture and straw. Fodder buyer speculated what the price of fresh irrigated fodder would be in dry season. Sorghum and cajan were not profitable when sold during the wet season (Table 7). Fodder farmers need to study the market to target production towards peak of sale.

Table 7: Cost of production, sales and economic benefit of irrigated fodder (GH**¢**/100m^2) in wet and dry season

Forage species	Cost of production*	Fodder Sale in wet season	Projected Fodder Sale in dry season	Net benefit in wet season	Projected net benefit in dry season
Sorghum	29.4	18.1	36.9	(11.4)	7.5
Brachiaria	29.4	47.3	94.2	17.9	64.8
Lablab	27.8	63.3	126.6	35.5	98.8
Cajanus	27.8	25.4	50	(2.4)	22.2

*include cost of land preparation, seed purchase, irrigation, fertilizer, transportation to the market excluding cost of labour

A survey to determine the motivation and willingness to continue irrigated fodder production was conducted to complement the fodder market survey. High demand for irrigated fodder (mean rank= 0.258), regular supply of irrigated fodder in the market (0.252) and a high likelihood of profit (0.235) were ranked as the chief extent of importance of motivational factors for selling irrigated fodder in the study areas.

Table 8: Respondents' perceived extent of importance of motivational factors for selling irrigated fodder in Northern and Eastern Ghana

Factors	**Rank**				**Rank Mean Index#**
	1	**2**	**3**	**4**	
Regular supply of irrigated fodder	7	2	3	5	4 (0.252)
High demand for irrigated fodder	7	4	2	0	5 (0.258)
High likelihood of profit	1	8	6	2	3(0.235)
Provision of storage facility	0	0	2	2	1 (0.050)
Access to credit	4	6	3	1	2 (0.230)
Total	**19**	**20**	**16**	**10**	

Index=[(4×number of responses for 1st rank+3×number of responses for 2nd rank+2×number of responses for 3rd rank+1×number of responses for 4th)] divided by (4×total responses for 1st rank+3×total responses for 2nd rank+2×total responses for 3rd rank+1×total responses for 4th rank). #The higher the rank for a given reason, the greater its importance

Livestock farmers ranked major factors for buying irrigated fodder are listed in Table 9. Evidence of good performance by the animals fed irrigated fodder (mean rank =0.299), regular supply of irrigated fodder in the market (0.269) and capacity building in conservation techniques of fodder (0.204) were ranked as the chief factors for buying irrigated fodder.

Table 9. Motivational factors for buying irrigated fodder as ranked by the livestock feed buyers in Northern and Eastern Ghana

Factors	**Extent of importance**				**Rank Mean Index#**
	1	**2**	**3**	**4**	
Regular supply of irrigated fodder in the market	7	5	3	1	5 (0.269)
Low price of irrigated fodder	1	1	-	-	2 (0.035)
Information on nutritional quality of the irrigated fodder	5	4	3	1	3 (0.194)
Evidence of good performance by the animals fed irrigated fodder	8	7	3	1	6 (0.299)
Capacity building in conservation techniques of fodder	5	5	2	2	4 (0.204)
Sale of irrigated fodder in easily transportable form	1	-	-	-	1 (0.020)
Total	**27**	**22**	**11**	**5**	

Index = [(4×number of responses for 1st rank+3×number of responses for 2nd rank+2×number of responses for 3rd rank+1×number of responses for 4th)] divided by (4×total responses for 1st rank +3 ×total responses for 2nd rank +2 × total responses for 3rd rank +1 × total responses for 4th rank). #The higher the rank for a given reason, the greater its importance

2.4. Tanzania results

Intervention	Emerging results / key findings
• **Feed Assessment (FEAST)** • **Forages** • **Cost: benefit analysis** • **Feed and fodder value chains** • **Fodder producer groups**	• **FEAST** was useful as rapid interactive tool to assess feed resources on-farm and to prioritize feed interventions •

2.4.1. FEAST

In Tanzania FEAST was implemented in the Babati district in the three villages of Hallu, Matufa, and Shaurimoyo. A total of 47 farmers (30 male and 17 female) from across the three villages were involved in focus group discussions and subsequent individual interviews. Farmers were selected based on land holdings, cropping and livestock ownership. Small landholdings were 0.5-1.0 ha (20% of the households) and above 6ha for large holdings (44% of the households). Farmers in the district practice mixed crop livestock farming with crop cultivation the main source of livelihood contributing about 41% of the total income. Livestock contributed 32% to total income. There were three major cropping seasons in the area: Masika (long rains), Vuli (short rains), Kiangazi (dry period. The main crops grown in the area include maize, paddy, pigeon pea, beans, sunflower, sweet potatoes, pumpkins, cowpeas, sorghum and wheat. Across the villages maize was the dominant crop grown. Livestock species raised include local dairy cows, crossbred dairy cows, draft oxen, sheep, goats, poultry, pigs and donkeys. In terms of tropical livestock unit, dairy cows are the dominant animals reared. The livestock production in the district is generally extensive with natural pasture grazing providing more than 68% of the feed resource and crop residues and other collected feeds proving the rest. Crop residues were collected from the farms after crop harvest, stored and fed during the dry season when grasses are inadequate. Feed scarcity was perceived as the main constraint for livestock production in Shaurimoyo and the second in Hallu and Matufa. In the latter two sites low genetic potential of breeds was ranked the first major constraint. The district was reported to have irrigation potential of about sixteen thousand hectares of land, of which more than five thousand hectares were already irrigated for food crops. Evaluation of high yielding Napier accessions under irrigation and rainfed conditions was proposed as an important entry point.

2.4.2. Perennial Forages

Forages species explored in Tanzania were Napier, Buffel Grass and Rhodes Grass. Fore the preferred species different cultivars/accessions were then tested. Napier out-yielded the other two grasses by at least a factor of 1.8. (However, farmers appreciated that Buffel and Rhodes Grass could be converted to hay much easier than Napier, which becomes significant in the context-of-forages-as-cash-crop, see below). After the preliminary investigations four Napier cultivars – ILRI 16835, ILRI 16937, Ouma and Kakamega 2 (KK2) cultivars were evaluated under pump irrigation technology and rainfed conditions (control) during the dry period of July to October 2017. In Mawemairo village, Napier cultivars under the irrigation technology were cut three times at intervala of 6 weeks. Cultivars under rainfed conditions could only be cut twice at intervals of 8 weeks. Overall the Napier hybrids ILRI 16835 and ILRI 16837 under irrigation gave DM yields of 12 t/ha. The Napier varieties Ouma and KK2 were superior giving dry matter (DM) yield of 15-18 t/ha. The superiority of Napier varieties over Napier hybrids were maintained under rain-fed conditions where Napier hybrids ILRI 16835 and ILRI 16837 yielded DM 5 t/ha while varieties Ouma and KK2 yielded DM of 6-8 t/ha. In Gichameda village, farmers selected and tested Napier cultivars Ouma and ILRI 16835. Ouma and ILRI 16835 gave DM yield of 14 and 22 t/ha respectively under pump irrigation technology while the DM yields for Ouma and ILRI 16835 under rain-fed conditions were 5 and 4 t/ha (Figure 4). These findings suggest that the relative performance of Napier hybrids versus Napier varieties is highly location specific. Leafiness was a farmer's criteria for forage quality. Leaf yield could vary by more than 2 - fold in 5 cultivars of Napier. Promising cultivars identified are ILRI 16837 and Kakamega 2 with 5.18 and 4.98 ton of leaf yield per ha, respectively

2.4.3. Feed and fodder value chains

Marketing of fodder was surveyed at 6 sites in Tanzania with focus group discussions, expert consultations and feed and fodder sample collections to determine price – quality relationships. Addressed were: 1) Mapping of feed and fodder value chains, 2) Profiling of value chain actors, 3) Characterization of market chain linkages between production and consumption of feed and fodder; 4) Opportunities for fodder markets beyond the urban and peri-urban domain; and 5) Feed and fodder price-quality relationships. A generalization of the feed and fodder value chain is in the Figure 1 below.

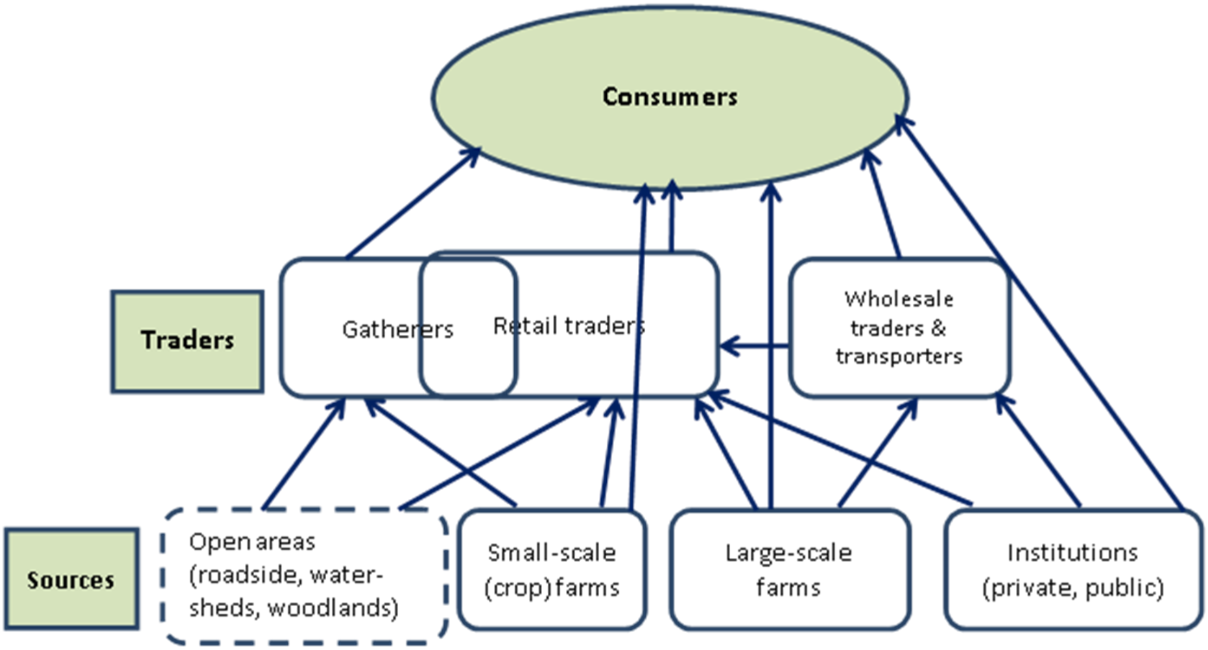

Figure 1: Mapping of feed and fodder value chains In Tanzania

Fodder markets were found to be are an important source of forage to smallholder dairy farmers particularly around urban and peri-urban areas of Tanzania. The largest (57%) proportion of fodder market actors comprised consumers, with about a third of them depending entirely on purchased fodder. Majority of fodder traders were males, 26 to 35 years old who sold fodder as a business and depended mainly on fodder gathered from open/public land. Producers comprised only 7% of the fodder market actors, and the majority were small scale farmers who produced fodder in excess of their requirement. Fodder trading took place throughout the year, but the fodder types and volume varied according to seasons. The major fodder types traded (in terms of volumes and availability) across all the sites were grasses from natural unimproved pastures and dry maize stover. The price of fodder was determined mainly by availability and quality, the main quality indicators being used was maturity and leafiness. Most of the fodder was traded in its fresh form and little or no conservation was done at market or farm level. This therefore had implications on price. Fodder quality, insufficient supply (due to scarcity of land for production and effect of seasonality), lack of technical knowledge and lack of capital were major challenges across all sites and fodder market actors. The study concluded that there is opportunity for improving the livelihoods of rural and urban poor through fodder marketing and suggested areas of intervention, the major ones being dissemination of improved technologies to enhance fodder production, utilization and conservation, provision of market information and establishment of policy, institutional and social structures to support fodder marketing.

2.5. Partnerships built

ILSSI partners with at least one university in each project country at different points in the project, as indicated in Table 3.

Table 3. ILSSI university partners in project countries

Country	**Institution/Organization**	**Type of partner**
Ethiopia	Amhara Regional Agricultural Research Institute	Sub-contracted research institution
Ethiopia	Southern Agricultural Research Institute	Sub-contracted research institution
Ethiopia	Bahir Dar University, Faculty of Civil & Water Resources Engineering	Joint activities (capacity development, use of laboratory for students)
Ghana	CSIR Animal Research Institute Development Studies	Sub-contracted research institution
Tanzania	Sokoine University for Agriculture	Sub-contracted research institution

2.6. HICD completed (individual and institutional)

Capacity for research, as well as capacity in irrigation, is generally low in all project countries. ILSSI therefore developed capacities across the spectrum of scientists who would generate evidence and of decision makers that would use scientific evidence for monitoring and planning. ILSSI engaged both current and future scientists, particularly at universities and national research institutions, including on research design and methods, data collection, analytical methods and analysis, as well as writing, presentation and publication preparation. Most students did not receive any support from ILSSI to cover graduate program fees, but received funds through the national university sub-agreements or direct internships to conduct field work, collect data and participate in conferences. For decision-makers, ILSSI convened or supported various conferences, workshops and trainings on key subjects, methods and research results. The combination of approaches and target groups aimed to generate interest, demand and knowledge of decision makers, and also the skills and expertise for current and future scientists to fulfill the demand for research-based evidence. In relation to emerging demand in Ethiopia from national stakeholders, ILSSI also provided a series of targeted trainings; microfinance institutions and farmers in project sites were trained on savings and credit in relation to credit products for irrigation technologies. Short- and long-term trainee figures for the project period are shown in Table 4.

Table 4. Long- and short-term trainees (2013 – 2018)

Type of training program	**Type of trainee**	**Number of trainees**

		93

2.7. Utilization of Research Outputs

2.7.1. Technologies at different stages of preparation for uptake

Technology tested in field during reporting period:

Technologies ready to scale

- ILSSI's suitability assessments, cost-benefit analysis, and business cases analysis suggest high potential fo solar irrigation pumps in Ghana and Ethiopia. ILSSI developed business models for Ghana and Ethiopia that suggest potential approaches to profitable investment given the contextual constraints.
- Wetting front detector was assessed with USAID support and considered positive for potential scaling, though numerous constraints are identified for commercial scaling. WFD garnered the highest interest in Ethiopia, where it is now integrated into other projects, including one led by FAO (note: IWMI is a partner in that project). In addition, the Ghana Irrigation Development Authority expressed interest in the WFD, though for use outside Feed the Future zone of influence; at local level, the District Department of Agriculture expressed interest in larger scale use given the potential for improving water productivity, particularly in water scarce areas. In Tanzania, Sokoine University of Agriculture intends to include the WFD in its demonstration sites being developed for promoting irrigation. In sum, WFD holds promise for scaling but with constraints to large commercialization. Steps have been made toward public sector acceptance and demand.
- Studies have also shown potential for the Berken plow to improve yields and groundwater recharge that would strengthen water productivity at multiple scales. Separate studies and support is provided to national partners to examine commercialization; relevant public sector institutions have been invited to see demonstrations and have received evidence generated through ILSSI. A private sector partner is involved.

Uptake of technologies

- The wetting front detector has received serious attention by public institutions in all the project countries. In Ethiopia, other projects are now applying WFD in the farmer fields, including on communal irrigation schemes. IWMI also provided technical training and backstopping to the Ethiopian Institute for Agricultural Research, as well as presentations to the national program for Small Scale and Micro Irrigation for Ethiopian Smallholders (SMIS) that seeks to improve capacity in smallholder irrigation nationally. In addition, in Tanzania, Sokoine University of Agriculture is installing and applying the WFD and other irrigation scheduling tools on their new model farmers for irrigation technology, as introduced by ILSSI. In Ghana, requests have been made by the Ghana Irrigation Development Authority for training at an institutional level on the WFD and related irrigation scheduling tools toward introduction in public irrigation schemes.

2.7.2. Influencing national and global dialogue

ILSSI sought to inform both national decision-making and programming on, and global research on and investments in small scale irrigation. This was based on a continuous engagement approach at sub-national and national level, ensuring consultation and input on research questions and design, as well as frequent engagement around emerging research results and evidence. ILSSI also identified opportunities at national level to support or convene conferences and workshops on small scale irrigation (Annex 4). At the same time, ILSSI recognized the need to share research results and influence debates at global level on small scale irrigation (Annex 5). ILSSI contributed to the debate and growing interest in farmer led irrigation through small scale irrigation technologies, including the range of benefits and limitations on expansion.

2.8. Further Challenges and Opportunities

ILRI’s perspective on phase 2

Annexes

Annex 1. References and publications

Peer reviewed

Non-peer reviewed

Conference papers and posters

Adie, A.; Yitayew, B.; Demeke, Y.; Ferede, L.; Yeheyis, M.; Bezabih, M.; Schmitter, P.; Blummel; Yimam, A. Y. 2018. Lessons from pilot trials with small-scale irrigated forage production in the Amhara Region: potential of integrating the perennial forage Napier grass with Desmodium and Pigeon Pea in cropping systems. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Bezabih, M.; Adie, A.; Gemiyu, D.; Zeleke, B.; Schmitter, P.; Blümmel, M. 2018. Lessons from small-scale irrigated forage production trials: potential of annual oat-vetch mixtures. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Muche, H.; Abdela, M.; Schmitter, P.; Nakawuka, P.; Tilahun, S.A.; Steenhuis, T.; Barron, J.; Adie, A.; Blummel, M. 2018a. Biological and mechanical techniques to increase infiltration in rainfed agriculture of the Ethiopian highlands. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Muche, H.; Abdela, M.; Schmitter, P.; Nakawuka, P.; Tilahun, S.A.; Steenhuis, T.; Barron, J.; Adie, A.; Blummel, M. 2018b. Promoting biological and mechanical techniques for enhancing rainwater infiltration and crop productivity in the Ethiopian highlands. 18th International Symposium on Sustainable Water Resources Development on 8-9 Jun 2018, Araba Minch University, Arba Minch, Ethiopia.

From related projects

Africa RISING report (acknowledgement to ILSSI)

Schmitter, P.; Tegegne, D.; Abera, A.; Baudron, F.; Blummel, M.; Lefore, N.; Barron, J. 2016. Evaluation of suitable water lifting and on-farm water management technologies for the irrigation of vegetables and fodder in Lemo district, Ethiopia. Nairobi, Kenya: ILRI. https://cgspace.cgiar.org/handle/10568/82714

Publications under review (accepted with revisions)

In preparation

Abdela, M.; Muche, H.; Schmitter, P.; Nakawuka, P.; Tilahun, S. A.; Steenhuis, T.S.; Barron, J.; Adie, A.; Blummel, M. 2018. Effects of tillage on runoff and recharge of degraded soils in the Ethiopian highlands. *In Preparation*.

Fenta, H.M.; Hussen, M.A.; Schmitter, P.; Nakawuka, P.; Tilahun, S. A.; Steenhuis, T.; Adie, A.; Blummel, M. Modified plow and biological measures to ameliorate degraded hardpan soils: The Robit Bata Watershed, Ethiopian highlands. *In Preparation*.

Muche, H.; Abdela, M.; Schmitter, P.; Nakawuka, P.; Tilahun, S. A.; Steenhuis, T.S.; Barron, J.; Adie, A.; Blummel, M. 2018. Modified plow and biological means to break hardpan in the Ethiopian degraded highlands: Case study with plots in Robit Watershed. *In Preparation*.

Annex 2. Data sets

Insert table of data sets transferred to TAMU

Annex 3. Long-term training: Students

Annex 4. National conferences

ILSSI either supported or co-convened the following national conferences:

1st Amhara Agricultural Forum 2016. Small Scale and Micro Irrigation for Ethiopian Smallholders. Bahir Dar, Ethiopia. 8-9 December 2016.

2nd Amhara Agricultural Forum 2017. Small Scale Irrigation and Agricultural Technologies for Sustainable Development in Amhara Region. Bahir Dar, Ethiopia. 16 January 2018.

International Conference on Irrigation and Agricultural Development (IRAD) 2017. University for Development Studies (UDS). Tamale, Ghana, 30-31 October 2017.

Annex 5. Global conferences