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Agronomic and Nutritional Evaluation of Selected Forage Legumes and Locally Available Feedstuff, and Characterization of Forage and Dairy Innovation Systems in Bako and Nekemte Peri-Urban Areas, Oromia, Ethiopia

By

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Addis Ababa University, College of Veterinary Medicine and Agriculture

Department of Animal Production Studies

June 2014

Bishoftu

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A Dissertation submitted to College of Veterinary Medicine and Agriculture of Addis Ababa University in Partial fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Production

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As members of the Examining Board of the final PhD open defense, we certify that we have read and evaluated the Dissertation prepared by: Mr. Diriba Geleti

Entitled:

"**Agronomic and Nutritional Evaluation of Selected Forage Legumes and Locally Available Feedstuff, and Characterization of Forage and Dairy Innovation Systems in Bako and Nekemte Peri-Urban Areas, Oromia, Ethiopia**" and recommend that it be accepted as fulfilling the dissertation requirement of the degree of **Doctor of Philosophy in Animal Production**

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Chairman	Signature	Date
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Internal Examiner	Signature	Date
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External Examiner	Signature	**D**ate

I hereby certify that I have read the revised version of this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement

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Dissertation Advisor	Signature	Date

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Associate Dean for Graduate Program	Signature	Date

DEDICATION

This dissertation is dedicated to my mother, Alemi Bongasie, who tirelessly labored and sacrificed whatever she had for my education, and also encouraged me to start this study program but untimely passed away while I was at halfway along.

STATEMENT OF AUTHOR

First, I declare that this dissertation is my *bonafide* work and that all sources of materials used for this dissertation have been duly acknowledged. This dissertation has been submitted in partial fulfillment of the requirements for a PhD degree at the Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this dissertation is not submitted to any other academic institution anywhere for the award of any academic degree, diploma or certificate.

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Place: College of Veterinary Medicine and Agriculture

Date of Submission: …….....

BIOGRAPHICAL SKETCH

The author was born in April 1973 in Sibu Sire district of East Wollega Zone of Oromia Regional State. He passed early school ages first at Gunjo Mariam Elementary and then at Sibu Sire Elementary and Junior Secondary Schools. He attended his high school education at Sibu Sire Secondary School. He successfully passed the Ethiopian School Leaving Certificate Examination and enrolled in Haramaya University in September 1991 where he studied Animal Sciences and graduated in July 1994. Up on completion, he was first recruited by Ethiopian Press Enterprise as freelance editor. Later in April 1995, he was employed by Oromia Agricultural Research Institute and assigned to Bako Agricultural Research Center to work as researcher in the Animal Feeds and Nutrition Research Division. He again joined Haramaya University in November 1998 for his Master of Science degree and graduated in July 2000 in Animal Production and then returned to Bako Agricultural Research Center.

The author has served at different capacities when he was at Bako: as head of Animal Feeds and Nutrition Research Division (October 2001-June 2004) and Director of Bako Research Center (January 2001-June 2006). In October 2008, the author was transferred to the then Ethiopian Meat and Dairy Technology Institute where he served as coordinator of the Animal Feeds and Nutrition Training and Consultancy Unit. In June 2008, the author was recruited by the Ethiopian Institute of Agricultural Research and assigned to the Debre Zeit Agricultural Research Center where he served as senior researcher in Animal Feeds and Nutrition Division and as coordinator of the National Forage Seed Research and Development Project.

Over the past 18 years of service in research and development, he has authored and co-authored 75 scientific publications (3 books, 15 peer reviewed journal articles, 16 book

chapters, 39 articles in conference proceedings and two newsletter articles). He is married and a father of a daughter and two sons.

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LIST OF ABBREVIATIONS

AOAC	Association for Official Analytical Chemists
ADF	Acid detergent fiber
ADL	Acid detergent lignin
AGP	Agricultural Growth Program
AI	Artificial insemination
ATVET	Agricultural Technical Vocational Education Training
BARC	Bako Agricultural Research Center
BOA	Bureau of Agriculture
BW	Body weight
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
cm	Centimeter
CP	Crude protein
CPY	Crude protein yield
CV	Coefficient of variation
DAP	Diammonium phosphate

DDM	Digestible dry matter
DM	Dry matter
DMI	Dry matter intake
DMY	Dry matter yield
DZARC	Debre Zeit Agricultural Research Center

LIST OF ABBREVIATIONS (*continued*)

EAAP	East African Agricultural Productivity Project
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
g	Gram
GDP	Gross Domestic Product
ha	Hectare
HC	Hemicellulose
ILRI	International Livestock Research Institute
IVDMD	*in vitro* dry matter digestibility
IVOMD	*in vitro* organic matter digestibility
IWMI	International Water Management Institute
kg	Kilogram
km	Kilometer
LSD	Least significant difference
ME	Metabolizable Energy
MJ	Mega Joule
MOA	Ministry of Agriculture
N	Nitrogen

NDF	Neutral detergent fiber
NGO	Non-government organization

LIST OF ABBREVIATIONS (*continued*)

NIRS	Near infrared reflectance spectroscopy
NS	Non significant
RFV	Relative Feed Value
SD	Standard deviation
SE	Standard error
t	Ton

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ABSTRACT

The role of forage legumes in enhancing the quality of fibrous feeds has been widely advocated. Their selection and integration into ruminant feeding systems is thus vital. Yield and quality of five accessions each of alfalfa, cowpea and Centrosema were evaluated; the former under Debre Zeit, and the latter two species under Bako conditions. Quality of leguminous forages adapted to Bako was assessed concomitantly with locally used roughages. Systemic problems hindering forage adoption were also pinpointed using value chain and innovation system frameworks in Bako and Nekemte peri-urban areas. In the alfalfa experiment, dry matter yield (DMY) was higher ($P<0.05$) for FG9-09(F) than in Magna 801-FG(F) whereas the other cultivars (FG10-09(F), Magna-788 and Hairy Peruvian)) had intermediate values between the two. The crude protein (CP) content was higher for Magna-788 ($P<0.05$) than Hairy Peruvian, while FG10-09(F), FG9-09(F) and Magna801-FG (F) had intermediate values between the two. The in vitro organic matter digestibility (IVOMD) did not vary between the accessions ($P>0.05$). Accordingly, Magna-788, FG9-09(F) and Magna801-FG(F) were suggested for promotion to varietal verification stages. In cowpea, DMY was least for ILRI-11976 ($P<0.01$) and highest for ILRI-9325. The mean CP was 17%, values ranging from 16% (WWT) to 18% (ILRI-9325), while IVOMD ranged between 64% (ILRI-6783) and 69% (WWT). Overall, WWT, ILRI-9325 and ILRI-11976 were top performers in DMY, CP content and IVOMD. In centrosema, DMY was highest for C. plumeri ILRI-191 and lowest for C. pubescens ILRI-233. The CP content ranged from 18.9% (C. pubescens ILRI-243) to 22.4% (C. virginianum ILRI-14541). The IVOMD ranged from 38.6% (C. pubescens ILRI-233) to 50.7% (C. plumeri ILRI-191). Generally, C. Plumieri ILRI-191, C. Virginianum ILRI-14541 and C. pubescens ILRI-12297 outperformed others in DMY, CP content and IVOMD. In fourth experiment, CP content was highest for "noug" cake

(32%), followed by herbaceous (24%) and browse (23%) legumes and least for cereal straws (3%). The IVOMD values were highest for browses (68%) followed by herbaceous legumes (67%) and least for straws (45%). The value chain analysis revealed that the role of improved forages in dairy feeding was not remarkable, with farmers widely depending on purchased feed ingredients. "Noug" cake (92%), pulse grain hulls and mill house scraps (58%) and cereal straws (50%) were indicated to be widely purchased in Nekemte area, while "noug" cake, (88%) and sugar cane tops (75%) were commonly purchased in Bako. The innovation system diagnosis revealed that diverse actors exist but they are poorly interacting. The key problems indicated to hinder forage/feed technology adoption were: informal institutional problems, formal institutional problems, actors' capability problems and poor interaction problems affecting 81%, 45%, 63% and 45% of the system actors, respectively. Crafting appropriate regulations for enabling feed and peri-urban dairying system were recommended. Promoting dialogue platforms and participatory and collaborative working cultures were also indicated to reinforce inter-actor interactions. Increased public investment to stimulate effective functioning of basic physical infrastructures (electricity, roads and water supply) was also indicated to be pivotal.

***Key words**:*

Forage legumes; feedstuff; dry matter yield; chemical composition; crude protein; digestibility; metabolizable energy; relative feed value;

1. INTRODUCTION

The Ethiopian livestock sector has considerable economic and social importance at household and national levels and provides significant export earnings. The sector contributes 15 to 17% of gross domestic product (GDP) and 35 to 49% of agricultural GDP and 37 to 87% of the household incomes (Behnke and Metaferia, 2011; Gebremariam *et al*., 2010). The productivity of the sector, however, is low owing to a number of constraints, among which feed shortage both in quality and quantity is very crucial.

In Ethiopia, ruminant feeds are obtained mainly from native pastures and crop residues. The contribution of the former, however, is diminishing from time to time due to poor management and continued expansion of crop farming (Melaku *et al*., 2003). This is resulting in the increasing role of crop residues which are generally of poor quality (Steinbach, 1997; Zewdie *et al*., 2011), justifying the need for exploring alternative options for their improvement. In this regard, the contribution of forage legumes has been widely advocated (Umuna *et al*., 1995), rationalizing the need for research activities aiming at selection of potential legumes for integration into the existing feeding systems. Against this background, forage legumes selection programs have been going on over the past five decades and a number of herbaceous and browse legume species were identified and recommended (EARO, 2000). Large scale germplasm evaluation works on promising materials are also underway at both national and regional levels with a number of candidate materials in pipeline. Alfalfa (*Medicago sativa* L.) is one of such potential species known for its high yield and quality (Campiglia *et al*., 1999), mainly under temperate and irrigated low land environmental conditions. This species was also reported to survive long periods of water stress by impeding its vegetative growth (Annicchiarico *et al*., 2010) and accessing water from deep layers through its long root system (Volaire, 2008).

Similarly, cowpea (*Vigna unguiculata* L. Walp) is a dual purpose legume with a potential to serve as a candidate for integration into a mixed crop-livestock production systems under medium to low altitude environments (Etana *et al*., 2013). It is known for its potential role in supplying quality haulms for livestock. It also brings N into the farming system through its biological N fixation (Agza *et al*., 2012). Centrosema species are also promising herbaceous legumes with a potential to adapt under sub-humid environments in western Ethiopia (Geleti *et al*., 2001). Evidences indicate that past selection programs focused more on aspects of environmental adaptation and biomass production potential rather than issues on nutritional quality, leading to paucity of information on the latter attributes. Information on nutritional quality, however, is of greatest significance for optimizing the utilization of available feeds and improving animal production and productivity. This highlights the need for generating forage quality database for promising accessions of forage legumes grown under diverse agro-ecologies. Generation of such database for pre-release pipeline accessions has become compulsory at advanced levels of varietal selection stages following the recently adopted forage variety development system in Ethiopia.

A critical concern in forage development also is that despite availability of a range of forage options, their adoption has remained low (Hall *et al.,* 2007). A recent study for example indicated that only 0.15% of smallholder farmers practice on-farm improved forage production (Lemma *et al*., 2010). It was further indicated that utilization of energy and protein feeds were negligible with only 0.8% of farmers reporting to have access to these ingredients. Competition for access to adequate feed was reported to be fiercer and in certain cases was reported to seriously damage community relationships by aggravating conflict over pasture resources (Ayele *et al*., 2012). Generally, efforts made over years had little impact on the progress of forage technology adoption (Lemma *et al*., 2010) implying the need for insights on the factors hindering the rate of adoption of these technologies to be able to suggest appropriate policy instruments.

The low adoption rate of forage technologies has traditionally been linked to limited knowledge of farmers, lack of competent and sustainable technical support and the low priority attached to promotion of forage technologies and shortage of planting materials (de Haan *et al.*, 2006; Ergano *et al.*, 2010). Consequently, technology transfer attempts in the past focused on addressing these problems, mainly through a top-down technology transfer model. But this model is now proved to be inadequate in enhancing the adoption of forage technologies owing to its supply driven nature and its little consideration to the various sources of knowledge (Hall *et al*., 2006).

The failure of these conventional approaches led to the emergence of new conceptual frameworks. More recently, value chain and innovation system frameworks have emerged as approaches for addressing the poor adoption of forage technologies owing to their potential for identifying the embedding blocking mechanisms. These approaches embrace the totality and interactions of actors involved in forage research and development and extend beyond knowledge and technology generation and encompass the factors affecting demand for and use of (forage) technologies for economic purposes (Hall *et al*., 2006). A value chain approach takes into account all the actors and activities from production to consumption and the dynamic relationships between actors involved in the chain (Rich *et al*., 2011). An innovation system approach asserts that adoption and utilization of (forage) technical interventions is messy and complex with new ideas developed and implemented by actors engaged in networks. The framework focuses on learning and the processes of human interaction from which learning emerges (Roling and Wagemakers, 1998). Key to both frameworks is the mapping and characterization of actors and their interactions, and the institutional factors influencing these interactions. Both approaches facilitate the identification of embedding systemic problems hindering successful innovation so that appropriate policy instruments would be formulated to fix the embedding problems.

Thus it is now understood that livestock feed shortage problems have less to do with shortage of knowledge and technology as often assumed in the conventional technology transfer model but with 'scarcity' of the 'capacity' to learn and innovate by the actors involved in the generation and use of (forage) knowledge (Hall *et al.,* 2006). The same authors have persuasively voiced that for ensuring adoption of forage technologies, strengthening the absorptive and learning capacity of farmers is very crucial. It has also been claimed that the capacity to use forage technologies is a function of the patterns of interactions among the innovation system actors and the factors that condition these interactions (Rich *et al*., 2011). Hence, this approach is currently being used extensively as an analytical framework for understanding the technological innovation systems and pinpoint systemic problems so that appropriate systemic instruments would be designed to fix the embedding systemic problems (Lemma *et al*., 2010).

Equally, the value chain framework focuses on the analysis of commodity value chains and facilitates the identification of systemic constraints and suggestion of possible remedial strategies (Rich *et al.*, 2011). Like the innovation systems framework, this approach also facilitates the mapping and characterization of the actors and actor interactions and factors conditioning these interactions along the chain. While the innovation systems approach deals with generation and use of knowledge at a particular stage of commodity value chain, the value chain approach focuses on activities of value creation, and market opportunities and linkages along the chain. A number of value chain thinkers also suggested that adoption of improved forage technical interventions are better facilitated when linked with market oriented commodity value chains such as peri-urban dairy production activities (Ergano *et al*., 2010). The combined use of the two approaches was also suggested to enable better pinpoint systemic problems embedding in the wider technological innovation systems (Anandajayasekaram and Gebre-medhin, 2009).

In addition, while systemic problems embedding in feed and dairy technological innovation systems were documented to some degree in the contemporary innovation system literatures elsewhere in Ethiopia (Lemma *et al*., 2010; Asres, 2012), there were no attempt made so far to specifically classify and define the problems using a systemic policy framework (Wieczorek and Hekkert, 2011). While different authors have provided records of possible systemic problems embedding in feed and dairy innovation systems (Lemma *et al*., 2010; Asres, 2012), in order for these listings to lead to formulation of coherent and reinforcing interventions, a logical matrix combining the actors of the innovation system, their functions and a particular systemic problem typology embedding in the system is imperative.

With this background, the present study was undertaken with the following general and specific objectives.

General objective

The general objective of the study was to evaluate the yield and quality of selected accessions of promising forage legumes grown under Debre Zeit or Bako site conditions and characterize the dairy feed and fluid milk value chains and innovation systems in Bako and Nekemte peri-urban areas.

Specific objectives

To evaluate the DM yield and quality of selected accessions of alfalfa grown at Debre Zeit and cowpea and Centrosema grown at Bako and identify promising genotypes for further promotion to variety verification stages;

To assess the nutritional quality of browse and herbaceous legume species adapted to Bako site conditions concomitantly with widely used fibrous feeds in the area;

To characterize the feed and dairy value chains and innovation systems and pinpoint systemic problems hindering forage adoption, and then suggest potential systemic instruments to avoid the problems.

2. LITERATURE REVIEW

In this section, past feed research activities in Ethiopia are briefly reviewed in the perspective of the proposed research work mainly focusing on native pastures, crop residues and improved forage and pasture species. Challenges associated with improved forage and pasture technologies has also been described with a view to highlight the need for pinpointing systemic problems hindering adoption and sustainable utilization.

2.1 Natural Pastures

Natural pastures consist of the main highland pastures of Ethiopia, with the grasslands accounting for about 30.5% of the area (Mengistu, 1997). The change of species composition in the grassland vegetation naturally depends upon a number of factors. Seasonal fluctuation in the availability and quality of natural pasture is a common phenomenon which results in serious feed shortage thereby affecting livestock production and productivity (Bogale, 2004).

Degradation of native grazing land relates to a combination of human exploitation exceeding the natural carrying capacity of the land resources and inherent ecological

fragility of the systems (Eba, 2012). The annual DM yield of the natural pasture on seasonally waterlogged fertile areas was estimated to be 4-6 ton ha^{-1}. Farming systems and altitude are important variables affecting vegetation distribution (Angassa, 1999). Botanical composition of plant species and productivity of native pastures are highly influenced by animal species, intensity of grazing and edaphic factors. Biomass production over time varies and therefore causes seasonal variation in forage availability (Holechek *et al*., 1998) and quality (Geleti *et al*., 2011). In addition to biomass yield, pasture management practices appear to affect species composition. For example, continuous overstocking decreases the proportion of desirable species and favors infestation by less nutritious and unpalatable species (Hassan, 2006).

In spite of the speedy expansion of crop production into natural grasslands, natural pastures still play an important role as ruminant feeds mainly in the western and pastoral southern regions of the country. Some grassland studies conducted in the highlands of the country had focused, among others, on improving the yield and quality of native grasslands through oversowing with improved forage species with varying success stories (Gizachew and Geleti, 1997). For example, over sowing of native pastures with a legume species *Stylosanthes guianensis* in western Ethiopia was noted to be a successful intervention mainly on stock excluded areas. Animals grazing native pastures over sown with *Stylosanthes guianensis* during the dry months of the year were observed to gain 108g day^{-1} as opposed to 19g day^{-1} gain for the control group grazed native pastures alone (Gizachew and Geleti, 1997).

Quality of native pastures in the central highlands also revealed remarkable seasonality (Sileshi and Bediye, 1991). The crude protein (CP) content varied from 3.2% in January to 12.1% in July while *in vitro* organic matter digestibility (IVOMD) ranged from 42% during the dry season to 57% during the main rainy season. In the same study, the critical nutrient lacking was indicated to be protein, and the supply of this nutrient to fall below maintenance requirement of animals for around 6 months of the year. A study on herbage quality was also undertaken in Western sub-humid zones of the country (Geleti *et al.*,

2011) and this study indicated that the CP content range from 5.03% to 8.07% with a mean of 6.17%. Similarly, the IVOMD ranged from 42.89 to 52.95% with an average value of 48.44%. The concentration of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) was 75.89, 48.73 and 8.16%, respectively indicating the poor nutritional status of the native pastures.

2.2 Crop Residues and Strategies for their Improvement

Crop residues are roughages that become available for livestock feed after crops have been harvested (Nordblom and Shomo, 1995). These feed resources represent a large part of ruminant feeds in Ethiopia, most of which are indeed underutilized (Yami *et al*., 1991). They can usually be grouped by crop type including cereals, grain legumes, roots and tubers. The role of crop residues as feed resources depends mainly on degree of intensification of crop-livestock systems and shortage of feed from natural grasslands. Farmers collect and store residues after harvest and selectively feed milk cows and work animals during critical periods of the year. Stubbles are also important feed resources in Ethiopia. According to FAO (1987), utilizable average dry matter yield of stubble grazing was estimated to be 0.5 ton ha^{-1} $year^{-1}$.

Sileshi and Bediye (1991) reported that in the central highlands, the available feed resources could only meet the maintenance requirements of animals. Asamenew *et al*. (1993) also indicated that on average, the available feed per farm meets only maintenance requirements of animals and very little is left over for growth and production. Overall, the

interdependence between the livestock and crop production shows the role of livestock in improving resource use efficiencies (Sonder *et al*., 2004).

Crop residues are generally characterized by high fibre content and low digestibility and intake (Wondatir *et al*., 2011). Most cereal straws and stovers are known for their lower nutritive value compared to haulms of grain legumes and vines from root crops such as sweet potato. The haulms of leguminous crops were reported to represent good quality roughages with CP levels ranging from 5% to 12% (Tolera, 2007). A number of studies (Leng, 1990; Oosting, 1993; Osuji *et al*., 1995) have suggested various options for improving the utilization of crop residues. Proposed potential strategies include chemical and mechanical treatment, use of commercial protein supplements and leguminous forage crops such as herbaceous and browse legumes.

The use of chemical treatments such as alkali-based agents and urea are less attractive due to cost and difficulty of application (Oosting 1993; McDonald *et al*., 1995). Economic limitations as well hinder resource-poor farmers to use commercial concentrate supplements. For smallholder farmers, use of forage legumes is the most promising strategy (Kaitho *et al*., 1998) as it can help overcome the protein deficiency of the fiberous basal diets, complement crop production and stabilize the ecosystem to maximize food and feed production from the same land area (Alemayehu, 1997). The leaves of multipurpose browse legumes can also be a valuable green manure or mulch of high nitrogen content for improving the fertility of soils, provide fuel wood and poles for various farm uses (Franzel and Scherr, 2002). To improve the utilization of crop residues, supplementation with forage legumes mainly under smallholder production systems can thus be considered as a potential strategy. To achieve this, evaluation, identification and integration of productive and nutritious browse and herbaceous legume species under varying agro-ecological and farming systems is thus very crucial.

2.3 Improved Forage and Pasture Species

As discussed in the foregoing section, improved forage and pasture species have diversified advantages. In the perspective of ruminant livestock production, the main benefit is to produce high biomass of better quality. Leguminous forages could also complement crop production by maintaining soil fertility through symbiotic N fixation.

It is often suggested that producers opt for high biomass yielding and nutritious grass and legume species for sizeable production impact (Tolera *et al*., 2012). Napier grass (*Pennisetum purpureum*), Rhodes grass (*Chloris gayana*), Guinea grass (*Panicum maximum*), Buffel grass (*Cenchrus ciliaris*), Sudan grass (*Sorghum Sudanese*) and Colombus grass (*Sorghum almum*) can be mentioned as highly productive species. As pointed out earlier, leguminous forage species are important sources of N, fermentable organic matter and minerals. The most adaptive and productive fodder legume species include: Leucaena (Leuceana spp), Pigeon pea (*Cajanus cajan*), Sesbania (*Sesbania sesban*), Calliadra (*Calliandra calothyrsus*) and Tree Lucerne (*Chamaecytisus palmensis*), among others. Herbaceous legume species like alfalfa (*Medicago sativa*), cowpea (Vigna unguiculata), Centrosema species, *Lablab purpureus*, Stylosanthes and Desmodium spp., can also be mentioned, among others.

Several forage species and accessions have been tested and a number of them recommended for wider dissemination in different agro-ecologies and production systems over the past five decades in Ethiopia. Even though there had not been an official release system for forages, about nine forage species have so far been registered nationally. The number of registered forage varieties is now increasing as the national research system has now developed a variety release system for forage and pasture crops. Traditionally, agronomic evaluation of forage crops focuses on biological attributes like ease of establishment, biomass production, and resistance to diseases and pests. But in most cases, quality data base for promising materials has not been adequately generated under

diverse growing conditions, suggesting the need for further work towards that end. Various forage production strategies have been assessed and proven to be successful under Ethiopian condition. For smallholder farmers with problems of land shortage, integration of food and forage crops is very suitable. In areas with problems of soil fertility, forage crops that can suitably be planted on soil bands, soil conservation structures, and as hedge and alley crops can be considered. A summary of recommended forage species for various agro-ecologies and their production strategies have been reviewed recently (Tolera *et al*., 2012). In this regard, highly productive and quality forage crops such as alfalfa, elephant grass, cow pea, lablab, vetch and others were observed to be suitable under intensified production systems.

Many studies demonstrating the potential role of improved forage crops in enhancing animal performance have also been conducted. Improved forages can generally be grazed *in situ*, utilized as green feed or conserved in the form of hay or silage for later use during the lean periods. Fodders with thicker stems like Napier grass and others can more suitably be utilized as green feed using cut and carry system. As previously stated, the leguminous species are rich in CP and minerals, and can thus be used as supplements to poor quality roughages. *Leucaena leucocephala* hay supplementation at a rate of 1.35 kg $head^{-1}$ day^{-1} was, for instance, reported to enable natural pasture grazing bulls to gain 262 g $head^{-1}$ day^{-1} during the dry season (Gizachew, 1993). In an experiment where protein source supplementation comprising different proportion of "*noug*" cake and *Leucaena leucocephala* were given to natural pasture grazing lambs, growth rates were reported to linearly increase from 45 to 64 g $head^{-1}$ day^{-1} as Leucaena gradually replaced "*noug*" cake (Gizachew and Tadesse, 1992). Browse and herbaceous legumes hay supplementation have also raised "*tef*" straw voluntary intake and growth rate of sheep (Gizachew and Geleti, 1997). In a study which compared oats-vetch mixture with native pasture hay using lactating crossbred cows, oats-vetch mixture was reported to support high milk yield (5.7 kg cow^{-1} day^{-1}) than native hay (5.0 kg cow^{-1} day^{-1}), and this difference was attributed to improved protein and energy intakes on the oats-vetch diet

(EARO, 2000). These suggest the need for identifying productive and nutritious legume genotypes for integration in to ruminant feeding systems for diverse farming systems and agro-ecologies of the country using valid germplasm and quality assessment procedures.

2.4 Systemic Problems Hindering Adoption of Improved Forages

A further critical issue associated with development of improved forages in Ethiopia is that despite availability of a variety of forage options, their adoption has remained extremely low (Lemma *et al*., 2008). Irrespective of their superior yield and quality, several forage technical options are yet to be widely adopted by farmers. This situation has traditionally been associated with low farmers' technical knowhow, lack of adequate technical support given to farmers, low priority accorded to dissemination of forage technologies and limited availability of inputs required for forage production such as forage seeds (IFAD, 2006; de Haan *et al*., 2006; Hall *et al*., 2007; Ergano *et al*., 2010). Forage technology generation and transfer efforts made over years thus focused on offsetting these constraints, mainly through "a transfer of technology" approach, which is often condemned for being largely top down and offering little opportunity for ensuring partnerships among diverse actors (Hall *et al*., 2006). This scheme has persistently been criticized for its hierarchical and supply-driven nature and limited success in enabling the adoption of forage technologies.

Accordingly, alternative approaches have flourished since the 1970s due to limitations of conventional linear thinking in understanding the source and thus the solutions of agricultural problems (Hjorth and Bagheri, 2006). A notable shift in this line has been the emergence of farming systems research and extension, which contributed to a better understanding of the role of diverse actors in bringing progress in sectoral and subsectoral development efforts (Tesfaye *et al*., 2002). This approach also helped to create awareness on new ways of doing research taking into account context and interactions (Schiere *et al*., 1999; Darnhofer *et al*., 2012). A further evolution within the

farming systems research tradition has been the shift from rapid rural appraisal to participatory rural appraisal (Webber, 1995). This move highlighted the need for interaction and dialogue between different actors and networks (Scoones and Thompson, 1994) based on the realization that flows of communication and exchange between different actors are critical for existing knowledge to be either reinforced or somehow transformed or deconstructed thus leading to the emergence of new forms of economically useful knowledge and technology.

Regardless of the extensive efforts made over years to generate and disseminate forage technologies, their successful adoption and utilization has remained low under alternative lines of research and development paradigms. For example, taking the case of integrated feed and breed technologies as a case, a recent study has indicated that only 0.15% of rural livestock keepers practice on-farm production of improved forages (Lemma *et al*., 2010). The use of energy and protein source concentrates (industrial byproducts such as oil seed cakes, brans and brewery residues) was indicated to be negligible with only 0.8% of farmers reporting to use them. Similarly, the population of exotic and crossbred dairy cattle was reported to account for only 0.64% and 0.1%, respectively, with the latter mainly owned by commercial farms (Chebo *et al*., 2012). Consequently, access to adequate feed is fiercer today than ever before, and in certain cases, was reported to seriously damage the relationships between communities by aggravating conflict over pastures (Ayele *et al*., 2012). Based on the foregoing review, it can thus be concluded that the efforts made over years had little impact on the progress of the subsector (Lemma *et al*., 2010).

More recently, value chain and innovation system approaches to development are gaining acceptance owing to their consideration to the totality and interaction of actors involved in a given commodity value chains and innovation systems. These approaches are distinguished by their scope to extend beyond the generation of knowledge, further encompassing the factors affecting demand for and use of knowledge (Hall *et al*., 2006;

Ayele *et al*., 2012). A value chain framework includes all the actors and activities from production to consumption and the dynamic relationships between actors involved at various stages of a given commodity value chain (Rich *et al*., 2011). It also claims that producers invest their resources into a given technical intervention when the return is encouraging and thus suggests that forage technology adoption would be sustained if the technical options are linked with production of gainful market oriented commodities such as milk.

In the same way, the innovation systems approach asserts that the process of innovation and sustainable adoption of introduced technical options is complex, with new ideas developed by actors engaging in networks to achieve desired outcomes. In consequence, contemporary innovation studies increasingly focus on learning processes with emphasis on facilitation and the processes of human interaction from which learning emerges (Roling and Wagemakers, 1998). The common feature of both analytical approaches is the mapping and characterization of actors and their interactions and pinpointing of systemic problems hindering learning and innovation for a given commodity value chain or technological innovation system such as feed and breed based peri-urban dairy production systems. An innovation systems approach focuses on knowledge generation and use, often at a particular stage of a value chain, while the value chain approach is more about value creation and market opportunities and linkages along the chain (Ayele *et al*., 2012).

Indeed, successful diffusion of new technologies is not a smooth and efficient process. It is now widely understood that generation of technical innovations is not only limited to considerations of technical issues but further requires insights on the systemic problems decelerating the adoption rate of technologies. Very often difficulties hampering the evolution of new technological innovation systems arise. In the literature, these problems are labeled as ‘system failures’ (Jaccobson and Johnson, 2010), ‘system imperfections’ (van Mierlo *et al*., 2010), ‘systemic problems’ (Farla *et al*., 2010) or ‘blocking

mechanisms' (Lamprinopoulou *et al*., 2012). While some have attempted to characterize the dairy innovation systems and identify constraints hindering progress of its trajectory, mainly under rural production settings in Ethiopia (Asres, 2012), there are still significant gaps, mainly in articulating systemic problems embedding in the feed and dairy innovation systems. Such endeavor is certainly an important first step for designing appropriate systemic instruments that lead to mitigation of systemic problems hindering adoption and utilization of forage technologies.

In the same way, systemic instruments are receiving growing attention among policy makers as novel means to bring about successful evolution of technological innovation systems (Vob *et al*., 2009). These instruments focus on the wider technological innovation system than on its particular elements and support processes that are required to enhance the progress of technological innovation systems (Smits and Kuhlmann, 2004). Systemic instruments aim to address systemic problems that arise at the innovation system level and which negatively influence the speed and direction of innovation processes (Edquist, 1997). Thus, in addition to pinpointing systemic problems, it is also vital to know as to what type of systemic policy instruments can best address the identified systemic problems. This implies the need for linking systemic instruments with embedding systemic problems so that the latter will be successfully moderated. This process could also lead to a clearer insight and a much more complete picture of a given technological innovation system and embedding systemic problems, leading to formulation of more effective innovation policies to accelerate the process of technological change in feed resources development (Wieczorek and Hekkert, 2011).

3. MATERIALS AND METHODS

This section generally describes information on the study locations, the experimental treatments evaluated and the experimental design used to layout the field studies. Furthermore, the laboratory and field research methods employed to collect the data and statistical procedures employed to analyze and summarize the information gathered were described.

3.1 Locations, Treatments and experimental design

3.1.1 Alfalfa experiment

This component was conducted at Debre Zeit Agricultural Research Centre (DZARC) (Latitude: $08^0$44’ N; Longitude: $38^0$38'E) of the Ethiopian Institute of Agricultural Research, located in East Shewa zone of Oromia Regional State, Ethiopia. The center is located at 47 Km East of Addis Ababa, at an altitude of 1900 masl. Information on temperature and rainfall of the site are summarized in Figure 1 of the appendix section. The site is characterized by tepid to cool sub-moist agro-ecological condition with the dominant soil types in the area being light (alfisols/holisols) and heavy black soil (DZARC, meteorological station).

Five alfalfa cultivars were grown at forage and pasture research field of the centre on finely prepared seed beds under supplementary irrigation during the dry months of the year. The cultivars were: FG10-09(F), FG9-09(F), Magna801-FG (F), Magna-788 and Hairy Peruvian, with the latter used as a check. The experiment was planted on 4 July 2012 on $12m^2$ plots (4m long and 3m wide), each plot consisting of 15 rows arranged length-wise in an east-west direction, with intra-row spacing of 0.2m at a seed rate of 20

kg ha^{-1}. At planting, diammonium phosphate (DAP) was applied at a rate of 100 kg ha^{-1} to the plots by uniformly broadcasting and then mixing with the upper soil layer using hand rakes. The alfalfa seeds were uniformly drilled in the rows and then evenly covered with soil. The plots were laid out in a randomized complete block design with four replications. At early stages of seedling development, weeds were controlled through a combination of manual weeding and hoeing, and subsequent weed removal and additional plot management practices were undertaken as deemed necessary.

3.1.2 Cowpea experiment

This experiment was conducted at Bako Agricultural Research Centre (BARC) located in subhumid agro-ecology of western Oromia during the main rainy seasons of 2012 (Year 1) and 2013 (Year 2). The area receives a mean annual rainfall of 1200 mm, 90% of which falls between June and September. Temperature averages 27^{o}C with a range of 22 to 31^{o}C (BARC meteorological station). Dominant soil types in the area are Nitosols with fertile alluvial soils in valley bottoms. Maize, '*tef*' (*Eragrostis tef*), '*noug*' (*Guizotia abyssinica*), sorghum and finger millet are the main crops grown in the area (BARC, 2003).

Five selected accessions of cowpea, four of them selected from prior advanced forage variety trials, were evaluated together with an already released cultivar, *V. unguiculata* WWT used as a standard check. Seeds of the four accessions (ILRI-9325, ILRI-11976, ILRI-6782 and ILRI-6783) were obtained from forage diversity gene bank of the International Livestock Research Institute (ILRI) in Addis Ababa and that of *V. unguiculata* WWT was obtained from the Animal Feeds and Nutrition Research Division of BARC. The seeds of the experimental accessions were planted on 6m^2 plots (2 m long and 3 m wide) having six rows arranged length-wise in an east-west direction, with intra-row spacing of 50 cm and replicated two times using a randomized complete block

design. Within rows the seeds were placed at 10cm distance from each other with each row containing 20 plants. Crop management practices (hoeing, weeding etc.) were practiced as required and no chemical fertilizer was applied during both seasons.

3.1.3 Centrosema experiment

This component was also conducted at BARC during the main rainy seasons of 2012 (Year 1) and 2013 (Year 2) and description of the environmental and production system characteristics of the area is as described under section 3.1.2. Five elite accessions of Centrosema belonging to the three Centrosema species and adapted to the sub-humid medium altitude climate of western Ethiopia were used (Table 1). Five gram (g) of seed of each accession was drilled uniformly in double-rows of 2m long with a spacing of 50 cm between rows in $2m^2$ (1m*2m) plot area. The two rows were drawn lengthwise in an east-west direction at 25cm distance away from the right and left margins of the plot and replicated two times in a randomized complete block design. The distance between the plots within replication was 1m and that between the two replications was 1.5m. Field management practices (hoeing and weeding) were done as desired and no chemical fertilizer was also applied to the experimental plots.

Table 1. Description of the Centrosema species and accessions

Species	Accession no.	Country of collection	1000 seed weight (gm)
C. pubescens	ILRI-233	Belize	31.82
C. pubescens	ILRI-243	Belize	19.96
C. pubescens	ILRI-12297	Colombia	19.80

C. plumieri	ILRI-191	Belize	108.06
C. virginianum	ILRI-14541	Colombia	11.48

3.1.4 Sampling of Browse and Herbaceous Legume Species Adapted to Bako Site and Concentrate and Straws and Hays

In this experiment, seven browse species (*Calliandra callothyrsus, Leucaena pallida, Leucaena diversifolia, Cajanus cajan, Gliricidia sepium, Leucaena leucocephala and Sesbania sesban*), and four herbaceous legume species (*Lablab purpureus, Stylosanthes guianensis, Desmodium unicenatum* and *Desmodium intortum*), and two samples for each of *"noug"* cake, cereal straws ('*tef*' and wheat) and native grass hays were collected from BARC and its surroundings. The environmental and farming system characteristics of the site are as described under section 3.1.2.

Edible plant parts of the leguminous species were collected from recommended species maintenance plots of the Animal Feeds and Nutrition Division. The seven browse legume stands maintained at the centre were cut back on June 1, 2012 to ensure uniformity of the regrowths at the time of sample collection for laboratory analysis. Edible leaves and twigs were collected at the end of September 2012, which coincides with a regrowth age of around four months. For the perennial herbaceous legume species, standardization cut and sample collection was also done as indicated for the browse species. Samples for *L. purpureus* were collected from a four months old legume stand established in early June of the same year on a quarter of a hectare at the same site. Samples harvested from diagonal spots were then chopped manually in to small pieces using sickle and one representative subsample was taken and dried in air draft oven at 65^{o}C for 72 hours and

maintained until analysis. Two "*noug*" cake samples, one obtained from the dairy farm of the BARC (hereafter referred to as "*Noug*" Cake 1) and another from oil processing mill in Bako town (hereafter referred to as "*Noug*" Cake 2) were also included. Straws of two cereal crops, "*tef*" and wheat, commonly used in dairy cattle feeding systems in the area were also collected from straw stacks owned by peri-urban dairy farmers in areas around Bako town. Two native grass hay samples, dominated by the grass species, *Cynodon aethiopicus,* were collected from the dairy cattle research farm of BARC (hereafter referred to as "Native Hay 1"), and from native grass hay conserved for use by peri-urban dairy farmers around Bako (hereafter referred to as "Native Hay 2").

3.1.5 Mapping of the Feed and Dairy Value Chains and Innovation Systems

This component was undertaken in Bako and Nekemte peri-urban areas. Bako peri-urban area is located in Bako Tibe District of West Shoa Zone of Oromia Regional State, while the latter was located in Guto Gida District of East Wollega Zone. In these areas, integrated forage and peri-urban dairy development interventions have been going on for the past two decades and farmers owning crossbred dairy cattle and channeling milk to the urban centres have increased over years. The environmental and farming system attributes for Bako area is as described under section 3.1.2. Nekemte is located at a distance of 331 Km to the west of Addis Ababa. Based on information obtained from nearby weather station, the altitude of the area is around 1770 ranging from 1200 to 2342 masl. The area is characterized by high mean annual rainfall ranging from 1376 to 2037 mm, and mean minimum and maximum temperature of 15^0C and 27^0C, respectively (Zemadim *et al*., 2011). Map showing the locations of the study is presented in Figure 1.

Figure 1: Map showing the locations of the study peri-urban sites

3.2. Data collection Procedures for Dry Matter Yield and Related Traits

In the alfalfa experiment, four randomly selected adjacent middle rows having a net area of 3.2 m^2 were harvested, and the fresh weight of the cut herbage mass was recorded just after mowing using field balance. This was done at full bloom stage, described as a stage when open flowers emerge on average of 2 or more nodes and with no seed pods present (Ball, 1998). The harvested biomass was manually chopped into small pieces using sickle and a subsample of 200 gm was taken and dried in air draft oven at 65^oC for 72 hours to determine herbage dry matter yield (DMY). For plant height, mean height of randomly selected five plants within a plot was recorded. Leaf to stem ratio was determined by separately harvesting a central section of two adjacent middle rows with a sampling area of 0.2 m^2 (0.5 m length x 0.4 m width) from the remaining rows in a plot, followed by partitioning the harvested sample in to leaf and stem fractions, and drying the fractions as indicated above for DMY determination.

In the cowpea experiment, two randomly selected middle rows with a net area of 2 m^2 were harvested at the stage of pod initiation and the fresh weight of the cut biomass was taken using field balance. The sub sampling and drying process of the 200 gm subsample for herbage DMY determination was done using the same procedures described for alfalfa experiment above. Crude protein yield (CPY) of the accessions was further determined as the product of CP content and herbage DM yield (Starks *et al*., 2006). In the Centrosema experiment, herbage mass harvested from the two rows of 2 m^2 area was cut at 50% flowering stage and the fresh biomass weight was taken using field balance. Herbage DMY and CPY values were determined using similar procedures described in the cowpea experiment.

3.3 Laboratory Analysis and Calculation of Indices

Chopped herbage mass from four replications for each accession of alfalfa, and from two replications for each accession of cowpea and Centrosema were pooled into one sample and homogenized and one representative sub-sample was taken for laboratory analysis. These pooled subsamples were then dried in air draft oven at 65^{o}c for 72 hours and maintained for chemical analysis being packed in a paper bag container at room temperature. The feed samples of the alfalfa (first, second and third cuts) and all samples of the cowpea and Centrosema and the 17 feed samples in the fourth experiment were transported to Holeta Research Center Nutrition Laboratory within two weeks after harvesting and ground to pass through 1 mm screen using Wiley mill. The samples from the fourth, fifth and sixth cuts of alfalfa experiment were analyzed at Animal Nutrition Laboratory of Hawassa University. The DM and ash contents were determined by oven drying at 105°C overnight and combusting in a muffle furnace at 500°C for 6 hours, respectively. The nitrogen (N) content was determined by Kjeldahl method and CP was calculated as N x 6.25 (A.O.A.C, 1995). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to the procedures of Van Soest and Robertson (1985). The *in vitro* organic matter digestibility (IVOMD) was determined using the modified Tilley and Terry *in vitro* method (Tilley and Terry, 1963). The metabolizable energy (ME) content was estimated from IVOMD using the equation: ME (MJ kg^{-1}DM) = 0.15*IVOMD (Beever and Mould, 2000).

For the 17 feed samples in the fourth experiment, the chemical composition and IVOMD contents were determined using the Near Infrared Reflectance Spectroscopy (NIRS) facilities available at Holetta Agricultural Research Center. The NIRS procedure was performed on 3 gm of ground sample using Foss NIRS 5000 in the 1108 – 2492 range with an 8 nanometer step. Before scanning, the samples were pre-dried at 60^{o}C over night in an oven to standardize moisture conditions. The spectra of each sample were taken by scanning for three consecutive times (Win Scan 1.5, 2000 Infrasoft International) (Fekadu *et al*., 2010), and CP and ME contents were calculated as described earlier.

The Relative Feed Value (RFV) index is used to rank feeds relative to the typical nutritive value of full bloom alfalfa hay, containing 41% ADF and 53% NDF on a DM basis, and having a RFV of 100, which is considered to be a standard score. At present, this index is widely used to compare the potential of two or more forages on the basis of energy intake (Schroeder, 2013). Accordingly, forages with RFV index greater than 100 are considered to have higher quality than full bloom alfalfa hay and those with a value lower than 100 are of lower value than the same. Such a single index was recommended for use in practical forage pricing and marketing (Schroeder, 2013; Uttam *et al*., 2010) and was calculated as: *RFV = DDM (%DM)* x *DMI (%BW)/1.29* (Uttam *et al*. 2010); where DDM (digestible dry matter) and DMI (dry matter intake potential as % of body weight) were calculated from ADF and NDF as: *DDM (%DM) = 88.9 – 0.78* x *ADF (%DM),* and *DMI (% body weight (BW)) = 120/NDF (%DM)* (Schroeder, 2013).

3.4 Dairy Feed and Fluid Milk Value Chain Analysis

In this activity, primary and secondary data were gathered through focused group discussion, personal farm visits and discussions with farmers using semi-structured questionnaires between May 2013 and July 2013. A total of 48 (N = 24 in each site) peri-urban dairy farmers engaged in integrated feed and dairy breed interventions were identified and were included in the interview to gather farm level primary data. The farmers involved the interventions were identified in collaboration with the feed and dairy research staff at BARC and the Livestock Development and Health Agency staff of the study districts. The key informants with whom discussions were made include: heads of zonal and district Agricultural Development Bureaus, and Livestock Development and Health Agencies, district level livestock extension experts and AI technicians, livestock researchers at BARC, heads of zonal and district public veterinary services providers, and heads of pertinent NGOs operating at the two sites. A value chain approach was used to identify actors involved along feed and fluid milk value chain segments and their core functions (Anandajayasekeram and Gebremedhin, 2009). Secondary sources of

information relevant to the subject were also collated from various published and unpublished sources and were examined to extract additional information to complement the primary data.

3.5 Characterization of the Feed and Dairy Innovation System

In this activity, semi-structured interviews were conducted with relevant actors involved in the generation, transfer and use of feed and dairy technical innovations. Insights of the various actors on feed and peri-urban dairy development issues were elicited, the discussion topics including: types of actors, their functions and strengths; patterns of inter-actor linkages; issues related to systemic problems including: institutional, infrastructural, capability and interaction problems and perceptions of actors regarding policies relevant to feed and peri-urban dairy production. The conceptual framework used in this activity as adopted from Hall *et al*. (2006) is illustrated in Figure 2.

3.6 Identification of Systemic Problems and Systemic Policy Instruments

The current feed and dairy innovation system was diagnosed for systemic problem typologies defined in Table 2 (Smith, 2000; Woolthuis *et al*., 2005; Chaminade and Edquist, 2006).

Table 2. Categories of systemic problems and their mechanisms as used in this study

Problem type	Problem mechanism
Infrastructural	Lack of physical and knowledge infrastructures (mainly of large scale structures with long time horizon of operation and low return for private investment)
Formal institutional	Absence or shortcoming of regulations and product quality standards creating unfavorable environment for innovation
Informal institutional	Culture, social norms and values, entrepreneurial spirit, lack of trust and lack of risk-taking tendencies that hinder innovation
Weak interaction	Limited interaction and too little knowledge exchange with other actors inhibiting the possibility of exploiting complementary sources of knowledge and interactive learning
Strong interaction	Intensive cooperation in closely tied networks, leading to lock-in into established trajectories and a lack of infusion of new ideas,

	due to too inward-looking behaviors, lack of weak ties to third actors and dependence on dominant partners
Capability	Lack of appropriate competences and resources at actor and firm level preventing access to new knowledge and leading to inability to adapt to changing circumstances to open up new opportunities and to switch from an old to a new technological trajectory
Missing actor	The absence of important actors in the innovation system

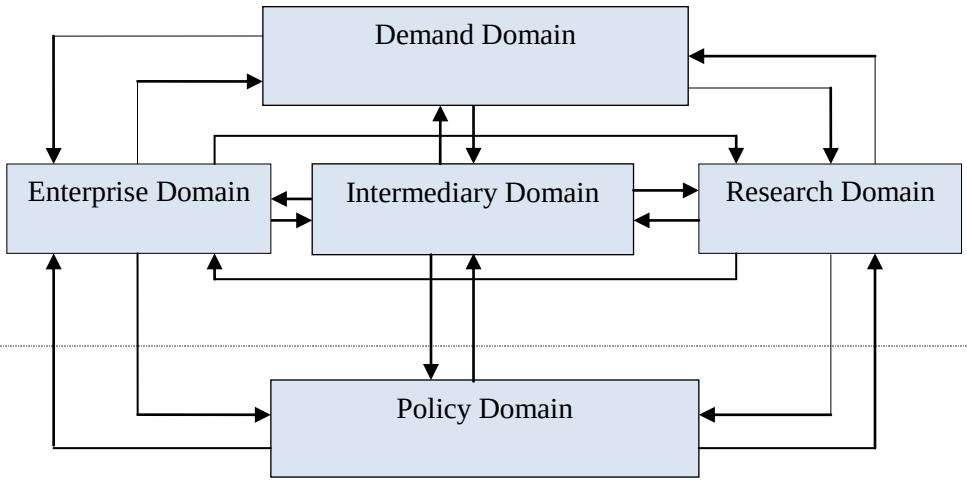


Figure 2. The conceptual framework used for the analysis of the innovation systems

Accordingly, empirical systemic problems were first driven through two descriptive case studies. The first of these studies focused on the analysis of dairy feed and fluid milk value chains at the two peri-urban sites (Geleti *et al*., 2014) while the second dealt with diagnosis of feed and dairy technological innovation systems in which an innovation systems framework was used (Hall *et al*., 2006). The empirically identified systemic problems from the two case studies were then tabulated and allocated to specific theoretical problem categories (Wieczorek and Hekkert, 2012). The systemic problems allocated to the various problem typologies were further combined in a matrix that integrates the problems with innovation system actors. Further, a group of actors in the innovation system reported to be affected by a specific empirically identified systemic problem were clustered and linked with that specific problem and this template resulted in a clear insight on the type of actors whose problem can be addressed by comparable policy instrument mixes. This latter matrix further led to an insight as to which of the systemic problems is rampant across the different actors of the innovation system by facilitating determination of the proportion of actors affected (***Y***) by a given systemic problem typology using the equation:

$$Y = (\text{Number of actors reported to be affected by a given systemic problem})/(\text{Total number of key factors identified in the system})*100$$

After systemic problems were identified and their prevalence is determined, possible goals of systemic policy instruments that need to be put in place to avoid the problems identified were proposed. This was followed by suggestion of potential policy instruments leading to completion of the cyclical systemic policy framework illustrated in Figure 3 (Wieczorek and Hekkert, 2012). Setting of the goals facilitated the suggestion of mutually reinforcing systemic instruments that take into account the specificities of the identified systemic problems.

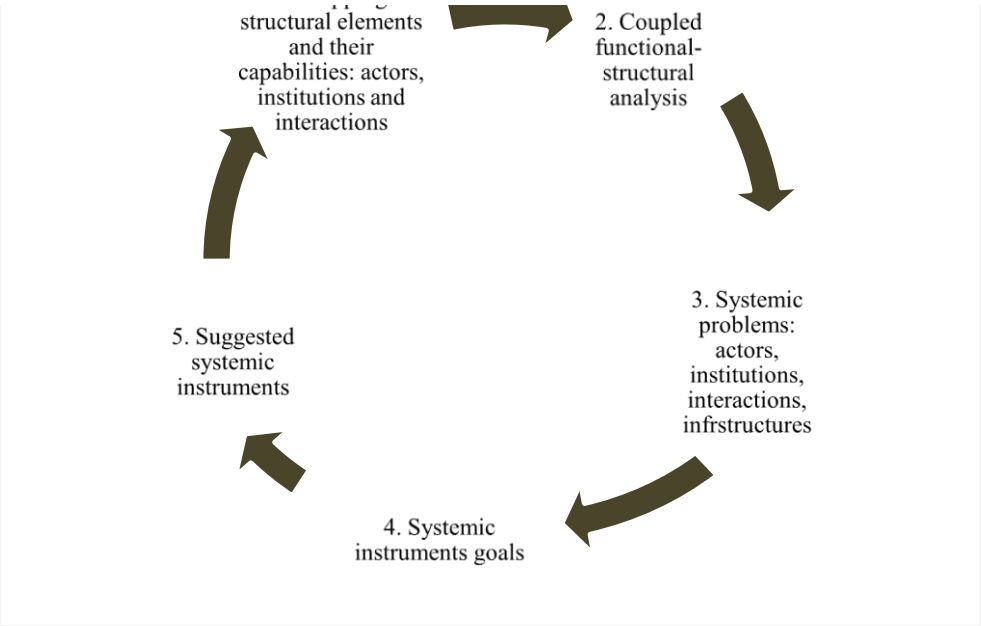


Figure 3. Systemic policy framework used to identify systemic instruments

3.7 Statistical Models and Data Analysis

In the alfalfa experiment, data on herbage DMY, plant height and leaf to stem ratio were subjected to analysis of variance where cultivar, cutting cycle and the interaction between cultivar and cutting cycle were considered as class variables in the model: $X_{ijk} = \mu + V_i + C_j + (Vi*Cj)_k + e_{ijk}$; where X_{ijk} stands for the measured variables, μ is the overall mean; V_i is the effect of cultivar; C_j is the effect of cutting cycle; and, V_i*C_j is the interaction between cultivar and cutting cycle, and e_{ijk} is the random error. For herbage quality traits, as composite samples pooled over the four replications were used within each cutting cycle, cutting cycles were considered as replication and the data was fitted to the following statistical model: $X_{ij} = \mu + C_i + V_j + e_{ij}$; where X_{ij} stands for the measured quality traits; μ for the overall mean; C_i for the effect of cutting cycle, V_j for the effect of variety and e_{ij} for the random error.

For the DMY of cowpea and centrosema experiments, year, accession and the interactions between year and accession were considered as class variables in the model as: $X_{ijk} = \mu + Y_i + V_j + (Y_i*V_j)_k + e_{ijk}$; where *Xijk* stands for herbage DMY; μ is the overall mean; Y_i is the effect of year; V_j is the effect of accession; and Y_i*V_j is the interaction between year and accession, and e_{ijk} is the random error. For herbage quality traits, year was considered as replication, and the data was fitted to the following model: $X_{ij} = \mu + Yi + V_j + e_{ij}$; where *Xij* stands for the herbage quality traits determined; μ for the overall mean; Y_i for the effect of year (here used as replication), V_j for cultivar effect and e_{ij} for the error term.

In the fourth activity, the data was first summarized using descriptive statistics for the whole feed samples using the MEANS procedure of Statistical Analysis System (SAS, 2002). The various feed groups (browse and herbaceous legume species, cereal straw

samples, native grass hays and "*noug*" cake samples) were further compared by considering the feed categories as a class factor using the model: $X_{ij} = \mu + F_i + e_j$; where X_i is the observed feed quality trait; μ is the overall mean; F_i the effect of feed group; and e_j, the random error. The GLM procedure of SAS was used to analyze the quantitative data (SAS, 2002) for the first four experiments and significant mean differences were declared at $P \leq 0.05$ using LSD (Least Significant Difference) test (Snedecor and Cochran, 1980). The quantitative data of the value chain component were also analyzed using the MEANS procedure in SAS (SAS, 2002). For the qualitative information generated through value chain and innovation system approaches, the information was systematically summarized and arranged by thematic areas to facilitate narration and discussion of the results.

4. RESULTS

This section is divided into six subsections. In the first sub-section (4.1), results from evaluation of the herbage production potential and nutritive value of five cultivars of alfalfa are presented. Data on biomass yield and nutritive value of selected accessions of cowpea and Centrosema are presented in the second (4.2) and third (4.3) subsections, respectively. Results from the evaluation of the nutritive value of the browse and shrub legume species and locally available fiberous feeds in Bako area are presented in the fourth sub-section (4.4). In the fifth sub-section (4.5), findings from the analysis of dairy feed and fluid milk value chains at the two peri-urban sites are described. In the sixth subsection (4.6), results from the characterization of the integrated feed and dairy innovation systems are presented.

4.1 Yield and Quality of Selected Alfalfa Cultivars

4.1.1 Herbage dry matter yield and related stand traits

Variance ratios (F-values) and levels of significance for the various factors considered in the analysis of variance for herbage DMY, plant height and leaf to stem ratio of alfalfa accessions are summarized in Table 1 of the appendix section. The effect of cultivar was significant for herbage DMY ($P<0.05$), plant height ($P<0.001$) and leaf to stem ratio ($P<0.001$). Cutting cycle significantly affected herbage DMY, stand height and leaf to stem ratio ($P<0.001$). The effect of the interaction of the two factors, however, was not significant for the three measured traits ($P>0.05$) and thus the average effects of the accessions and cutting cycles were presented separately.

Mean values for herbage DMY, stand height and leaf to stem ratio for the five alfalfa cultivars are presented in Table 3. The DMY was significantly higher ($P<0.05$) in the cultivar FG9-09(F) than in Magna 801-FG(F) whereas the other three cultivars had intermediate values between the two. Plant height was highest ($P<0.001$) for Hairy Peruvian followed by FG9-09(F) and lowest for FG10-09(F). Leaf to stem ratio was highest ($P<0.001$) for Magna801-FG(F) and Magna-788 and least for Hairy peruvian, with FG10-09(F) and FG9-09(F) having intermediate values between the two.

The effect of cutting cycle on herbage DMY, plant height and leaf to stem ratio is presented in Table 4. A total of eight harvests were taken at an average interval of 54.6±12.4 days between October 2012 and October 2013. The interval between harvests was longer for the main rainy months than the dry and short rainy months. The study evidently indicated that cuts taken following the rainy months had higher DMY than those cuts taken during the dry months of the year. Accordingly, DMY was highest ($p<0.001$) for the 8^{th} cut that followed the main rainy months of 2013 followed by the 4^{th} cut that followed the short rainy months of 2012, and was least for the 6^{th} cut. Stand height was highest ($P<0.001$) for the 3^{rd} and the 7^{th} cuts, while it was least for the 6^{th} cut. The leaf to stem ratio was highest ($P\leq0.001$) for the 6^{th} cut and lowest for the 7^{th} cut, with the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} cuts having comparable and intermediate values between the two.

Table 3. Herbage yield, plant height and leaf to stem ratio of the five alfalfa cultivars

Cultivar	DMY (t ha^{-1})	Plant height (cm)	Leaf to stem ratio
FG10-09(F)	4.36^{ab}	74.48^{d}	0.45ab
FG9-09(F)	4.77^{a}	81.74^{b}	0.44b
Magna 801-FG(F)	4.22^{b}	78.78^{bc}	0.48a
Magna-788	4.45^{ab}	75.01^{dc}	0.48a
Hairy peruvian	4.52^{ab}	86.51^{a}	0.40c
SE	0.18	1.52	0.01
P-level	*	***	***

Note: SE, standard error; *significant at P=0.05; *** significant at P≤0.001; NS, not significant; cultivar means for DMY and stand height with common superscript letters are not significantly different

4.1.2 Herbage nutritive value

Table 5 shows the chemical composition of the different herbage quality traits of the five alfalfa cultivars. The ash content was highest (P<0.05) for FG10-09(F) followed by that of Magna801-FG (F) and FG9-09(F), and was least for Hairy Peruvian, with that of

Magna-788 falling between the two. The CP content was significantly (P=0.05) higher for Magna-788 than Hairy peruvian, with FG10-09(F), FG9-09(F) and Magna801-FG (F) having intermediate values between the two. The NDF and ADF contents were highest for Hairy Peruvian (P<0.05) while no significant variation was observed among the cultivars for ADL (P>0.05).

Table 4. Effect of cutting cycles on yield, stand height and leaf to stem ratio of alfalfa

Harvesting cycles	DMY (t ha^{-1})	Stand height (cm)	Leaf to stem ratio
Cycle 1	4.27^{d}	55.45^{d}	0.44b
Cycle 2	4.03^{d}	79.67^{c}	0.49b
Cycle 3	5.82^{c}	96.69^{a}	0.46b
Cycle 4	6.90^{b}	83.32^{c}	0.49b
Cycle 5	1.66^{e}	84.94^{bc}	0.47b
Cycle 6	0.69^{f}	48.98^{e}	0.54a
Cycle 7	4.60^{d}	95.89^{a}	0.32d
Cycle 8	7.72^{a}	89.48^{b}	0.37c
SE	0.23	1.92	0.01
P-level	***	***	***

Note: SE, standard error; *** significant at P≤0.001; cutting cycle means of all traits with common superscript letters in the same column are not significantly different; Cutting dates: Cycle 1, Oct.19, 2012; Cycle 2, Dec. 26, 2012; Cycle 3, Feb. 26,

2013; Cycle 4, April 2, 2013; Cycle 5, May 20, 2013; Cycle 6, June 25, 2013; Cycle 7, Aug. 20, 2013; Cycle 8, Oct. 10, 2013;

The IVOMD, ME and RFV index of the five alfalfa cultivars are presented in Table 6. The IVOMD and ME did not significantly vary between the accessions (P>0.05). Though not significant, the least IVOMD and ME values were recorded for Hairy Peruvian. The RFV was also lowest for Hairy Peruvian (P<0.01) with values for FG10-09(F), FG9-09(F), Magna801-FG(F) and Magna-788 being statistically similar.

Table 5. Chemical composition of the five alfalfa accessions

Cultivars		Herbage quality traits (% DM)				
	DM %	Ash	CP	NDF	ADF	ADL
FG10-09(F)	89.2^{a}	10.69^{a}	18.43^{ab}	38.85^{b}	22.59^{ab}	5.59
FG9-09(F)	89.14^{a}	10.52^{a}	18.87^{ab}	39.28^{b}	21.67^{b}	5.24
Magna801-FG(F)	89.09^{ab}	10.63^{a}	18.66^{ab}	37.69^{b}	21.49^{b}	5.63
Magna-788	88.42^{b}	10.46^{ab}	19.56^{a}	36.86^{b}	20.71^{b}	5.97
Hairy peruvian	89.40^{a}	10.03^{b}	18.15^{b}	43.53^{a}	26.19^{a}	5.69
SE	0.22	0.16	0.45	1.09	1.3	0.46
P-level	*	*	*	*	*	NS

Note: SE, standard error; * significant at P=0.05; NS, not significant; cultivar means with common superscript letter in the same column are not significantly different

Table 6. IVOMD, RFV and ME values of the five alfalfa accessions

Cultivars	IVOMD (%DM)	ME(MJ kg^{-1}DM)	RFV[#]
FG10-09(F)	69.13	10.34	174.05[a]
FG9-09(F)	67.41	10.11	174.79[a]
Magna-801-FG(F)	69.8	10.47	188.36[a]
Magna-788	68.49	10.27	189.55[a]
Hairy Peruvian	67.08	10.06	154.01[b]
SE	0.9	0.15	6.19
P-level	NS	NS	**

Note: SE, standard error; ** significant at P<0.01; cultivar means with common superscript letter in the same column are not significantly different; [#] RFV has no unit

4.2 Yield and Quality of Selected Cowpea Accessions

4.2.1 Herbage dry matter yield and crude protein yield

Table 7 shows the mean DMY and crude protein yield (CPY) of cowpea accessions as affected by year and accession. The effect of year was not significant for DMY (P>0.05) but that of accession was significant (P<0.01). Though not significant, the DMY was higher for Year 1 than Year 2. The mean DMY was least for ILRI-11976 (P<0.01) and

highest for ILRI-9325, with the remaining accessions (WWT, ILR-I6782 and ILRI-6783) having intermediate values between the two. The CPY for ILRI-9325 was significantly higher ($P<0.01$) than that of ILRI-11976, while WWT, ILRI-6782 and ILRI-6783 had intermediate CPY values between the two accessions.

Table 7. Herbage DMY and CPY of cowpea as affected by year and accession

Factors	Description	DMY(t ha^{-1})	CPY(t ha^{-1})
Year	Year 1	12.54±0.62	$2.34±0.1^{a}$
	Year 2	10.74±0.62	$1.68±0.1^{b}$
Accession	WWT	$13.68a±0.98^{a}$	$2.25±0.17^{ab}$
	ILRI-9325	$13.95a±0.98^{a}$	$2.55±0.17^{a}$
	ILRI-11976	$7.96b±0.98^{b}$	$1.14±0.17^{bc}$
	ILRI-6782	$11.41±0.98^{a}$	$1.91±0.175^{b}$
	ILRI-6783	$11.21±0.98^{a}$	$2.00±0.17^{b}$

Note: Year and accession means in the column with no superscript letter in common are significantly different

4.2.2 Herbage nutritive value

Table 8 presents the mean chemical composition of the five cowpea accessions. Except for DM content ($P<0.01$), no significant variation between accessions was detected for the different quality attributes determined ($P>0.05$). The overall mean ash content was 9.2% while that of CP was 17.4%, with values for the latter ranging from 16.37% for

WWT to 18.18% for ILRI9325. The overall NDF, ADF and ADL mean values were 43.3%, 34.2% and 6.1%, respectively.

Table 8. Chemical composition of the five cowpea accessions

Accessions	DM %	Ash	CP	NDF	ADF	ADL
		% DM				
WWT	91.65[ab]	9.05	16.37	42.68	31.07	5.62
ILRI-9325	90.93[c]	9.30	18.18	42.92	34.12	6.73
ILRI-11976	90.99[c]	9.25	17.96	43.44	31.65	5.27
ILRI-6782	91.87[a]	9.05	16.46	43.70	37.83	6.26
ILRI-6783	91.51[b]	9.25	17.84	43.78	36.53	6.36
Overall	91.39	9.18	17.36	43.30	34.24	6.05
SE	0.08	0.6	1.14	3.69	2.47	0.54
P level	***	NS	NS	NS	NS	NS

Note: DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; ***, significant at P<0.001; % DM values in the column with no superscript letter in common are significantly different; NS, non significant; SE, standard error for accession mean; [#]RFV has no unit; SE, standard error of the mean

Table 9 shows the IVOMD, RFV and the ME values of the five cowpea accessions. The value for IVOMD ranged from 64% (ILRI-6783) to 69% (WWT), with an overall mean of 67%. The mean RFV index was 135, ranging from 128 (ILRI-6782) to 142 (WWT),

while the overall mean ME (MJ kg^{-1} DM) content was around 10 ranging from 9.5 for ILRI-6783 to 10.4 for WWT.

Table 9. IVOMD, RFV and the ME content of five cowpea accessions

Accessions	IVOMD (%DM)	RFV[#]	ME (MJ kg^{-1}DM)
WWT	69.43	142.16	10.42
ILRI-9325	68.65	135.85	10.30
ILRI-11976	68.35	139.09	10.26
ILRI-6782	65.61	127.89	9.84
ILRI-6783	63.56	128.63	9.54
Overall	67.12	134.72	10.07
SE	2.19	15.30	0.33
P level	NS	NS	NS

Note: IVOMD, *in vitro* organic matter digestibility; RFV, relative feed value; ME, metabolizable energy; NS, non significant; SE, standard error for accession mean; [#]relative feed value index has no unit.

4.3 Yield and Quality of Selected Centrosema Accessions

4.3.1 Herbage dry matter yield and crude protein yield

Table 10 shows the DMY and CPY of the Centrosema accessions evaluated in the third experiment. The DMY and CPY values were significantly affected by year ($P < 0.001$) and accession ($p<0.05$ for DMY; $P<0.001$ for CPY). The effect of the interaction between year and accession was not significant for DMY ($P>0.05$). Significantly higher DMY and CPY values were recorded for Year 2 than Year 1 ($P<0.001$). The herbage DMY was highest ($p<0.05$) for *C. plumeri* ILRI-191 and *C. pubescens* ILRI-243, followed by *C. virginianum* ILRI-14541 while it was least for *C. pubescens* ILRI-233. Similarly, CPY was highest ($p<0.001$) for *C. plumeri* ILRI-191 and lowest for *C. pubescens* ILRI-233 with the remaining accessions (*C. pubescens ILRI-12297, C. pubescens ILRI-243* and *C. virginianum ILRI-14541*) having intermediate values between the two.

4.3.2 Herbage nutritive value

Mean values for the chemical composition of the five Centrosema accessions are presented in Table 11. The accessions did not significantly vary in their chemical composition ($P>0.05$). The overall DM and ash contents were 93.34% and 8.21%, respectively, and the CP content ranged from 18.86% (*C. pubescens* ILRI-243) to 22.37% (*C. virginianum* ILRI-14541), with an overall mean of 21.02%. The NDF, ADF and ADL contents were 49.98%, 35.71% and 9.42%, respectively.

Table 10. Herbage DMY and CPY of the Centrosema accessions

Factors considered	Factor description	DMY(t ha^{-1})	CPY(t ha^{-1})
Year	Year 1	2.24±0.36[b]	0.47±1.29[b]
	Year 2	10.84±0.36[a]	2.30±1.29[a]
Accessions	*C. pubescens* ILRI-12297	5.64±0.56[ab]	1.25±0.27[bc]
	C. pubescens ILRI-243	7.35±0.56[a]	1.46±0.27[ab]
	C. pubescens ILRI-233	5.26±0.56[b]	0.99±0.27[c]
	C. plumeri ILRI-191	7.35±0.56[a]	1.67±0.27[a]
	C. virginianum ILRI-14541	7.10±0.56[a]	1.57±0.27[ab]

Note: Year and accession means in the column with no superscript letter in common for DMY and CPY are not significantly different (P>0. 05)

Table 11. Chemical composition of the five Centrosema accessions

	DM (%)	Ash	CP	NDF	ADF	ADL
		% DM				
C. pubescens ILRI-12297	93.98	8.96	22.14	47.36	33.58	9.16
C. pubescens ILRI-243	93.19	8.42	18.86	51.35	39.91	11.07
C. pubescens ILRI-233	92.34	8.35	19.86	53.13	36.32	8.79

C. plumieri ILRI-191	93.63	7.27	21.88	46.79	32.65	6.90
C. virginianum ILRI-14541	93.54	8.07	22.37	51.25	36.09	11.20
Mean	93.34	8.21	21.02	49.98	35.71	9.42
SE	0.64	0.74	2.33	3.35	3.34	1.13
P level	NS	NS	NS	NS	NS	NS

Note: DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; NS, non significant; SE, standard error

Table 12 presents the IVOMD, RFV and ME values of the Centrosema accessions evaluated. The overall mean IVOMD was 43.9% with values ranging from 38.6% (*C. pubescens* ILRI-233) to 50.7% (*C. plumeri* ILRI-191). Similarly, the overall mean for RFV was 115.03 with values ranging from 106.16 (*C. pubescens* ILRI-243) to 126.16 (*C. plumieri* ILRI-191). The ME content ranged from 5.79 for *C. pubescens* ILRI-233 to 7.61 for *C. plumieri* ILRI-191, with an overall mean of 6.58.

Table 12. IVOMD, RFV and ME values of Centrosema accessions

Accessions	IVOMD (% DM)	RFV[#]	ME (MJ kg^{-1} DM)
*C. pubescen*s ILRI-12297	44.14	123.80	6.62
C. pubescens ILRI-243	42.64	106.16	6.39
C. pubescens ILRI-233	38.62	108.89	5.79
C. plumieri ILRI-191	50.69	126.16	7.61

C. virginianum ILRI-14541	43.31	110.15	6.49
Mean	43.88	115.03	6.58
SE	2.38	10.71	0.36
P level	NS	NS	NS

Note: IVOMD, *in vitro* organic matter digestibility; RFV, relative feed value; ME, metabolizable energy; NS, non significant; SE, standard error of the mean; #RFV has no unit

4.4 Nutritional Quality of Browse and Herbaceous Legumes Adapted to Bako Area and that of "*Noug*" Cake, Cereal Straws and Native Hay Samples

Descriptive statistics (mean, standard deviation, and coefficient of variation) for the chemical composition of the feed samples evaluated in this experiment are presented in Table 13. The mean DM content of the samples was 93%, with values ranging from 90% for native grass hay to 96% for *S. guianensis.* Variation in DM content among the feeds was not wide, with values tightly clustered around the mean (SD = 1.81; CV = 1.9%). The mean ash content was around 7% with values ranging from 3% for *C. callothyrsus* to 11% for wheat straw. The mean CP content was 20% having a wider range of values (SD=9.4; CV = 46.8) ranging from 3% for wheat straw to 34% for "*noug*" cake.

The mean NDF content was 62%, with values widely scattered around the mean (SD = 13.6; CV = 21.9%). The value for NDF was lowest for "*noug*" cake (29%) collected from oil processing mills in Bako town (*Noug* cake 2) and highest for wheat straw (80%). A pattern comparable to that of NDF was also observed for ADF, with minimum (4%) and maximum (16%) values being for "*noug*" cake and wheat straw, respectively. The overall mean for hemicellulose (HC) and cellulose contents were 20 and 32%, respectively. The

"*noug*" cake sample collected from oil processing mills in Bako had lower HC (6%) and cellulose (13%) contents, while higher HC (30%) and cellulose (44%) contents were observed for *L. purpureus* and wheat straw, respectively.

A summary statistics for IVOMD, ME and RFV index is given in Table 14. The IVOMD ranged from 38% for wheat straw to 69% for each of *S. sesban* and *L. pallida,* with a mean of 63%. The ME content (MJ kg^{-1} DM) ranged from around 4 for wheat straw to 10 for *C. callothyrsus* with an overall mean of 8.7. Wide variation among the feeds was observed for RFV index (SD = 43; CV = 46%), the lowest value recorded for wheat straw (53.5) and highest value for "*noug*" cake that was collected from oil extraction mills in Bako town (226.5). The results generally revealed that straws and native grass hays that are dominantly used in the feeding system of dairy cows in Bako area were lower in quality than the "*noug*" cake and the legume species samples, containing high levels of detergent fibres and low levels CP, IVOMD, ME and RFV.

Table 13. Chemical composition of the leguminous species and selected local feeds

Feed type	DM (%)	Ash	CP	NDF	ADF	ADL	HC	Cellu.
		% DM						
C. callothyrsus	91.6	2.6	22.8	64.2	47.5	12.2	13.9	21.9
L. pallida	91.4	6.2	23.7	64.5	39.5	12.6	16.7	35.2
C. cajan	90.7	5.1	24.2	60.3	35.6	12.4	25.1	26.8
G. sepium	92.3	4.4	25.2	64.1	48.2	12.3	24.7	23.2

L. diversifolia	94.7	8.9	19.6	62.1	42.5	8.9	15.9	35.9
L. leucocephala	95.6	6.6	20.9	63.9	45.7	6.1	19.6	33.6
S. sesban	95.3	6.3	25.3	46.8	32.9	11.1	18.2	39.7
L. Purpureus	94.7	3.8	25.1	77.4	47.3	16.3	30.1	31.0
S. guianensis	95.9	5.3	23.7	71.5	40.3	14.1	31.2	26.2
D. unicenatum	94.2	5.8	24.6	60.3	41.2	6.6	19.1	34.6
D. intortum	95.0	3.8	22.9	64.9	40.6	4.2	24.3	36.5
"*Noug*" cake1	92.2	9.2	29.1	36.9	28.8	10.6	8.2	18.2
"*Noug*" cake 2	94.1	6.5	34.0	29.1	23.1	9.9	6.1	13.2
"*Tef*" straw	92.9	8.9	3.9	75.1	50.4	8.9	24.7	41.4
Wheat straw	91.5	11.1	2.8	80.3	54.8	10.5	25.5	44.3
Native Hay1	93.7	9.5	5.2	55.7	39.7	5.4	15.9	34.3
Native Hay2	90.2	10.1	6.4	72.1	50.3	6.5	21.7	43.8
Mean	93.3	6.7	19.9	61.7	41.7	9.9	20.1	31.8
SD	1.8	2.5	9.4	13.6	8.2	3.4	6.9	8.9
CV (%)	1.9	37.0	46.8	21.9	19.7	33.8	34.6	28.2

Note: DM, dry matter; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; HC, hemicellulose; Cellu., cellulose; SD, standard deviation; CV, coefficient of variation;

Table 14. IVOMD, ME and RFV of the leguminous species and local feeds

Feed type	IVOMD (% DM)	ME (MJ kg-^{1} DM)	RFV[#]
C. callothyrsus	69.1	9.74	83.8
L. pallida	69.3	9.8	94.3
C. cajan	68.9	9.7	74.4
G. sepium	67.5	9.5	83.6
L. diversifolia	62.6	8.6	77.5
L. leucocephala	67.6	9.5	125.7
S. sesban	69.3	9.8	75.2
L. purpureus	68.7	9.7	62.5
S. guianensis	68.6	9.7	74.7
D. unicenatum	65.5	9.1	87.6
D. intortum	64.9	9.1	81.9
"*Noug*" cake1	61.1	8.4	167.1
"*Noug*" cake2	52.1	6.9	226.5
"*Tef*" straw	51.3	6.7	61.4
wheat straw	38.3	4.5	53.5
Native Hay 1	59.3	8.1	96.8
Native Hay2	61.5	8.5	64.1

Mean	62.7	8.7	93.6
SD	8.5	1.4	43.5
CV (%)	13.5	16.6	46.5

Note: IVOMD, *in vitro* organic matter digestibility; ME, metabolizable energy; RFV, relative feed value; SD, standard deviation; CV (%), coefficient of variation; #RFV has no unit;

Results from the group-wise analysis of variance for the chemical composition and nutritive values of the five feed groups are presented in Table 15. No significant difference was observed among the five feed groups for DM and ADL contents (P>0.05). The ash content was lower for the herbaceous legume samples than the cereal straws (p<0.001) with the other groups having intermediate values between the two.

Table 15. Chemical composition and nutritive value of the five feed groups

Component	Cereal straws	Native hay	"Noug" cake	Herbaceous legumes	Browse legumes	Significance
DM%	92.2±1.2	92.0±1.2	93.1±1.2	94.9±0.9	93.1±0.7	NS
% DM						
ASH	10.0±1.2^{a}	9.8±1.2^{ab}	7.8±1.2^{b}	4.7±0.8^{b}	5.7±0.6^{b}	***
CP	3.4±1.4^{c}	5.8±1.4^{c}	31.6±1.4^{a}	24.1±0.9^{b}	23.1±0.7^{b}	***
NDF	77.7±4.9^{a}	63.9±4.9^{ab}	33.1±4.9^{c}	68.5±3.5^{ab}	60.9±2.7^{b}	***

ADF	52.6±3.7[a]	45.0±3.7[b]	26.0±3.7[c]	42.4±2.6[b]	41.7±1.9[b]	***
ADL	9.7±2.4	6.0±2.4	10.3±2.4	10.3±1.7	10.8±1.3	NS
HC	25.1±3.1[a]	18.9±3.1[a]	7.11±3.1b	26.16±2.2[a]	19.2±1.6[a]	***
Cellulose	42.9±4.1[a]	39.1±4.1[a]	15.69±4.1c	32.1±2.9[ab]	30.9±2.2[b]	***
IVOMD	44.8±2.7[c]	60.4±2.7[b]	56.6±2.7[b]	67.0±1.9[a]	67.8±1.4[a]	***
ME	6.72±0.4[c]	9.07±0.4[ad]	8.49±0.4[b]	10.04±0.29[a]	10.16±0.2[a]	***
RFV	57.5±13.9[b]	80.5±13.9[b]	196.8±13.9[a]	76.7±9.8[b]	87.8±7.4[b]	***

Note: Means within row having superscript letters in common are not significantly different; NS, Not significant; ***, p<0.001%; DM, dry matter; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; HC, hemicellulose; IVOMD, *in vitro* organic matter digestibility; ME, metabolizable energy; RFV, relative feed value

The CP content was highest for the "*noug*" cake samples (32%) followed by the herbaceous (24%) and browses (23%) legumes, and was least for the cereal straws (3%). The NDF content was higher for the cereal straws (78%) than the "*noug*" cake samples (33%) with the other feed groups having intermediate values between the two. Similarly, the ADF content was higher for cereal straws (53%) than "*noug*" cake. The IVOMD content was highest for the browse legumes (68%) followed by the herbaceous legumes (67%), and was least for the cereal straws (45%) and a consistently similar trend with the IVOMD was also observed for the ME values. The RFV was higher for "*noug*" cake than for cereal straws (58) with the other feed classes having intermediate values between the two.

4.5 Feed and Dairy Value Chain Mapping

4.5.1 Characteristics of surveyed farm households

Data on general characteristics of the households surveyed in this activity are presented in Table 16. The majority of farm households surveyed were male headed, with the overall mean being close to 90%. The mean age of household heads was 48 and 46 years at Nekemte and Bako, respectively. The mean family size was similar across the two sites, being around 7 persons. The larger proportion of the household heads were educated, with 50% of them falling in 7-12 grades range, around 23% of them being diploma holders and 10% of them having BA/BSc degree and above. Regarding the career history of the respondents, 13% at Nekemte and 4% at Bako were retired government employees, while 13% of the respondents at Nekemte and 8% at Bako were active government employees. Around 17% of the respondents at Nekemte reported to largely rely on dairying for their livelihood, whereas a respective 29% and 75% of the respondents at Nekemte and Bako reported to be involved in both crop and livestock production activities. The proportion of respondents involved in trade was 29% at Nekemte and 13% at Bako.

Table 16. Characteristics of the surveyed peri-urban dairy farm households

Variable		Nekemte	Bako	Overall
	Male	91.67	88.00	89.79
Household head[Ψ]	Female	8.33	12.00	10.21
Age of household head	Years	48.29	46.17	47.23

Family size	No. of persons	7.42	7.25	7.33
	Read and write	0.00	8.33	4.16
	1-6 grade	8.33	16.67	12.50
	7-12 grade	33.33	66.67	50.00
	Diploma	41.67	4.17	22.92
Education[Ψ]	≥ BA/BSc	16.67	4.17	10.42
Career history[Ψ]	Retired employee	12.5	4.17	8.33
	Gov. employee	12.5	8.33	10.41
	Mainly dairying	16.67	0.00	8.33
	Dairy and crop	29.17	75.00	52.08
	Trader	29.17	12.5	20.83

Note: [Ψ] % of respondents; Bako n=24; Nekemte n= 24

4.5.2 Fluid milk value chain mapping

A generic schematic diagram depicting the map of fluid milk value chain in Nekemte and Bako peri-urban areas is depicted in Figure 4. At both sites, the main value chain segments identified include input supply, production, marketing (distribution), processing and consumption.

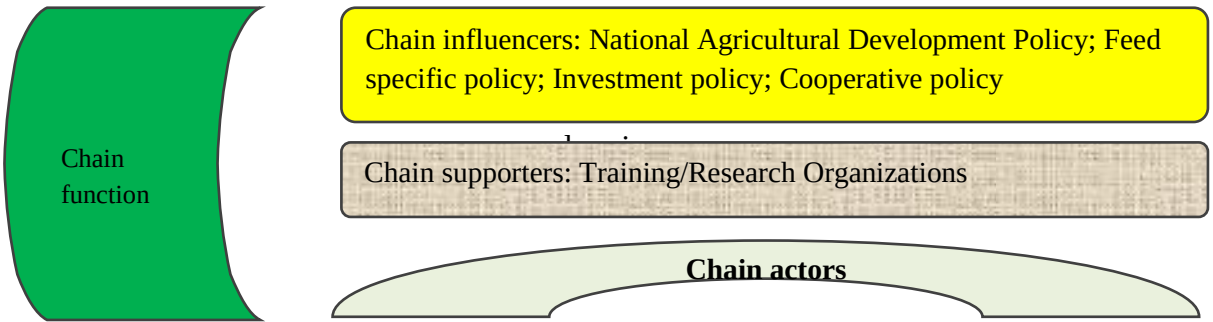


Figure 4. A schematic diagram depicting the fluid milk value chain in Bako and Nekemte peri-urban areas

Source: Author’s illustration based on information gathered from the field study

The key actors along the chain include input suppliers, producers, (traditional) processors and consumers. Under the input supply segment, inputs like feed, heifers and breeding, and animal health services, land and labour, and housing inputs were found to be important. Under milk production segment, prevailing production sub-systems, dairy cow ownership pattern and milk production performance of cows were appraised. Market outlet options for fluid milk, and aspects of milk processing and consumption were also considered.

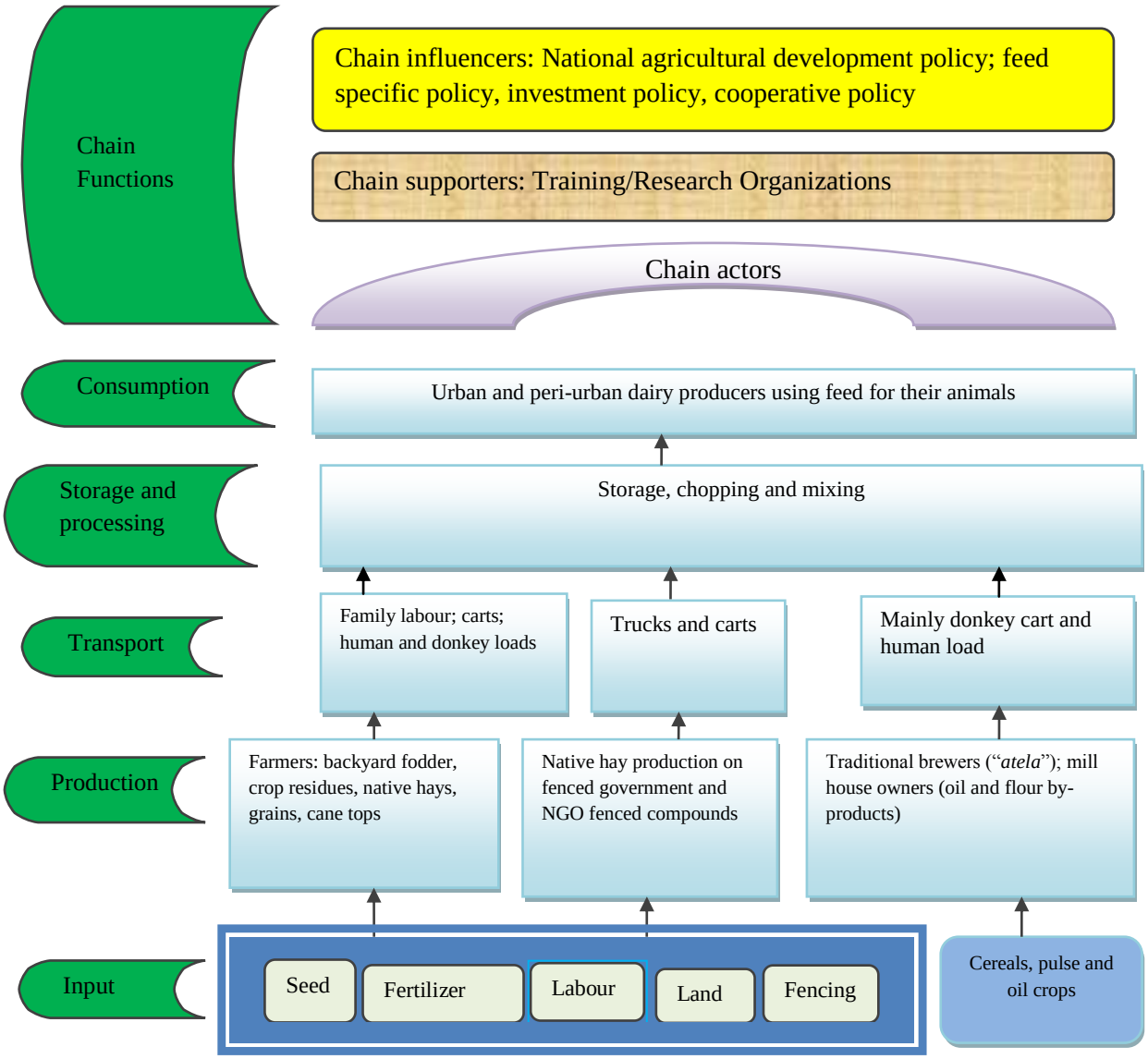


Figure 5. Peri-urban dairy feed supply chains in the two peri-urban sites

Source: Author's illustration based on information gathered from the field study

4.5.3 Input supply

4.5.3.1 Dairy feed and its supply chain

In both peri-urban sites, dairy cattle feeds were observed to be sourced in two ways (Figure 5). These were: through purchases (for oil seed cakes, pulse grain hulls, mill house scraps and native grass hays); and through on-farm production (for improved forage species and crop residues).

Grass hays were observed to be supplied by native hay producing farmers in nearby rural sub-districts, and by opportunistic hay producers (individuals and organizations that grow natural pastures on fenced plots for sale to peri-urban dairy producers). Small scale oil and flour processing mills also supply ingredients like oil seed cakes, pulse grain hulls and mill house wastes. The hulls are mainly sourced from pulse grain processing, mainly faba bean, field pea, chick pea and lentil. The frequency of farms using various feeds acquired through purchase in Nekemte and Bako area is depicted in Figure 6.

"Noug" cake (92%), pulse grain hulls and mill house scraps (58%), cereal straws (50%), "*atela"* (46%) and local grass hays (42%) were indicated to be the commonly used purchased feeds ingredients on farms in Nekemte area. The use of wheat bran, baled hay, and mineral supplements other than common salt and feed grains was negligible, and these are mainly used on relatively big farms with better resource endowments to acquire the ingredients from Addis Ababa area. Maize and soya bean grains primarily obtained from private commercial farms operating in Nekemte area were observed to be used by 4% of the farms. Entirely all visited farms indicated to use common salt as a mineral supplement.

At Bako, "*noug*" cake (88%), sugar cane tops (75%) and '*atela*' (54%) were the widely purchased feeds. Green grass fodders sold at open market points (29%), native grass hay (21%) and cereal straws (21%) were also indicated to be important in this location. Maize grain was reported to be used on 13% of the farms where as 4% of the respondents indicated to use linseed cake, indeed purchased from Ambo area, and 4% of the respondents indicated not to use any purchased feed on their farm.

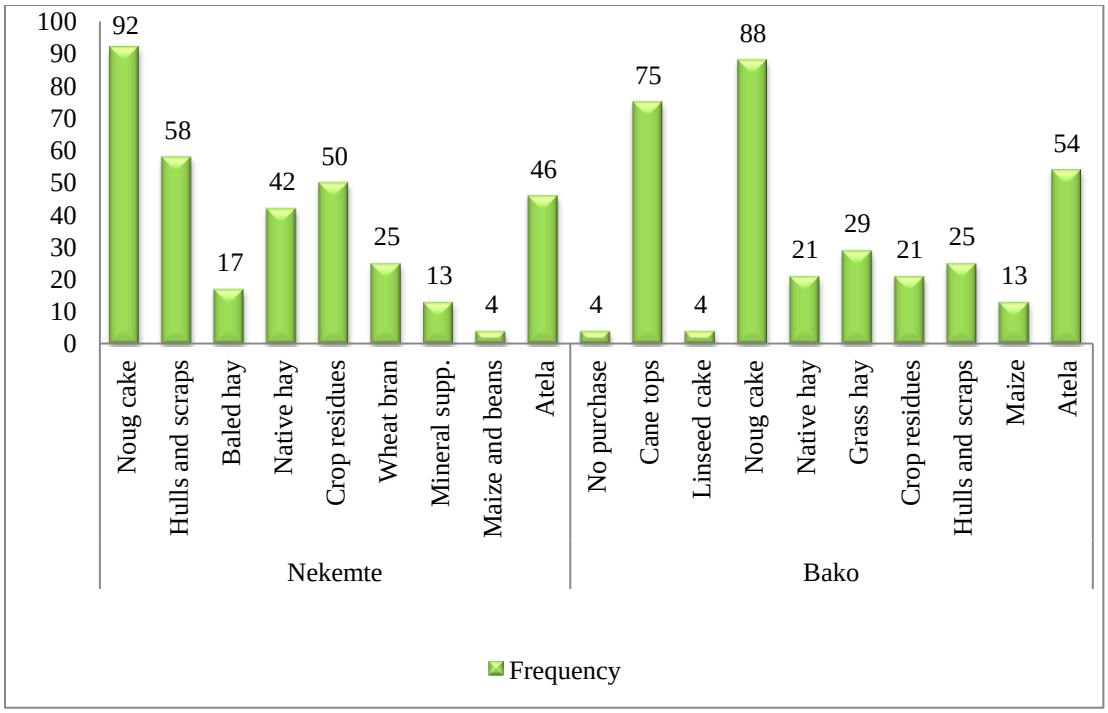


Figure 6. Frequency of farms using various purchased feed ingredients across the visited farms in Nekemte and Bako peri-urban areas

Source: Author's illustration based on field data

Improved forage species were also important as an element of the peri-urban dairy development package at both sites. Some attributes of improved forage production related activities are presented in Table 17. Accordingly, a respective of 58% and 67% of the farmers in Nekemte and Bako claimed to practice improved fodder production on-farm.

Their biomass contribution, however, was generally viewed to be negligible. Discussions held with key informants showed that though considerable commitment for growing improved forage production is expressed by farmers at the time of receiving the feed and breed packages, a tendency of gradually backsliding from improved forage production is widespread. In Nekemte, out of farmers practicing on farm feed production, 28.6% and 71.43% were involved in native grass hay and improved forage production, respectively,

with a respective land area under native grass hay and improved forages being 0.68 and 0.43 hectares.

Similarly, 6% of the farmers at Bako reported to produce hay on an average area of 0.25 hectares, while around 93.8% indicated to own land allocated to improved forages amounting to 0.4 hectares. At both sites, forage planting materials were reported to be obtained from BARC and district livestock extension service providers. Improved forage species commonly planted were Rhodes, elephant grass and Sesbania and Leucaena spp. Lack of irrigation water, prevailing free grazing tradition, and sesbania leaf beetle, intensive management requirements of improved forages and labour shortage were mentioned to be the main constraints.

Table 17. Aspects of on-farm improved fodder production by peri-urban dairy farmers (n=24 in each site)

Issue	Response	Nekemte	Bako
Do you practice on farm fodder production? (% of all farmers interviewed in each site)	%Yes	58.33	66.67
	%No	41.67	33.33
What type of fodder? (% of producers who practice on farm fodder production)	Native hay	28.57	6.25
	Improved fodder species	71.43	93.75
Area of land allocated (ha) forage production	Private native hay land	0.68	0.25
	Improved forage species	0.43	0.44

All respondents (100%) in both sites indicated that feed shortage is a critical issue. Lack of land, improved seed, low technical knowledge on forage husbandry and shortage and high price of concentrates were indicated to be the major constraints. Although demand for concentrates is rising, no actor was found to be involved in production or retailing of these feeds in both sites. Some producers were observed to use partial grazing on nearby

open grazing areas and these indicated the following problems to be critical: high termite and weed infestation, advance of urban area in to the urban-rural fringe and massive construction works (residential quarters, stores, teaching and health organizations), among others.

4.5.3.2 Supply of heifers and other breeding inputs

Bako Agricultural Research Center was reported to have been the main actor involved in the supply of crossbred heifers in both sites. But it currently lacks the capacity to engage in this activity due to resource and herd health problems. Regarding the latter problem, it was observed that the on-station breeding stock maintained for heifer multiplication was threatened by an outbreak of Contagious Bovine Pleuro-pneumonia, which resulted in the interruption of heifer production activities. The number of dairy heifers distributed since 2000 by the center is presented in Figure 7. It was indicated that at least 109 crossbred heifers were distributed to seven selected urban/semi-urban sites since the year 2000. The relatively big and some smallholder peri-urban farms indicated to acquire heifers from local sources such as farmers owning crossbred animals, and from other distant potential areas like Addis Ababa and Debre Zeit.

Regarding the supply of AI services, semen for artificial insemination was reported to be obtained from the National Artificial Insemination Center located in Addis Ababa. Work for establishing new zonal semen production center in Nekemte is currently underway through financial support of the Agricultural Growth Program (AGP) of the Federal Ministry of Agriculture (MOA). Liquid N production and semen freezing for distribution to various districts is carried out by Nekemte Liquid Nitrogen Production and Distribution Center (Figure 8). However, the majority of dairy farmers in both sites were observed to incline more to the use of natural mating compared to AI which indeed is induced by the widespread inefficiencies of the latter system.

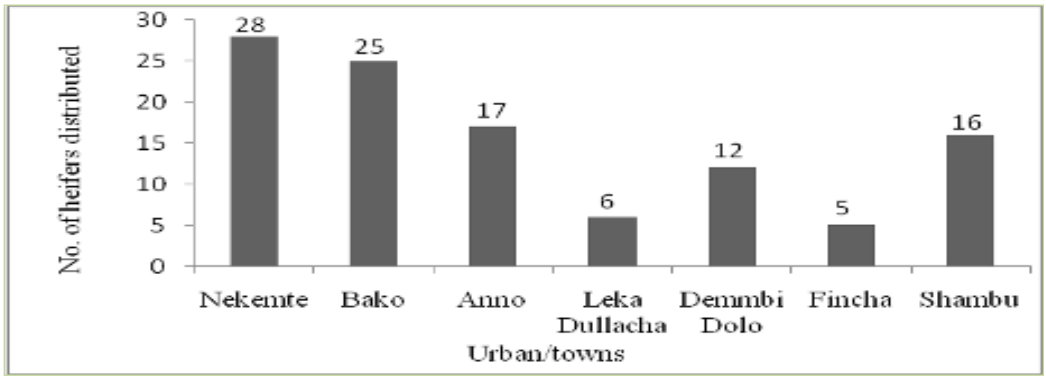


Figure 7. Number of in-calf heifers distributed to urban/rural towns by BARC
Source: Author's illustration based on data gathered from BARC

3.5.3.3 Supply of veterinary services

Discussions with key informants from district veterinary clinics at both locations revealed the following dairy cattle diseases to be critical, among others: mastitis, chronic bovine pleuro-pneumonia (mainly in Bako area), and internal and external parasites. Reproductive health problems like repeat breeding and abortion were also indicated to be common. Information collated from the district trade offices revealed the existence of a respective, seven and three veterinary drug vendors operating at Nekemte and Bako, with their scope limited to drug vending. Normally veterinary services were observed to be provided by the public veterinary service providers though these services were rated inadequate in terms of financial, material and knowledge capabilities.

Figure 8. Liquid N production and semen freezing facilities in Nekemte area

4.5.3.4 Land

Land is the other important input in peri-urban milk production at both study sites. The study showed that a respective 33% and 21% of farmers at Nekemte and Bako do not own a separate land allocated for dairying, and hence keep their animals in residential compounds. A respective of 71% and 94% of farmers at Nekemte and Bako were observed to have a piece of land for growing improved forages. Similarly, a respective of 25% and 75% of the farmers at Nekemte and Bako were observed to be engaged in crop-livestock mixed farming, and thus own land for both operations (Figure 9). At each site, rented-in land for native hay production was owned by 4% of the respondents. Similarly, a respective of 29% and 6% of the farmers at Nekemte and Bako, have reported to own a piece of privately owned land allocated for local grass hay production. For producers residing in the areas closer to the urban centers, urban land use for dairying has become an exceedingly contested issue, and as a result they are facing pressure from the neighborhood and local authorities to shut off their farms on account of human and environmental health concerns.

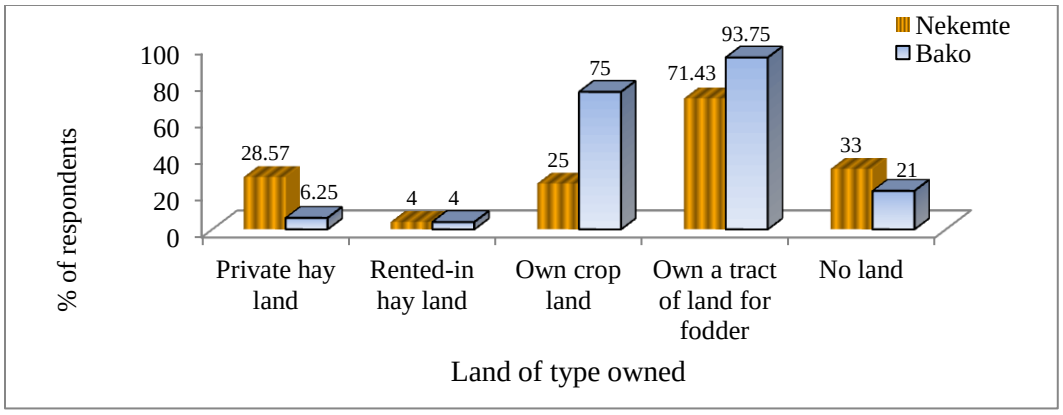


Figure 9. Land ownership by the type of land in Nekemte and Bako area

Source: Author's illustration based field data

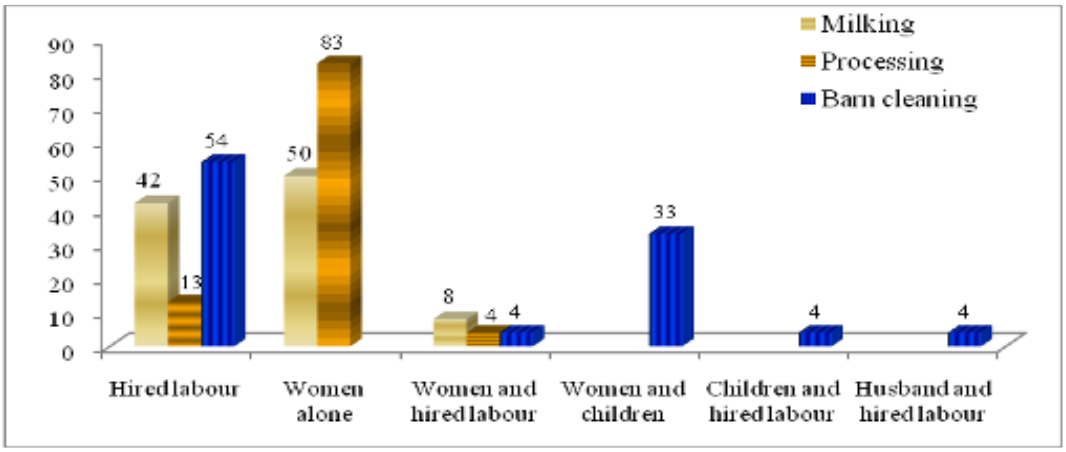


Figure 10. Source of labour for main dairying activities in Nekemte

Source: Author's illustration based on field data

4.5.3.5 Labour

Labour is also one of the key inputs in peri-urban dairying operations. Figure 10 depicts the different sources of labour for the various dairying activities at Nekemte. Milking was observed to be primarily done by women (50%), followed by hired labour (42%), and women and children (33%). Similarly, milk processing was observed to largely be the activity of women (83%), followed by hired labour (13%). Dairy barn cleaning is mainly carried out by hired labour (54%), followed by women and children (33%).

The sources of labour for major dairy activities in Bako area are given in Figure 11. It was indicated by 88% of the respondents that milking is done by women, followed by hired labour (12%). Similarly, milk processing was reported to be practiced mainly by women (92%) and hired labour (8%). Considerable labour contribution for barn cleaning was reported to come from children (42%), followed by hired labour (17%) and women and children (17%). Further, 12% of the respondents indicated that both women and children are involved in barn cleaning, while 12% reported cleaning to largely be undertaken by women alone.

4.5.4 Milk production

Peri-urban dairy farming households are the main operators at this stage of the value chain. Based on the number of animals and status of farmstead structures and facilities available, the farms were classified into two subsystems: small-scale and medium sized peri-urban dairy farms. Both subsystems are available in Nekemte area, but the former

predominates in Bako. About 12% of the farms visited in Nekemte are medium-sized farms, while about 88% are small-scale ones.

Table 18 shows the pattern of cow ownership and daily milk yield of the cattle genotypes under Nekemte and Bako peri-urban conditions. Accordingly, the mean number of local dairy cows owned/household was high at Bako (1.83 ± 1.71) compared to Nekemte (0.83 ± 1.46). Conversely, the number of crossbred cattle per household was 2.67 ± 1.88 for Bako and 7.29 ± 8.12 for Nekemte. Pooled over the two breeds, the mean number of cows owned per household was high at Nekemte (4.06 ± 4.07). Daily milk yield was comparable at both sites for the local breeds, while for crossbred cattle yield values for Nekemte (9.79±2.04) exceeds that of Bako (6.54 ± 2.32).In the same way, overall milk yield animal^{-1} day^{-1} was observed to be higher at Nekemte (5.78 ± 5.6).

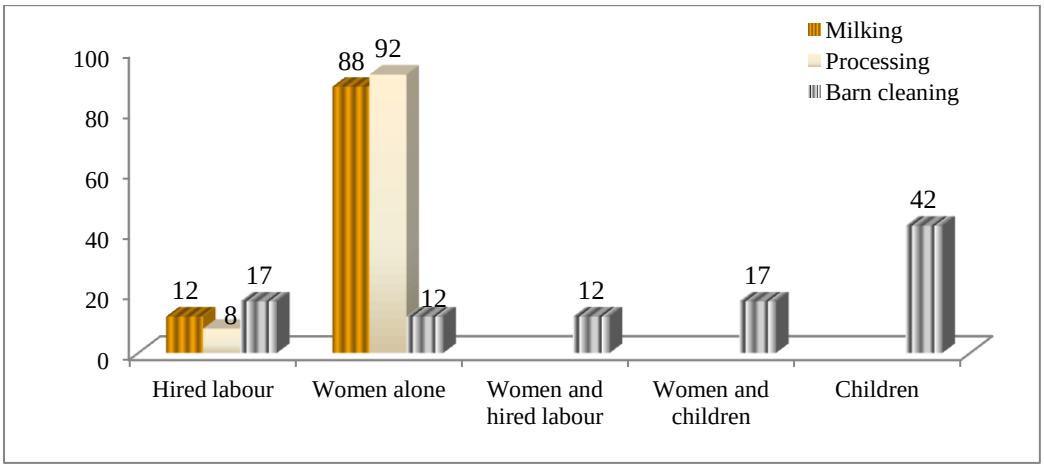


Figure 11. Source of labour for main dairying activities in Bako area

Source: Author's illustration based on field data

Table 18. Mean number of dairy cows per household by breed type and their daily milk yield

Variable	Site	Breed		Overall
		Local	Cross	
Number of cows owned household^{-1}(mean ± SD)	Bako	1.83 ± 1.71	2.67 ± 1.88	2.25 ± 0.59
	Nekemte	0.83 ± 1.46	7.29 ± 8.12	4.06 ± 4.57
Milk yield in litres day^{-1} cow^{-1} (mean ± SD)	Bako	1.42 ± 1.17	6.54 ± 2.32	3.98 ± 3.62
	Nekemte	1.78 ± 0.44	9.79 ± 2.04	5.78 ± 5.66

Note: SD, standard deviation

4.5.5 Marketing (distribution)

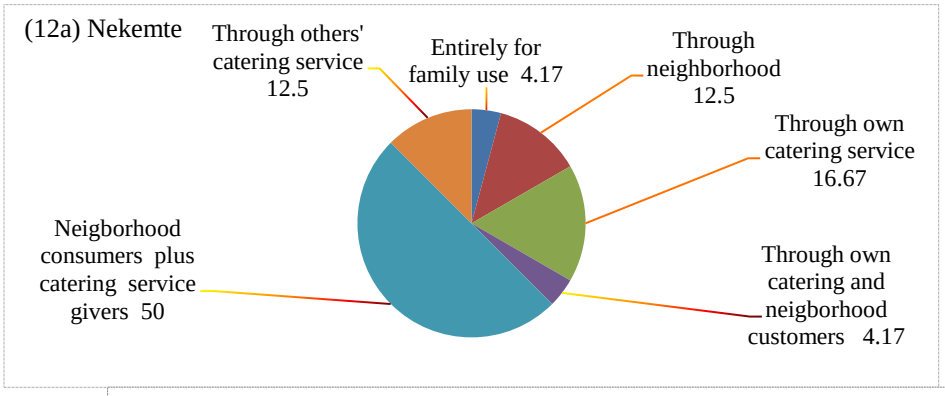
Fluid milk and processed milk products obtained from traditional processing are the main items traded in both sites. At Nekemte, milk is primarily produced for market purpose, and the larger share is channeled through informal market outlets (Figure 12a). All respondents at Nekemte indicated that only a little fraction of milk produced is retained for family consumption. Only about 4% of the respondents have reported to allocate the entire milk produced for household use (Figure 12a), while about 13% have indicated to channel their milk to consumers in the neighborhood. A practice of vertical integration is also evolving in that 17% of the respondents have indicated to channel their milk through own catering service outlets like cafeterias, restaurants or hotels.

Around 4% of the interviewed households reported that they channel their milk through own catering and neighborhood customers, while 50% indicated to channel through neighborhood and other customers involved in provision of catering services. At Bako, 29% of the respondents reported to use the entire milk produced for family consumption, while the majority sale to cafeterias, restaurants or hotels (46%). Milk sale to neighborhood customers, and neighborhood plus catering service providers, altogether contributes to 25% at Bako (Figure 12b). It was evident that pooled across the sites, the larger proportion of the respondents (67%) channel their milk to neighborhood and

catering service providers, followed by 33%, who reported to produce milk for home consumption only. Milk price was observed to not vary widely within each site; price per litre was reported to be 15 Ethiopian Birr at Nekemte and 12 Ethiopian Birr at Bako by entirely all the respondents interviewed.

4.5.6 Processing

The survey showed that no formal milk collection and processing activities exist in both study locations. Milk processing here thus refers to the act of traditionally converting milk into milk products at home or by catering service providers to derive other milk products. Accordingly, milk is processed into regularly consumed products like plain hot milk, a mix of coffee and milk (*macchiato*), fermented whole milk, butter, traditional ghee, buttermilk and cottage cheese. Dairy farmers and catering service providers are the main actors who process milk into these milk derivatives. At household level, milk processing activities are carried out using traditional processing methods and inputs.



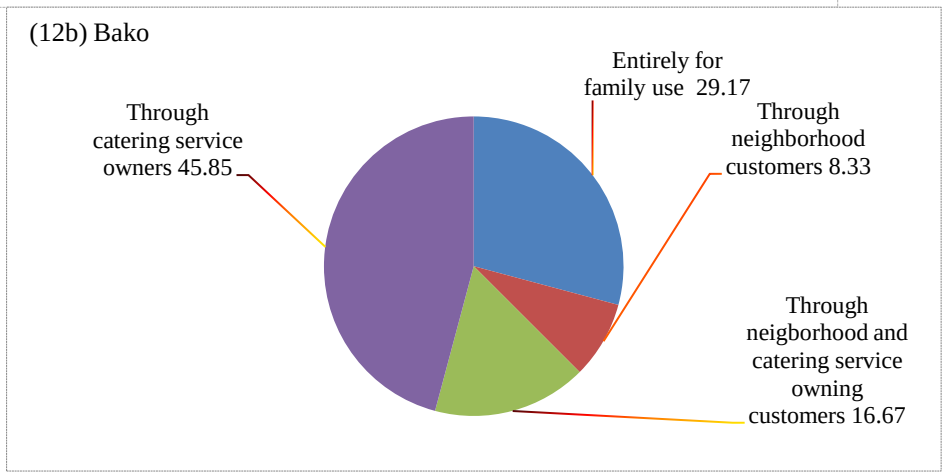


Figure 12. Milk sale outlets in Nekemte (12a) and Bako (12b) peri-urban areas

Source: Author's illustration based on field data

4.5.7 Consumption

At the study sites, milk and milk products are consumed by family members, and urban and itinerant consumers. At household level, children are prioritized in consumption allocation followed by household head and infirm members of the family. Since butter, butter milk and cottage cheese are served with other food items; they are not prioritized among household members. At Nekemte, clarified butter (traditional ghee), buttermilk and cheese are normally seasoned with different traditional spices, and are served with pancake (*injera*), round thick bread locally called '*chumbo*', and a traditional food called '*anchote*'.

4.6 Characterization of Feed and Dairy Innovation Systems

4.6.1 Actors and their functions

Diverse actors engaged in peri-urban dairy development were identified and these are mapped in Figure 13. In line with Hall (2006), the actors were categorized into five domains: (1) Enterprise domain – actors using codified knowledge and generating largely tacit knowledge; (2) Research domain – actors generating codified knowledge; (3) Intermediary domain – actors playing an intermediary (knowledge brokering) roles; (4) Demand domain – actors consuming feed and peri-urban dairy products and services; and (5) Policy domain – actors involved in the formulation of policies related to feed and peri-urban dairy value chain development. A concise account of the functions of the actors is in order.

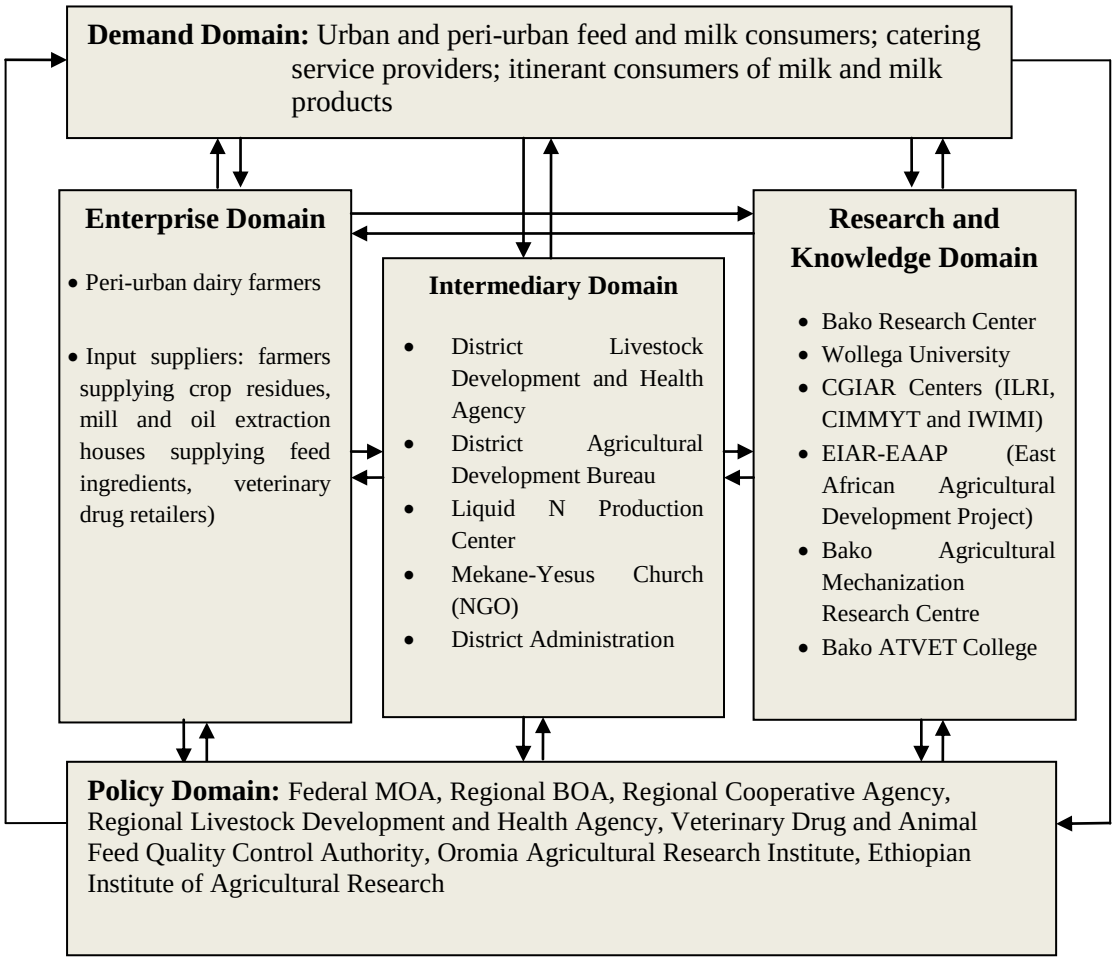


Figure 13. Schematic diagram depicting the structural elements of the diagnosed innovation system

Source: Author's illustration based on field information

4.6.1.1 Enterprise domain

The actors in this domain were: peri-urban dairy producers, crop and livestock mixed farmers and private actors involved in the supply of feed and veterinary drugs. The peri-urban dairy farmers are involved in milk production and channel it to consumers (neighborhood customers and catering service providers in the urban centers). Farmers in

the nearby rural sub-districts are involved in the supply of crop residues. Urban and peri-urban dairy farmers were observed to have less access to commercially compounded concentrate feeds and rely more on locally obtainable energy and protein ingredients such as hulls of faba bean, field pea, lentil and chick pea, and oil seed cakes and mill house scraps. Private veterinary drug vendors in both sites were engaged in veterinary drug supply activities.

4.6.1.2 Research domain

Regional, national and international research actors operating in the two sites and their functions are presented in Table 19. The BARC is the key actor involved in feed and dairy research. The center has developed different technical options that can potentially be exploited in feed and peri-urban dairy development. It also generated information on milk handling and processing systems, and characterized the livestock production systems so that interventions would be better tailored. Non-technical issues, however, have historically received little attention. This study also revealed that such inclinations are still common though there were some evidences of progress through on-farm research attempts undertaken in collaboration with other international research and development organizations. The International Livestock Research Institute (ILRI), International Maize and Wheat Improvement Center (CIMMYT) and International Water Management Institute (IWMI) were also involved in on farm research activities but with more focus on rural smallholder production systems.

The Department of Animal Sciences of Wollega University has also some evolving research activities in feed resources, dairy and animal health. The Bako Agricultural Mechanization Research Centre is involved in the demand based production and distribution of milk processing and feed chopping equipments, though to a limited extent. The Bako ATVET College is mainly focusing on training of development agents in animal sciences with only limited forage germplasm maintenance works while ILRI is involved in forage germplasm supply and provision of technical support to researchers.

Table 19. Research actors and their functions

Research actors	Potential contributions made/could be made

BARC	Forage variety and dairy feeding system development; on-farm evaluation of forage options; seed/planting material production and distribution; on-farm testing of the productivity and profitability of dairy technologies.
Wollega University	Evolving research in the areas of feeds, breeding and health
Bako AMRC	Prototype development and multiplication of milk processing equipments
Bako ATVET College	Development agents training; maintenance of selected forage species; technical support to districts in the areas of forage development and AI service delivery
ILRI	Germplasm supply; capacity building for researchers; evaluation of on-farm feed options
CIMMYT	On-station evaluation and on-farm testing of maize and forage legume integrated options; capacity building for researchers in the feed sector
IWMI	Evaluation and promotion of water efficient and environment friendly forage options; capacity building for researchers
EAAP	On-farm testing of dairy feed options; financial support to regional forage development initiatives

Note: BARC, Bako Agricultural Research Center; ATVET, Agricultural Technical Vocational Education Training; ILRI, International Livestock Research Institute; CIMMYT, International Maize and Wheat Improvement Centre; IWMI, International water Management Institute; EAAP, East African Agricultural Productivity Project

The International Maize and Wheat Improvement Center is involved in on-station evaluation and on-farm testing of forage-maize systems. The International Water Management Institute was involved in activities linked with evaluation and promotion of water efficient and environment friendly fodder options. The East African Agricultural Productivity Project (EAAP), implemented by EIAR in collaboration with BARC was also involved in on-farm testing of forage options targeting dairy value chain improvement and provision of financial support for implementation of on-farm forage development initiatives but with focus on rural dairy systems.

Despite the existence of diverse research actors operating in the diagnosed peri-urban sites, their role in enhancing the progress of peri-urban feed and fluid milk innovation system is not noticeable at present. Strengthening the interaction between these actors is thus vital for facilitating innovation activities. Engaging research and development decision makers at national and regional levels in dialogues over priority national and regional research agenda in a particular production system was also indicated to be vital to improve synergy and proper targeting of technological interventions to be tested on farm.

4.6.1.3 Intermediary domain

A large number of intermediary actors existed in the sites with public actors being dominant. The District Livestock Development and Health Agency focuses on promotion of livestock development packages, among which feed, breeding and animal health services are the major ones, their main target being rural dairy system. These actors were thus condemned by peri-urban dairy farmers for their bias against them. The farmers have indicated to suffer from constraints such as lack of technical inputs (feed, health and breeding services), land (for construction of milk retailing shops, dairy farm expansion and fodder production), infrastructural problems such as electric power, road and water

supply (mainly for relatively big farms where feed processing facilities were observed not to fully function due to power shortage) and lack of facilitation in organizing peri-urban dairy producers into dairy cooperatives. At both peri-urban sites, there were no functional peri-urban dairy cooperatives at the time of data collection for the present work.

In general, failure to provide effective support to the peri-urban dairy producers, inefficient AI and health service delivery, and lack of tailor-made interventions at district level to the peri-urban dairy subsector were repeatedly indicated to be critical. It was apparent that lack of appropriate and realistic support schemes for the emerging peri-urban dairy subsector and limited awareness on new developments related to livelihood support activities and poor access to pertinent knowledge sources were noted to constrain the intermediary actors from lucratively delivering their services.

4.6.1.4 Demand domain

These consist of consumers of milk and milk products, and dairy feed ingredients. These include dairy farmers and urban and itinerant consumers. As outlined in previous section on feed and milk value chain component, fluid milk and milk derivatives are products consumed at both sites.

4.6.1.5 Policy domain

In the present setting, regional policies are formulated by the regional council. Budget for livestock research and development and overall political leadership to ensure effective implementation of regionally planned activities, in a manner aligned with national and regional priorities, is also provided by the same body. Bureaus of investment, and Trade

and Industry deal with investment permits, and license private service providers. Regional Bureaus of Finance and Economic Development regulate budget use by public organizations, and coordinate activities of NGOs. The Bureau of Health was observed to have no visible role in relation to dairy development currently, but its future involvement is expected to be crucial in addressing public health concerns related to intensive peri-urban dairy development. The overall regional policy guidance for district level feed and dairy development is provided by Regional Livestock Production and Health Agency.

At federal level, the Ethiopian Government has recently established independent executive body within the MOA led by State Ministry. This is a newly organized body nationally catering for livestock development and is organized into three directorates: (1) Animal Production and Feed Directorate, focusing on dissemination of inputs for livestock production and feed resources development; (2) Animal Health Directorate, focusing on health and quarantine service provision, and regulatory services; (3) Pastoralist Directorate, mandated for the pastoral areas, and dealing with animal health and production issues in the pastoral areas of the country. A new positive move also was the establishment of Animal Feed and Drug Administration and Control Authority, focusing on policy issues related to regulation of feed and drug quality and their production processes.

4.6.2 Interactive relationships of actors

The general patterns of interaction between the main actors in the feed and dairy technological innovation system diagnosed are illustrated in Figure 14. The linkage patterns observed include: two way strong interactions with comparable influence; two way interactions but weak and episodic in nature, and two way interactions with unequal influence.

In view of that, the interaction existing between the regular public extension service providers (District Bureau of Agriculture, District Livestock Development and Health Agency and Liquid N Production Center) on one hand and the District Administration office on the other was of two way type with the latter actor having more influence. It was also indicated that these linkages are more of communication on polices and regulatory issues related to livestock, crop and natural resource development. The function of this linkage as perceived by many informants was not more on learning and innovation except in cases where technical issues are discussed.

The linkages existing between NGOs and the District Administration office was indicated to be weak and intermittent. Likewise, NGOs were observed to have rare knowledge sharing links with public research centers. In Nekemte for example, Development and Social Services Commission of the Ethiopian Evangelical Church Mekane Eyesus was reported to have occasional linkages with BARC where the feed and nutrition, and dairy research staff of BARC participate in the training of development agents of the Commission. Linkages existing between the public extension service actors were judged to be of two way type and strong and to have a routine resource and knowledge sharing functions.

The interaction between BARC and District Administration was reported to be weak and episodic. The linkage between the BARC and the International Research Institutes were indicated to be of two directions and strong with resource and knowledge sharing functions. On the other hand, linkages existing between International Research Institutes and the district administration office were indicated to be weak and limited only to facilitation role of the latter in the organization of meetings of the local stakeholders working with the research institutes. The agricultural development projects (mainly AGP) was indicated to have a strong resource and knowledge sharing link with district extension service providers in the livestock and crop subsectors. The relationships existing between peri-urban dairy producers and district extension service providers were

also weak. It was argued that services rendered by the regular extension service providers are biased towards rural producers than the emerging market oriented peri-urban dairy subsector.

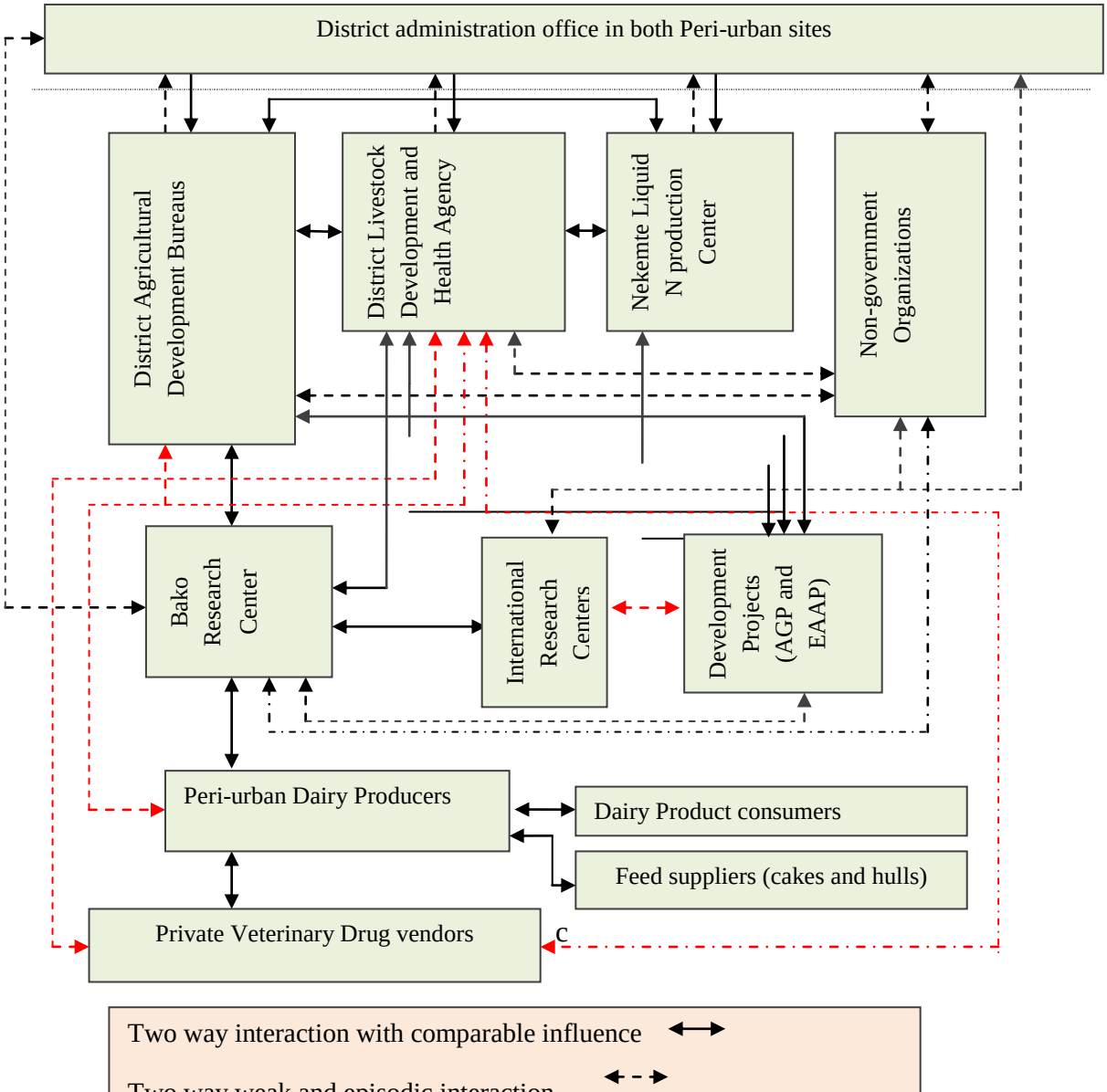


Figure 14. Interaction between key actors in the peri-urban feed and dairy innovation systems

Source: Author's illustration based on field information

On the other hand, there was strong linkage between peri-urban dairy producers and dairy product consumers and informal feed ingredient suppliers but with limited role for learning and innovation as they are more of input and output market links. The links between the emerging private service providers (specifically the veterinary drug vendors) and district development offices (mainly with livestock development and health) are limited to regulatory (policing) roles. In general, linkages existing between the actors in the diagnosed innovation system were observed to be weak and often episodic, and unfavorable for collective learning and innovation to take place. Hence there is a need to work towards changing attitudes and practices of actors so that lively and productive interactions creating opportunities for learning and innovation will arise.

4.6.3 Perceptions on the competencies of actors

Table 20 summarizes the strengths of key actors involved in the diagnosed feed and dairy innovation system based on the perceptions of the different informants interviewed. Generally, it was evident that there are considerable infrastructural, institutional and capability potential for the actors to complement each other for enhancing innovative activities provided that effective interaction and knowledge sharing practices take place.

4.6.4 Embedding systemic problems

The matrix of the key actors of the innovation system and systemic problem typologies faced by the actors, based on the information generated through the diagnostic assessment, is presented in Table 21. This joined actor-problem matrix gives an impression on the type of embedding problems affecting a particular actor type and facilitates the identification of coherent systemic instruments that help address the systemic problems pinpointed.

Table 20. Competencies of the various innovation system actors

Actor	Strengths
District Livestock Agency, and Bureau of Agriculture	Fairly educated staff; perceptible presence at grass roots level; political capital
Liquid N Production Center	Fairly educated staff; endowed with infrastructural capacity (required machineries available)

Bako Agricultural Research Center	Better competence to search technical solutions to the needs of emerging new sectors; substantial technical capability; better connected to diverse knowledge sources; emerging technology piloting activities on-farm
International Research Centers (ILRI, IWMI, CIMMYT)	Technical capability; connected to diverse sources of knowledge; organized knowledge management; innovation oriented operational cultures; well articulated innovation generating strategies; well organized forage diversity gene bank; better financial capability; better facilitation skills
Development Projects (AGP and EAAP)	Better financial capability; connected to diverse knowledge sources; interest to closely work with existing government structures
Non-government organizations	Better financial capability mainly for social sectors' development; growing participatory traditions; structural and financial flexibilities for enabling innovations
Private veterinary drug vendors	Fast response to customer needs compared to existing public veterinary actors
Peri-urban dairy farmers	Apparent enthusiasm to expand dairying business; tendency to innovate in the face of challenges; motivation of some to advance cooperative culture
Feed ingredient suppliers	Noticeable interest in feed related entrepreneurial activities
Consumers	Passionate to pay for milk and products; zealous about feeding milk to toddlers
District Administration	Passionate to see livelihood of the community improved; enthusiasm to respond to community development needs; political capital; potential to mobilize the community and non-public actors for development

Accordingly, six systemic problem typologies were observed to embed in the diagnosed feed and dairy innovation system: (1) Infrastructural problems (lack of physical and knowledge infrastructures); (2) Institutional problems (presence or absence of formal or informal institutions); (3) problems of weak interaction between actors; (4) Strong interaction problems (5) actor capability problems, and (6) 'missing actor' problems. A brief account of the systemic problems observed to embed in the system diagnosed is thus in order.

4.6.4.1 Infrastructural problems

Peri-urban dairy farms, mainly those which were relatively big, were observed to lack required infrastructures such as reliable electric power supply, unfavorable feeder roads for input and output transport and lack of reliable water supply system. The lack of feed and milk quality testing and veterinary diagnostic facilities were observed to be some of the knowledge infrastructural problems that actors with research and health related functions were observed to face. Bako Research Center, one of the research actors in the system, was indicated to lack knowledge infrastructures such as functional internet facilities, and laboratory facilities for animal nutrition, health and dairy product quality testing (Table 21).

Table 21. Matrix of actors and systemic problem typologies that the actors were indicated to face

Actors	Systemic problem typology and specific problem subtypes
Dairy producers	**Physical infrastructure problems**: unreliable electric power and water supply system; unfavorable feeder roads for dairy input and output transport
	Knowledge infrastructure problems: lack of lab facilities for veterinary diagnostic services and functional milk and feed quality testing; poor access to dairy knowledge resources
	Informal institution problems: farmers' hesitant behaviors to experiment with feed and dairy interventions; farmers' lack of motivation to form cooperatives; farmers' too risk aversive behaviors; farmers' mistrust of each other; farmers' mistrust of government actors; individualistic and short term benefit hunting inclinations
	Capability problems: dairy farmers' lack of competence to formulate their demand as to the kind of support they need from

	policy makers; farmers' lack of awareness on input quality and associated risks, and little competence for exploiting existing feed and dairy related knowledge
	Strong interaction problem: expectations of strong support from government service providers

Table 21. Matrix of actors and systemic problem typologies that the actors were reported to face (*continued*)

Actor	Systemic problem typology
Feed suppliers	**Physical infrastructure proble*ms***: Lack of feed storage infrastructure; poor road network to safely transport feed and other inputs from sources
	I**nformal institutional problems:** deceitful behaviors (for example, mixing feed ingredient with inert materials); mistrust of each other; mistrust of government actors mainly revenue authorities; secretiveness; short term benefit hunting tendencies
	Capability problems: Lack of awareness on feed quality standards; lack of skill in feed formulation
	Missing actor problems: no formal feed producing/trading actor in the system
	Strong interaction problem: a tradition of expecting much support from government actors
Drug vendors	**Knowledge infrastructure problems**: lack of disease diagnostic facilities to adjust drug recommendations

Informal institutional problems: deceptive behaviors; short term benefit hunting tendencies

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Table 21. Matrix of actors and systemic problem typologies that the actors were reported to face (*continued*)

Actor	Systemic problems typology
District Livestock Agency	**Formal institutional problems**: Lack of policy on peri-urban farming; no feed and dairy product quality and safety regulations
	Informal institutional problems: top-down and coercive approaches; habit of covering up failures; bias of extension services against market oriented peri-urban dairying sector; peri-urban dairying de-legitimizing inclinations
	Capability problems: lack of competence to quickly reconfigure to new systems and paradigms; lack of competence to initiate interventions to fix local problems; lack of awareness on veterinary drug and feed quality regulations
District Bureau of Agriculture	**Formal institutional problems**: Lack of policy on urban/peri-urban agriculture; no functional feed and dairy product quality and safety regulations
	Informal institutional problems: coercive and top-down approaches; habit of covering up failures; bias of agricultural extension services against market oriented peri-urban dairy niches; peri-urban dairying de-legitimizing tendencies

Capability problems: lack of competence to quickly reconfigure to new systems and paradigms; lack of competence to initiate interventions to fix local problems; lack of awareness on veterinary drug and feed quality regulations

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Table 21. Matrix of actors and systemic problem typologies that the actors were reported to face (*continued*)

Actor	Systemic problem typology
Development projects (AGP, EAAP)	**Weak interaction problems**: weak interaction with peri-urban dairy producers
Non-government organizations	**Weak interaction problems**: poorly linked to public sector actors; weak linkage with urban dairy farmers
	Informal institutional problem: suspicious of public actors
	Strong interaction problems: strong compliance with donor interests and priorities than local feed and dairy sector problems
BARC	**Physical infrastructure problems**: lack of vehicle resources to effectively implement on-farm technology piloting and innovation triggering activities; unfavorable road network
	Knowledge infrastructure problems: No functional internet facilities; no functional nutrition, health and dairy laboratory facilities
	Formal institutional problems: presence of staff promotion regulations reinforcing the 'publish more' culture; absence of regulatory mechanisms that value on-farm learning and innovation

activities in career development; no well organized feed and dairy research strategy

Informal institutional problems: "Publish more" attitudes; reluctance to non-technical issues in technology generation

Weak interaction problem: weak interaction with the majority of policy and development actors

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Table 21. Matrix of actors and systemic problem typologies that the actors were reported to face (*continued*)

Actor	Systemic problems typology
International Research Institutes (ILRI, IWMI and CIMMYT)	**Formal institutional problems**: operational cultures conditioned by global research policies, leading to a focus on mega research themes than site-specific niche sector priorities, often distancing them from local development issues
	Weak interaction problems: limited on-farm technology showcases to support interactive learning and innovation
Consumers	**Informal institutional problems**: Customers' behaviour remarkably conditioned by existing social norms and habits, like abstention from milk consumption during fasting periods as an act of religious ceremony resulting in fall of milk demand
District Administration	**Formal institutional problems**: No appropriate policy on urban/peri-urban agriculture
	Informal institutional problems: resistive inclinations of urban administrators to introduced peri-urban dairy innovation systems; top-down inclinations in decision making

Capability problems: low technical skill to lucratively guide local development efforts; insufficient facilitation and managerial skills; lack of awareness on existing veterinary drug and feed quality regulation

Missing actor problem: no functional organ catering for peri-urban dairy development, for example within the city administrative structure

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4.6.4.2 Formal institutional problems

Lack of a clear subsectoral policy favoring peri-urban dairy development was one of the formal institutional problems observed to embed in the system diagnosed. There was also a lack of functional product quality and safety regulation mechanisms. Owing to such deficiencies, quality of feed and dairy products was indicated to be poor and handling of the products to be unsafe and unhygienic. Technology and knowledge generating stakeholders such as BARC and Wollega University were also indicated to have stringent regulations in place which reinforce the 'publish more' inclinations of researchers. On the contrary, no appropriate regulation was available which considers on-farm technology piloting activities in staff promotion. There was also lack of well articulated forage and dairy related research and innovation policies guiding their overall activities.

4.6.4.3 Informal institutional problems

Informal institutions are those institutions that evolve spontaneously and are the implicit 'rules of the game'. The informal institutional problem subtypes observed to embed in the system diagnosed as captured during the field study are summarized in Table 21.

4.6.4.3.1 Top-down attitudes of extension workers

Peri-urban dairy farms located mainly in the rural-urban fringe were observed to normally be supervised by village development agents to track on-farm implementation progress. It was indicated that there are times when the agents tend to incline to top-down and coercive approaches to ensure that on-farm intervention are implemented as planned and outlined in the package manuals. But from the innovation systems stand point, this may rather stifle innovation and learning, and contradicts with innovative approaches that lead to consensus building and collaborations, that rather favour healthier on-farm learning and innovation. In this regard, a statement by one farmer, noted during an interview, which could more or less be translated as: "...dairy farming is mighty easy for experts 'farming' between two lines of a clean paper..." is worth mentioning. This evidently reflects the perception of a mildly discontented farmer with the top-down and coercive approaches of the technical experts.

4.6.4.3.2 **Farmers' hesitant attitudes to the introduced technical innovations**

Feed and dairy innovation progress was observed to be slow in both peri-urban sites diagnosed. Farmers were observed to be hesitant to sustainably experiment with the introduced forage and breed technical interventions. As also observed in the value chain component, farmers often backslide from innovating with introduced forages and AI breeding system. In case of improved forages, factors indicated to induce such behaviors were: low productivity and poor persistence of the introduced forages which, in turn, were indicated to be linked with poor management system. In the case of AI, the low conception rate of cows induced by the low level of competence of AI technicians and the poor quality of semen used were indicated to be important. These situations were observed to lead to erosion of farmers' confidence and gradually resulting in farmers'

hesitant inclinations. Farmers were observed to make a new path of their own instead, for example, through opting for other alternative feeds sourced from cropping systems, native pastures and from mill houses (hulls and milling by-products). In case of animal breeding interventions, the observation was that they often fall back on natural mating, using both local and cross-bred bulls.

4.6.4.3.3 Innovation de-legitimizing tendencies of other actors in the system

Resistive and de-legitimizing tendencies of urban inhabitants and authorities, and organizational actors concerned with environmental sanitary issues were also noted to be the major impediment to sustainable progress of the peri-urban feed and dairy integrated innovation systems. This situation was observed to be a critical constraint for those farmers closer to the urban centers. Farmers were observed to be forced to shut off their farms despite the apparent contribution of such livelihood activities to the wellbeing of their family.

4.6.4.3.4 Misalignment between implicit research objectives and dairy farmers' technology needs

It was observed that traditions of designing forage and livestock research projects to achieve the implicit motive of publishing more research papers are persisting than for solving critical problems of the peri-urban feed and dairy subsector. Furthermore, due to the technical jargons used to conform to publication guidelines, the generated information is not often communicated to livestock keepers. Personal academic interests of the research actors were noted to implicitly given priority when developing research projects over the significance of research results to solving priority needs of peri-urban dairy producers. This tradition has further been terribly reinforced by staff promotion regulations which to a greater extent are based on the number of publications. Discussion with the research staff in BARC and academic staff of Wollega University revealed that

the interest to have more published papers was highly perceptible. Publishing research information may not be a problem by itself, but it could hinder successful innovation when it becomes an implicit 'rule of the game' conditioning research program formulation and implementation. Currently, there are some efforts for strengthening on-farm technology piloting activities by BARC through farmers' research group approach. But such on-farm knowledge brokering activities do not result in the generation of research data qualifying for publication in journals, discouraging the evolution of such positive moves.

4.6.4.3.5 Extension service providers' bias against peri-urban dairy innovation system

Historically, rural livestock keepers have been the focal clientele for regular public extension service providers. Over years, these actors have been promoting livestock development interventions through a 'transfer of technology' model to rural farmers. Emerging niche sectors such as peri-urban dairy farmers have not been on their agenda. The existing extension system has not yet been reconfigured to engage itself for effectively supporting such emerging market oriented actors operating under urban and peri-urban setting. Even research organizations seem not to be as such concerned in this respect, except some efforts made through short-lived project activities in collaboration with other development partners.

4.6.4.3.6 Milk consumption cultures conditioning consumers' behaviour

Seasonal variations in demand for milk and milk products were indicated to pose milk demand problems in the study areas. Some respondent farmers have indicated the

incidence of low demand for milk and milk products during the fasting periods. Such established traditions were observed to significantly constrain behavior of milk consumers leading to reduced milk demand.

4.6.4.4 Weak interaction problems

The dairy farmers interviewed indicated that their interaction with district livestock development actors, research and academic organizations and commercial compound feed producers is weak. Due to weak inter-actor interactions, possibilities for interactive learning and innovation were observed to be underexploited and producers were found to often fall short of adapting to new technologies. In addition, such weak interactions were observed to induce a lack of shared vision in technology development trajectories, which in turn was indicated to result in mismatch of technology generation endeavors and the needs of dairy farmers.

4.6.4.5 Strong interaction problem

This particular systemic problem was observed to occur between NGOs and their donors, where the NGOs were observed to exhibit a strong compliance with the interests and priorities of donors, a condition indicated to distance them from real problems of emerging sectors and from working trustworthily with other actors, mainly, government actors. The same problem was observed to prevail between dairy farmers and public organization actors where farmers tended to expect much support from government actors rather than striving to solve their problems by their own.

4.6.4.6 Capability problems

There was lack of competence on the side of peri-urban dairy producers to formulate their demand regarding the kind of support they need from policy makers. Similarly, lack of awareness on input quality and associated risks by farmers and a situation of being locked-in into traditional technological trajectories were pervasive. The regular extension service providers were observed to lack competence to quickly reconfigure to new production systems and paradigms, and to be short of capacity to design flexible approaches for fixing real grassroots level problems. Lack of awareness of the feed and health actors on veterinary drug and feed quality regulations promulgated at federal level was also observed. The local administrators were also viewed as lacking adequate technical skill to lucratively lead development efforts of existing public organizations and to be short of facilitation and managerial capacity which in one way or another was observed to negatively affect the feed and dairy innovation processes.

4.6.4.7 'Missing actors' problems

This systemic problem typology refers to the missing of important actors in the innovation system. The study indicated that some important functions of the innovation system were observed to be affected due to the absence of relevant actors in the innovation system who could undertake such functions. For instance, dairy heifers are important inputs in on-farm dairy related innovation activities. But there was no functional actor dealing with such entrepreneurial activities in the system. Commercial compound feed producers or retailers were not also present in the diagnosed innovation system. There was also no organ responsible for coordinating policy issues linked to peri-urban feed and dairy production in the administrative structure of the urban governments in both case study sites leading to a disorganized treatment of developmental issues related to peri-urban dairying. Formal feed suppliers and traders were also observed to be absent in the diagnosed innovation system.

4.6.5 Prevalence of systemic problems

The matrix of pinpointed systemic problems and inventory of main actors affected by a specific problem typology is presented in Table 22. This matrix gives an idea on the frequency of key system actors affected by a given problem typology out of the total actors identified to exist in the system diagnosed (Table 22).

Table 22. Matrix of systemic problems, cluster of actors affected by the specific problem typology and prevalence of each systemic problem

Problems type	Innovation system actors affected	% of actors affected[#]
Physical infrastructure problems	Dairy farmers; feed suppliers; District Bureau of Agriculture; BARC	36
Knowledge infrastructure problems	Dairy farmers; veterinary drug vendors; District Bureau of Agriculture	27
Informal institutional problems	Dairy farmers; feed suppliers; veterinary drug vendors; Livestock Development and Health Agency; District Bureau of Agriculture; NGOs; BARC; International Research Centers; District Administration	81
Formal institutional problems	Livestock Development and Health Agency; District Bureau of Agriculture; BARC; International Research Centers; District Administration	45
Weak interaction problems	Dairy farmers; Development projects; NGOs; District Bureau of Agriculture; International Research Centers	45
Strong interaction problems	NGOs; Dairy farmers	18

Capability problems	Dairy farmers; feed suppliers; Livestock Agency; District Bureau of Agriculture; Liquid N Production Center; BARC; District Administration	63
'Missing actor' problems	Feed supplier (missing); District Administration (a functional organ coordinating urban/ peri-urban agriculture is missing)	18

Note: #To calculate the percentage of actors affected by a particular problem typology, the total number of key actors (n=11) was taken from the summary in Table 21 and this was used in the denominator, and the number of actors in the second column of Table 22 was counted and used as numerator and this ratio was multiplied by 100.

Accordingly, informal institutional problems and capability problems were at the top, affecting 81and 63% of the actors, respectively. Formal institutional problems and weak interaction problems also occurred widely, each of them affecting 45% of the actors in the system. Physical (36%) and knowledge (27%) infrastructural problems and 'missing actor' (18%) problems were also important systemic failures that deserve considerable policy attention.

4.6.6 Potential systemic instruments proposed to avoid the pinpointed problems

Table 23 presents sets of systemic policy instruments, and the goals that were identified to be achieved by the instruments to address the embedding problems. The stated goals were meant to guide suggestion of appropriate systemic tools for addressing the systemic problems. They highlight as to what instruments need to be put in place to create mechanisms required for the innovation system to progress. Based on the set goals,

concise description of the proposed systemic instruments that need to be put in place within the scope of the present study are thus in order.

To address the infrastructural problems (physical and knowledge infrastructures), strengthening public investment in infrastructures such as electric power supply, feeder roads and water supply systems were considered to be vital. To stimulate the functioning of knowledge infrastructures such as diagnostic laboratories in the assessed innovation system, rehabilitating the laboratories (feed, health and dairy), mainly existing at BARC and Wollega University through improved financial support was suggested. The absence of formal institutional mechanisms (regulations, quality standards etc.) can be circumvented through formulating appropriate policy frameworks that would favour peri-urban dairying business and also help enhance the supply of quality feed and dairy inputs and outputs. Crafting appropriate regulations that would encourage on-farm learning and innovation activities by research and knowledge generating actors and amending the stringent regulations such as staff promotion rules that are in place but observed to reinforce the identified informal institutional problems was indicated to be critical.

Table 23. Suggested policy instruments for addressing the key problems pinpointed

Systemic instrument goals	Suggested instruments to address the set goals
Strengthen physical infrastructures	Strengthen public investment in electricity, road and water supply

Strengthen knowledge infrastructures	Strengthening non-functional labs (nutrition, milk quality and health) existing at BARC and Wollega University through improved grant; improve access of research and knowledge actors to diverse knowledge sources through strengthened grant; local sectoral development staff need to have access to knowledge sources on continuous basis
Facilitate existence of accommodating formal institutions	Formulating policies favoring peri-urban dairying; crafting regional feed, drug and dairy product quality and safety regulations; formulating appropriate regulations for staff promotion favoring technology piloting activities; revising stringent regulations such as staff promotion schemes disfavoring participatory technology transfer endeavors
Ensure the existence of beneficial informal institutions and shun the ones that hinder innovation	Adopting participatory and interactive paradigms to development as opposed to coercive and top-down schemes; developing incentive systems to reinforce the culture of inter-organizational collaboration; circumvent deceptive and dishonest behaviors of mainly private actors through training and formulating formal institutions to institutions to regulate such barriers
Stimulate actor interactions for enabling learning and innovation	Strengthen innovation and learning capacity of actors through on-farm piloting activities and establishing dialogue platforms; build the habits of working together to bring about innovation; establish mechanisms to improve interaction and linkage; develop functional institutional arrangements for facilitating collective experiential learning
Enhance actors' capability	Strengthen competence of actors through training initiatives; trigger attitudinal and behavioral change of actors through establishment of dialogue platforms that enable information and idea exchange
Strengthen existing actors or establish	Strengthen platforms that encompass diverse actors so that they could function effectively to contribute to innovation and learning; institute relevant actors that would contribute to learning and

Moreover, for addressing the weak inter-actor interactions, adopting participatory and interactive learning schemes and developing incentive and accountability systems to reinforce the culture of actors' collaboration was indicted to be vital. Similarly, circumventing deceptive attitudes mainly of private input suppliers through crafting legal frameworks to regulate such behaviours was indicated to be imperative. In the same way, strengthening on-farm technology piloting activities and establishing dialogue platforms to enhance interactive learning relationships of actors were suggested to be potential actions that need to be considered. There is also a need to enhance the competence of public actors so that they would be able to adequately reconfigure themselves with shifts in production systems, changes in regional and national policy frameworks and paradigms through appropriate capacity enhancement training and knowledge sharing schemes.

Systemic problems in the diagnosed feed and dairy innovation system were also observed to be independent of each other, rather they reinforce each other. For example, the mismatch between research program objectives and farmers' real technological needs induced by the implicit motives of researchers to publish more research papers (i.e. informal institutional problem) was observed to be exacerbated by the presence of staff promotion regulations, which is a formal institutional mechanism reinforcing the behavior of the research actors. The reluctance of farmers to sustainably innovate with introduced feed and breed technical innovations (informal institutional problem) was observed to be induced by the lack of capability (competence related problems) on the side of AI technicians. The widespread technical competence problems in the studied system could further be explained in terms of the weak interaction or knowledge infrastructural problems embedding in the system just to cite few of the cases.

5. DISCUSSION

In this section, results from the different activities are discussed in the order presented in the preceding (result) section. Accordingly, results of herbage yield and nutritive value of alfalfa, cowpea and Centrosema are discussed in the first three consecutive subsections (5.1 - 5.3). Results from the fourth experiment that dealt with evaluation of the quality of adapted browse and herbaceous legumes in Bako area are discussed under the fourth (5.4) subsection. Similarly, results from the analysis of dairy feed and fluid milk value chains, and from characterization of the innovation systems of integrated feed and breed based peri-urban dairy development interventions are discussed in the fifth (5.5) and sixth (5.6) subsections, in that order.

5.1 Yield and Quality of Alfalfa Cultivars

5.1.1 Herbage yield

The significant cultivar differences observed for herbage DMY of alfalfa in this study concurs with reports of other workers (Marijana *et al*., 2008; Monirifar, 2011; Sun *et al*., 2011). In a study where 16 alfalfa cultivars were evaluated, Hayek *et al*. (2008) also reported significant differences in DMY between cultivars with overall mean of around 12 t ha^{-1}. Mean DMY in the order of 11 t ha^{-1} was reported in a study where three alfalfa cultivars were evaluated (Zeinab *et al*., 2013) indicating the comparatively low herbage yield potential of the cultivars evaluated in the present study. Quite the reverse, DMY values ranging from 1.78-3.23 t ha^{-1} (Afsharmanesh, 2009) and from 0.67-2.16 t ha^{-1} were reported (Awad and Bakeri, 2009), which were indeed much lower than those observed in the present study. Such wide range of yield values could be attributed to varietal and environmental factors or their interactions.

The non-significant cultivar by cutting cycle interaction effect for the three herbage traits recorded implies that the performance of the cultivars was independent of harvesting cycles. This is an observation of vital practical importance in forage variety selection endeavors. Had the interaction effect of the two factors been significant, it would have been implied that the relative rank in the performance of the cultivars had changed across the cutting cycles (Fernandez, 1991), a situation which normally complicates selection for a stable variety due to reduction in the progress from selection efforts (Yau, 1995).

The significant cultivar differences for plant height concurs with other reports in the literature (Altinok and Karakaya, 2002; Sengul, 2002). Ullah *et al.* (2009) also reported genotypic differences for plant height and further indicated this trait to be influenced by differential response of genotypes to prevailing site and crop management conditions such as fertilizer (Dineshkumar, 2007), variety and the interaction of fertilizer and variety (Mohammadjanloo *et al.,* 2009). The non-significant cultivar differences in leaf to stem ratio concurs with reports of Afsharamanesh (2009) but was in disagreement with that of others (Lamb *et al.,* 2003; Hayek *et al*., 2008; Monirifar, 2011; Heidarian and Mostafavi, 2012). Among the cultivars, Hairy Peruvian had inferior leaf to stem ratio which could be due to its distinctly higher plant height, as stand height and stem proportion are positively correlated. Leaf to stem ratio is strongly associated with forage quality (Juan *et al.*, 1993; Kratchunov and Naydenov, 1995; Julier *et al*., 2000; Sheaffer *et al.*, 2000) and the consistently low CP, IVOMD and RFV of Hairy Peruvian can be linked to this established fact.

5.1.2 Cutting cycle effects on herbage traits

The number of yearly harvests achieved in this study was low in consideration of what has usually been achieved for stands of alfalfa managed under Debre Zeit conditions (Solomon, personal communication). Experiences confirm that cut and carry alfalfa could be harvested at shorter intervals, usually every 30 days, with higher number of cuts

achieved during the dry months of the year under irrigated conditions. An interval of around 55 days between cuts observed in the present study was relatively long which could mainly be linked with shortage of water, and the predetermined harvesting stage for yield determination. The interval between harvests was longer during wet months than dry months which could apparently be associated with the fact that when light conditions do not trigger transition from vegetative to reproductive growth, shoots remain in the vegetative stages of development (Gramshaw *et al.,* 1981; Sheaffer *et al.,* 1988), thereby delaying the predetermined stage of biomass removal which in this work was full bloom stage as described by Ball (1998).

Low herbage DMY for the dry months of the year evidently implies the importance of adequate moisture availability for growth and development in alfalfa (Sammis, 1981). In view of this, water deficiency was reported to diminish the rate of shoot growth through a variety of mechanisms, among which the following were highlighted: reduced shoot elongation rate, decreased internode length, slow rates of leaf development and reduced leaf area expansion (Grimes *et al*., 1992; Brown *et al.,* 2009). The higher leaf to stem ratio recorded for cuts taken in the dry months concurs with what was reported elsewhere (Carter and Sheaffer 1983; Halim *et al.,* 1989) who implied a more negative effect of water deficiency on stem growth than on leaf area leading to higher leaf to stem ratios for stands grown under water stress.

5.1.3 Herbage quality

High quality alfalfa was reported to contain >19% CP, <31% ADF and <40% NDF (Ball *et al*., 1997; Kazemi *et al*., 2012). In this study, Magna-788 had CP concentration of around 0.6 units greater than the threshold value indicated, while the other four cultivars had comparable CP levels, ranging from 18.15% to 18.87%. Indeed, all the cultivars had CP values of above 15%, a level suggested for a protein source supplement to be considered optimal to support lactation and growth in dairy cattle (Nsahlai *et al*., 1996).

The NDF content of all the cultivars was below values reported in the literature (Laura *et al*., 2012; Sheaffer *et al*., 2000; Markovic *et al*., 2007), while the ADL content of the cultivars was closer to that reported by Markovic *et al*., (2007) but much lower than that reported by Yu *et al*. (2003). In general, a wider range of values observed for CP and fiber fractions of alfalfa in the literature can be attributed to factors such as cultivar, climatic factors and agronomic management practices or their interactions.

The non-significant difference in IVOMD among alfalfa cultivars was in disagreement with what has widely been reported. For instance, Volenec and Cherney (1990) reported significant differences in IVDMD among alfalfa cultivars and these differences were indicated to be associated with variation in digestibility of the stem fraction (Tremblay *et al*., 2002). Also, a significant difference among 14 alfalfa varieties was reported for IVOMD, with values ranging from 59 to 66% (Kamalak *et al*., 2005), which indeed were much lower than those recorded in the present work. Selection for improved forage quality has also been successful for increasing IVDMD of alfalfa (Monirifar, 2011). The RFV index recorded for the alfalfa cultivars in this study was higher than a threshold value of 151 which apparently suggests the cultivars to have prime quality standard, with the highest value recorded for Magna-788.

5.2 Yield and Quality of Cowpea Accessions

5.2.1 Herbage and crude protein yield

The non-significant effect of year on DMY for the cowpea accessions could be associated with similarity in environmental variables like amount and distribution of rainfall and temperature during the two seasons. The significant difference between accessions for DMY concurs with other reports (Singh *et al*., 2003; Anele *et al*., 2011a), where improved and local cowpea varieties were compared and higher herbage yield values were recorded for improved varieties than the local ones. Anele *et al*. (2011a) also reported significant ($P<0.05$) differences in DMY between commercial and improved

cowpea cultivar groups. The DMY of four of the accessions (WWT, ILRI-9325, ILRI-6782 and ILRI-6783) was higher than those reported for three commercial (6.46 t ha^{-1}) and three improved (8.76 t ha^{-1}) cowpea varieties (Anele *et al*., 2011b).

5.2.2 Herbage quality

The overall mean CP content of the cowpea accessions in this study was comparable to 18% (n=3) reported by Anele *et al*. (2011b) but lower than that of 23% (n=4) reported by others (Ravhuhali *et al*., 2010). The CP concentration of cowpea available in the literature was observed to vary widely and this could be attributed to differences in crop management (Sing *et al*., 2010), variety (Ravhuhali *et al*., 2010; Anele *et al*., 2011a), plant part (Savodogo *et al*., 2000; Rivas-Vega *et al*., 2006) or season of the year (Anele *et al*., 2011a; Anele *et al*, 2011b). In this regard, Singh *et al*. (2010) reported a mean CP content of 13% for cowpea samples collected from a field to which farm yard manure was applied and a value of 14% for the samples grown on plots to which chemical fertilizers (urea, DAP and muriate of potash) were applied. Ravhuhali *et al*. (2010) also reported significant varietal differences for CP with values ranging from 20 to 26% in a study where four cowpea varieties were evaluated. Similarly, in a study where quality of plant parts was assessed, CP values of around 8 and 15% were reported for the stem and leaf fractions, respectively (Savodogo *et al*., 2000). A significant seasonal variation ($P<0.001$) for CP content of two groups of cowpea varieties (with each group consisting of three cultivars) was also reported with a respective mean values of 16 and 21% for samples collected during wet and dry seasons (Anele *et al*., 2011a). In general, the mean CP content of the accessions was higher than the 15% threshold value normally suggested to be required to support lactation and growth in dairy cattle (Nsahlai *et al*., 1996). This indicates the adequacy of the materials for use as supplement to animals dependent on roughage diets of poor quality.

The mean NDF content of the accessions was comparable to that of 45% reported by Ravhuhali *et al*. (2010). A mean NDF values of around 54 (Dahmardeh *et al*., 2010), 56%

(Singh *et al*., 2010) and 61% (Anele *et al*., 2011a), which apparently surpass those observed in this work were also reported. The mean ADF content of the accessions was comparable to that reported for a variety named 'Agripes' (33%) but higher than that of 'Blackeye' (24%) reported in the literature (Ravhuhali *et al*., 2010). In the same way, Dahmardeh *et al*. (2009) reported a mean ADL content of 16 and 18% for pure stand cowpea samples grown during two successive seasons. Similarly, Anele *et al*. (2011b) reported a respective ADL content of around 21 (n=3) and 16% (n=3) for commercial and improved cowpea varieties. Thus, the ADL content in the present work was much lower than the aforementioned literature values. On the contrary, Singh *et al*. (2010) reported an ADL content of 9%, a value closer to that observed in this work. According to Kazemi *et al*. (2012) forage legumes with a respective NDF and ADF values falling within a range of 40 – 46% and 31 – 40% are rated as having a first grade quality standard. The NDF and ADF contents of the accessions evaluated in this work apparently fall within these ranges indicating their potential to be used as source of supplement for improving the feeding value of poor quality roughages.

The mean IVOMD was higher than the threshold value of 50% required for feeds to be considered as having acceptable digestibility (Owen and Jayasuriya, 1989), and was also higher than values reported earlier for other herbaceous (65%) and browses (55%) legume species (Bediye *et al*., 1996). The mean RFV index of close to 135 observed for the five cowpea accessions falls within the range of 125–151 required for legume hays to be considered as having a quality status of first grade (Kazemi *et al*., 2012). Moreover, the observed mean RFV index exceeded a standard value of 100 for full bloom alfalfa implying the higher nutritive value of the accessions evaluated. The mean ME of 10 MJ kg^{-1} DM observed in this work is quite similar to that reported earlier (10 MJ kg^{-1} DM) for other protein supplements (Bediye *et al*., 1999).

5.3 Yield and Quality of Centrosema Accessions

5.3.1 Herbage and crude protein yield

The significant year effect on herbage DMY of Centrosema accessions could be associated with stand age as herbage mass during the first year is often lower for most of the perennial herbaceous legumes. In an experiment conducted using *C. pubescens* for two years (2001 and 2002), a non significant (P>0.05) inter-annual variation in DMY with mean values of 4.08 t ha^{-1} for the first year and 4.26 t ha^{-1} for the second year was reported (Barnes and Ado-Kwafo, 1996), which apparently contrasts with what was observed in the present study. The mean herbage DMY recorded during the second year lies slightly above the range of 3–10 t ha^{-1} reported for *C. pubescens* (Martens *et al*., 2012).

5.3.2 Herbage quality

The mean ash content of the five Centrosema accessions was higher than those reported for *C. pubescens* (Valarini and Possenti, 2006; Udeh *et al*., 2007; Ukanwoko and Igwe, 2012) but comparable to values reported by others for the same species (Aka and Kamalu, 2004; Aka *et al*., 2011; Obua *et al*., 2012; Nworgu and Egbunike, 2013). The CP content of all the accessions were well above 15%, a level considered adequate to meet the requirements of lactation and growth in dairy cattle (Nsahlai *et al*., 1996). A wide range of CP values (8.19% - 28.03%) is available in the literature for the different Centrosema species which could be associated with species or accession differences, natural environmental conditions under which the forages were grown, herbage husbandry methods (planting time, fertilizer use etc.) and season (Larbi *et al*., 1999). For example, significant differences in CP content was reported for *C. pubescens* grown under varying levels of phosphorus fertilizer and planting dates (Omokanye *et al*., 2001). In the study reported by the same author, stands of *C. pubescens* that received phosphorus at levels of 30 or 60 kg ha^{-1} contained high levels of CP for samples collected from late

planted stands. In the present study, the CP content did not differ between the two years (P>0.05) which is in agreement with reports of Omokanye *et al*. (2001).

The mean NDF content of the accessions (49.98%) fell within the range of 41.50 (Medugu *et al*., 2012) and 61.23% (Ratnawaty *et al*., 2013) and closer to those values reported for *C. pubescens* (Evitayani *et al*., 2004; Valarini and Posenti, 2006). On the contrary, the mean NDF observed in the present work was inferior to those reported for *C. pubescens* (Soebarinoto *et al*., 2012; Ratnawaty *et al*., 2013) and *C. pascuorum* (Ratnawaty *et al*., 2013). Equally, the ADF content (35.71%) was similar to those reported by Medugu *et al*. (2012) and Ukanwoko and Igwe (2012), but slightly lower than that reported by Evitayani *et al*. (2004) and Valarini and Possenti (2006). The ADL values observed in the present study were similar to those reported by Valarini and Posenti (2006) but higher than those recorded by Evitayani *et al*. (2004).

A wide range of IVOMD values were reported for different Centrosema species in several published works, ranging from 32.5% (Larbi *et al*., 1999) for *C. plumieri* to 64.7% for *C. pascuorum* (Ratnawaty *et al*., 2013). The mean IVOMD for the five Centrosema accessions evaluated in this study was higher than values reported for *C. plumieri* (32.5%), *C. arenarium* (41.6%) and *C. brasilianum* (42.4%), but closer to those of *C. macrocarpum, C. acutifolium, C. virginianum, C. pascuorum* and *C. schottii* (Larbi *et al*., 1999). Comparatively lower IVOMD value was observed for Centrosema species in this work than those reported for *C. pascuorum* (Ratnawaty *et al*., 2013). In general, recorded digestibility values in this study were lower than the threshold of 50% required for feeds to be considered as having acceptable digestibility (Owen and Jayasuriya, 1989) and also inferior to those values reported earlier for other herbaceous (65%) and browse (55%) species by Bediye *et al*. (1996). The wide range of values observed in the literature can be linked, among others, to genotypic and environmental differences.

The mean RFV index of 115 recorded in this work falls within the range of 103–124 that leguminous hays of second grade quality are required to have (Kazemi *et al*., 2010). The magnitude of the index was indeed higher than a standard value of 100 for full bloom alfalfa which implies the potential of the accessions to be considered as supplements to low quality roughages (Schroeder, 2013). Similarly, the mean ME value of 6.58 MJ Kg^{-1} DM of the Centrosema accessions was slightly lower than the lower threshold of 7.5 MJ Kg^{-1}DM (Owen and Jayasuriya, 1989) and the value that was reported earlier (10 MJ Kg^{-1}DM) for other protein supplements (Bediye *et al*., 1999).

In general, the fiber contents of the Centrosema accessions was much lower than values reported for commonly used roughage feeds, which were generally higher than 50% (Fekadu *et al*., 2010) and was indicated to result in low DM intake induced by slow rate of digestion (Melaku, 2004). The NDF and ADF contents compared well with good quality leguminous hay with NDF and ADF values ranging from 47–53% and 31-40%, respectively (Kazemi *et al*., 2012) suggesting the potential of the accessions to be considered as source of plant protein supplement to low quality roughages in the target farming system. Among the accessions, *C. plumieri* ILRI-191, *C. pubescens* ILRI-12297 and *C. virginianum* ILRI-14541 were top performing ones and can thus be promoted to the next varietal verification stages to finally select a top ranking accession for release as variety.

5.4 Nutritional Quality of Browse and Herbaceous Legumes Adapted to Bako Area

The highly significant differences between the fiberous, leguminous and concentrate feed groups evaluated in this activity for CP, detergent fibers, HC and cellulose was as anticipated. Kazemi *et al*. (2012) reported that legumes, grasses and legume-grass mixtures containing greater than 19% CP as having prime quality standard and those with CP below 8% to be rated as inferior. The mean CP content of the browse and herbaceous

legume groups was higher than 19% apparently indicating their potential as an alternative plant protein sources for enhancing the feeding value of poor quality roughages. The herbaceous and browse legumes also had CP values exceeding 15%, a level considered adequate for supporting lactation and growth in dairy cattle (Nsahlai *et al*., 1996).

Singh and Oosting (1992) indicated that feeds containing NDF values of below 45% to be categorized as high quality and those with values ranging from 45% to 65% as medium, and those with NDF values higher than 65% as low quality. The mean NDF content of the two cereal straws in this study was higher than 65% and closer to the 70% straw NDF reported earlier (Assefa, 2006). The straw and native hay samples in the present study were evidently of low quality and their high cell wall content could thus limit feed intake as DM intake and NDF concentration are normally correlated negatively (Ensminger *et al*., 1990). The NDF content of herbaceous and browse legumes was higher than mean values reported earlier (47%) for eleven herbaceous (Bediye *et al*., 1996) and eight browse (46%) legumes (Bediye *et al*., 1999).

The ADF content of "*noug*" cake was closer to that reported earlier (Bediye *et al*., 1999). The herbaceous and browse legumes had higher ADF levels than that were previously reported for herbaceous and browse legume species (Bediye *et al*., 1999). According to Mihai *et al*. (2012), legumes with ADF values less than 31% are rated as having superior quality, whereas those with values greater than 55% are considered inferior. Likewise, Kellems and Church (1998) also indicated that roughages with less than 40% ADF are categorized as high quality and those with values greater than 40% as of poor quality. Except for samples of "*noug*" cake, all the other feed classes had ADF values greater than 40%. Although the leguminous species had higher CP, their higher NDF and ADF contents could limit their potential as the high levels of fiber could set a limit to feed intake by physical fill effects and reduced digestibility (McDonald *et al*., 1995; Buxton, 1996). The ADL content was relatively low for native hay samples and values for the straws, "*noug*" cake and the herbaceous and browse legume groups were nearly equal. The ADL content for the two legume groups and "*noug*" cake was closer to the maximum level of 10% which was indicated to limit DM intake (Reed *et al.*, 1986).

According to Kellems and Church (1998), ADL fraction is indigestible, forming complexes with cellulose and hemicellulose fractions through physical encrustation, apparently hindering exposure of the cellulose and hemicellulose fractions to microbial enzymes which is essentially true for cereal straws and other low quality roughages (McDonald *et al*., 1995).

The IVOMD for the cereal straws was lower than the critical threshold of 50% required for feeds to be considered as having acceptable digestibility (Owen and Jayasuriya, 1989). The digestibility values for the herbaceous and browse legume classes were higher than suggested critical thresholds (Owen and Jayasuriya, 1989) and other values reported previously (Bediye *et al*., 1996) for herbaceous (64.5%) and browse (55.1%) legume species. The ME content (MJ kg^{-1} DM) of the straws was lower, while that of grass hay was slightly higher than values reported for dry forages and roughages (7.3) reported previously (Bediye *et al*., 1999). The "*noug*" cake samples were observed to contain low ME than 10.1 MJ kg^{-1} reported earlier (Bediye *et al*., 1999). The herbaceous and browse legume species as a group had similar ME values and this agrees with those reported earlier (10.2) for potential protein supplements (Bediye *et al*., 1999). Except for the cereal straws, the other feed groups in the current work contained ME values greater than the lower critical threshold (Owen and Jayasuriya, 1989).

The RFV index of the cereal straws was closer to that reported for wheat straw (Schroeder, 2013). The native grass hay samples and the herbaceous and browse legume groups had comparable RFV indices which were comparable to that reported for sudan grass (83) harvested at heading stage (Schroeder, 2013) but lower than those reported for three wetland grasses, *Paspalum distichum* (118.08), *Sparaganium erectum* (114.73) and *Aeloropus litoralis* (124.23), known for their high DM digestibility (Heydari *et al*., 2006). Except for "*noug*" cake, the other feed groups had a quality index lower than 100 implying their lower nutritional status when compared to full bloom alfalfa hay.

In general, results from this particular activity revealed that the cereal straws and native grass hays widely used in the study location as roughages of dairy cattle were of inferior quality compared to "*noug*" cake samples and the leguminous species. The herbaceous and browse legume species can thus be considered as potential alternative plant protein supplements that can replace conventional protein source ingredients.

5.5 Analysis of Feed and Dairy Value Chains

5.5.1 Characteristics of surveyed households

The larger proportion of male headed than female headed dairy farm households in this work might partly be explained by the relatively better access of male heads to dairy knowledge and required input sources. The mean age of household heads pooled across the two sites was comparable to the 47.6±1.7 years (n = 60) reported by Wondatir (2010), 47.35 years (n = 180) reported by Tiruneh *et al*. (1998) and 46.02±0.75 years (n = 280) reported by Hailu *et al*. (2011). The high proportion of the household heads with better educational status could be considered as an opportunity for success in dairying business as high educational level is linked to the ability of accessing, processing and utilizing knowledge related to dairying (Ghilu *et al*., 2011). Limited number of respondents reported to exclusively depend on peri-urban dairying for their livelihood and this indicates that the subsector is mainly used as a source of supplementary income which also concurs with the view of Hovorka (2006). It was also reported elsewhere that this form of dairying offers supplementary employment opportunities to a larger proportion of the urban and peri-urban residents (Mugisa *et al*., 1999).

5.5.2 Input supply

The absence in both sites of formal and well structured peri-urban dairy feed supply chain concurs with observations noted from related works in other production systems earlier (Abera *et al*., 2012). Introducing the feed and dairy breed based interventions in both sites encouraged informal feed suppliers such as oil processors, grain millers, opportunistic hay producers, crop residue suppliers and traditional brewers to partner with dairy farmers leading to evolution of informal feed supply chain. From the perspective of enhancing value chain innovation, this local informal network need to be further nurtured through introducing appropriate innovation support interventions for the partnership to sustainably progress so that the system will continue evolving into self generating local coalition of actors supporting peri-urban dairy feed supply chain.

A tendency of farmers to revert from innovating with improved forages, and rather falling back on poor quality roughages and purchased ingredients was observed, which was in disagreement with the widespread view of value chain thinkers claiming that adoption of improved forages would be enhanced when linked with market oriented innovation activities (Ergano *et al*., 2010; Ayele *et al*., 2012).The renting-in of hay land practiced by limited number of dairy producers can be considered as an important innovative stride in feed production. Farmers were also observed to create their own mechanism of sourcing feed through partnering with crop farmers in nearby sub-districts. In this regard, it is important that hay production activities on rented-in land or on own hay land be supported through training on appropriate hay production and pasture management techniques as pasture quality and pasture field management system was observed to be poor.

The weak breeding and veterinary services delivery systems in the case study sites in this work concurs with reports from previous studies (Staal *et al*., 2006). While provision of well organized breeding services by way of natural mating or AI is critical in maintaining

appropriate blood level, this was not observed to aptly taking place in both areas. Similar situations have also been reported from a range of earlier works (Staal *et al*., 2005; Kebede *et al*., 2011). The dairy cattle diseases and reproductive health problems noted in this work also concurs with earlier reports (Lema *et al*., 2001; Abreham *et al*., 2010). The widespread inefficiency of the existing veterinary service delivery systems observed in this study also matches with earlier observations in which the scenario was described as non-participatory and implemented by experts of low technical capacity and operating under critical shortage of budget and facilities (Gebremedhin *et al*., 2007). The emerging private veterinary drug vending businesses, though limited to veterinary drug vending, is a promising trend. It is, however, important that necessary technical and regulatory support services be provided to these nascent actors for the system to further evolve into pluralistic, interactive and accountable system. This latter position concurs with what has often been highlighted by many researchers. Tegegne *et al*. (2010), based on information from a large body of related works, for example, concluded by highlighting that the role of the private sector has to be promoted and supported in different forms to ensure proper dairy input supply system.

The peri-urban dairying venture at the two sites was observed to be highly delegitimized by urban residents and some urban administration authorities. This disappointing inclination was suggested to be linked mainly to public health and sanitary concerns in the urban areas. This is a critical issue deserving significant attention as despite its limitations, this emerging sector plays an important role as a social safety net mechanism for many poor people, mainly women and retired people in Ethiopia and beyond (Maxwell *et al*., 1998; Mugisa *et al*., 1999; Prain, 2000).

The significant contribution of women in on-farm dairying activities, mainly milking, and milk processing may entail a work load on women. This indeed was an important observation as on-farm technological interventions increasing the drudgery of women had been noted to result in low technology adoption, a situation noted even to be true under cases where the interventions were indicated to improve household welfare as measured

by the total income earned (Yilma *et al*., 2009). Moreover, women were reported to provide most of the labour required on-farm yet experiencing limited control over income gained from dairying (Mullins, 1998). It is thus vital that research on gender differentiated impacts of the current and other similar interventions be assessed in the future.

5.5.3 Milk production

The mean daily milk yield of local cows recorded in this study was comparable to that reported earlier (1.7 lts) under on-farm conditions, but slightly lower than values reported under an on-station management system (Kebede *et al*., 1998). The on-farm daily milk yield of F1 crossbreds for Bako site was comparable to yield levels reported previously under similar system (Kebede *et al*., 2011). Equally, milk yield of crossbreds at Nekemte was closer to values reported by Kebede *et al*. (2011) and Mekasha *et al*. (2003), which were 9.40 and 9.79 lts day^{-1}, respectively, and falling within the range of 9-12 lts day^{-1} reported by Moges and Baars (1998). The observed differences between the study sites could be attributed, among other factors, to variations in husbandry systems and extent of exotic blood level of the population studied. Taken as a whole, the higher mean yield recorded at Nekemte can be associated with the larger population of crossbreds in this site or differences in environmental conditions.

5.5.4 Marketing, processing and consumption

The dominance of the informal milk marketing system in the present study is in agreement with reports from other parts of Ethiopia. For instance, around 95% of the milk marketed at national level was reported to be channelled through informal outlets (Yilma *et al*., 2011), a system is characterized by direct delivery of fresh milk to immediate neighborhood customers or catering service providers. Muriuki and Thorpe

(2001) also indicated that the share of milk sold through formal market in Ethiopia (5%) is much lower than values for Kenya (15%). A comparatively larger proportion of milk produced at Bako was entirely consumed at home, which can be associated with the low entrepreneurial character of the farmers in this area. This situation can also be linked to the fact that the larger proportion of farmers at Bako were engaged in crop-livestock production, and none of them indicated income derived from dairying business to be the sole source of livelihood. Another likely reason can be the price factor, in that milk price at Bako was relatively low compared to that of Nekemte, a situation that might have depressed the attitude of milk marketing.

A noteworthy entrepreneurial attempt observed in Nekemte area was the tendency of some dairy farmers to start own catering businesses and processing own milk into other milk derivatives. This was viewed to be beneficial as it is expected to reduce transaction costs that some farmers in both areas reported to face. Though the problem was not overtly talked about as critical during this field study, an important issue at marketing, processing and consumption stages of the studied value chain, and that need to be given due attention in the future is related to milk quality and safety and sanitary standards. These issues mainly require efforts to improve the regulatory mechanisms in both case study areas through strengthening formal institutional schemes for ensuring quality control.

5.6 Characterization of Feed and Dairy Innovation Systems

In this component, key insights that would facilitate the formulation of appropriate systemic instruments for circumventing the pinpointed innovation system problems were drawn. One of the vital lessons was that despite the diverse actors existing in the diagnosed feed and peri-urban dairy innovation systems, their interaction was indicated to be weak and not favoring learning and innovation. This observation matches well with

earlier findings documented for maize and livestock (Mengistu, 2010), and forage and dairy (Lemma *et al*., 2010) integrated technological innovations systems.

The systemic problems observed to embed in the present innovation system were also found be common in other technological innovation systems, mainly existing in developing countries (Carlsson and Jacobsson, 1997; Smith, 2000; Chaminade and Edquist, 2006). Informal and formal institutional problems, capability problems, inadequate infrastructures and weak interaction problems were also widely reported in the literature (Carlsson and Jacobsson, 1997; Smith, 2000; Chaminade and Edquist, 2006). Actor capability problems which were pervasive in the system diagnosed in this work were also widely reported elsewhere (Afuah and Utterback, 1997; Anderson and Tushman, 1990; Woolthuis *et al*., 2005). In the literature, these problems were also labeled as 'transition' (Smith, 1999) or 'learning' failures (Woolthuis *et al*., 2005) and were claimed to prevent producers from effectively learning, and thus leading to a lock-in into traditional technological trajectories (Smith, 1999). A similar phenomenon was also reported to prevail in the present feed and dairy system as was revealed by a value chain analytical framework (Geleti *et al*., 2014).

The weak inter-actor interaction problems indicated to be persistent in the present system were claimed to negatively influence effective learning and innovation (Woolthuis *et al*., 2005). Such weak interaction among actors were also referred to as "weak network failure" (Carlsson and Jacobsson, 1997) or "dynamic complementarity failure" (Woolthuis *et al*., 2005) in the existing systemic literatures. According to Woolthuis *et al*. (2005), weak inter-actor interaction problems were indicated to lead to lack of shared vision in technology development trajectories which in turn was indicated to cause mismatches between technologies and farmers' real needs.

The lack of physical infrastructures was also common in the diagnosed system and these infrastructural constraints were observed to be characterized by their large size and long term horizon of operation. This implies the difficulty for the private actors to invest in such facilities, suggesting the need for policy makers to interfere through strengthening financial investment in such basic facilities, a view coinciding with the claims of other researchers (Woolthuis *et al*., 2005). A careful examination of the pinpointed systemic problems further revealed that the problems were not independent of each other, with one problem in one part of the system inducing another problem in the other part of the same system, implying the need for formulating coherent systemic instruments that reinforce each other in circumventing the identified systemic weaknesses (Wieczorek and Hekkert, 2012).

6. CONCLUSIONS AND RECOMMENDATIONS

This section concisely reiterates the major findings of the study. Important aspects of the research methodology and the objectives of the activities were succinctly described. This is followed by a recitation of the important findings of the work. Finally, appropriate recommendations within the scope of the work reported are given.

6.1 Conclusions

Five accessions of three legume species (alfalfa, cowpea and centrosema) were evaluated for herbage DMY and quality in the first three experiments. A randomized complete block design replicated four times (for alfalfa accessions evaluated at Debre Zeit); and replicated two times (for cowpea and Centrosema accessions evaluated at Bako) was used. In the fourth experiment, nutritional quality of seven browse species (*Calliandra callothyrsus, Leucaena pallida, Cajanus cajan, Gliricidia sepium, Leucaena leucocephala and Sesbania sesban*), and four herbaceous legume species (*Lablab purpureus, Stylosanthes guianensis, Desmodium unicenatum and Desmodium intortum*), and two samples for each of "*noug*" cake, cereal straws ("*tef"* and wheat) and native grass hays collected from BARC and its surroundings were evaluated. The peri-urban dairy feed and fluid milk value chain analysis in the fifth activity employed a value chain framework while for characterization of the feed and dairy innovation systems in the sixth activity; an innovation systems framework was used. The objectives were to select promising forage accessions that can further be promoted to variety verification stages (for the first three activities) and to identify systemic constraints embedding in feed and dairy value chains and innovation systems and hindering progress of the feed and dairy value chains and innovation systems.

In alfalfa experiment, it was revealed that DMY was significantly higher ($P<0.05$) in the cultivar FG9-09(F) than in Magna 801-FG(F) whereas the other three cultivars (FG10-09(F), Magna-788 and Hairy Peruvian) had intermediate values between the two. The CP content was higher for Magna-788 ($P=0.05$) than Hairy peruvian, while FG10-09(F), FG9-09(F) and Magna801-FG (F) had intermediate values between the two. The IVOMD and ME did not significantly vary between the accessions ($P>0.05$). The RFV was lowest for Hairy Peruvian ($P<0.01$), whereas FG10-09(F), FG9-09(F), Magna801-FG(F) and Magna-788 had comparable RFV index. For cowpea, DMY was least for ILRI-11976 ($P<0.01$) and highest for ILRI-9325, while WWT, ILR-I6782 and ILRI-6783) had intermediate yield values. The mean CP was 17%, with values ranging from 16% for WWT to 18% for ILRI-9325. The IVOMD ranged from 64% (ILRI-6783) to 69% (WWT) with an overall mean of 67%. The RFV index was 135, varying from 128 (ILRI-6782) to 142 (WWT), while the ME (MJ kg^{-1} DM) content was 10 ranging from 9.5 (ILRI-6783) to 10.4 (WWT).

In centrosema, the herbage DMY was highest ($p = 0.05$) for *C. plumeri* ILRI-191 and *C. pubescens* ILRI-243, followed by *C. virginianum* ILRI-14541 while it was least for *C. pubescens* ILRI-233. The CP content ranged from 18.86% (*C. pubescens* ILRI-243) to 22.37% (*C. virginianum* ILRI-14541), with an overall mean of 21.02%. The mean IVOMD was 43.9% with values ranging from 38.6% (*C. pubescens* ILRI-233) to 50.7% (*C. plumeri* ILRI-191). The mean RFV was 115.03 with a range of 106.16 (*C. pubescens* ILRI-243) to 126.16 (*C. plumieri* ILRI-191). The ME content ranged from 5.79 for *C. pubescens* ILRI-233 to 7.61 for *C. plumieri* ILRI-191, with an overall mean of 6.58. For the herbaceous and browse legumes, the CP content was highest for "*noug*" cake samples (32%), followed by the herbaceous (24%) and browse legume species (23%) and was least for the cereal straws (3%). The IVOMD content was highest for the browse legumes (68%) followed by the herbaceous legumes (67%) while it was least for the cereal straws (45%). A consistently similar trend with that of IVOMD was observed for the ME content of the samples. The RFV was higher for "*noug*" cake than for cereal straws (58) with the other feed classes having intermediate values between the two feed categories.

Moreover, analysis of the feed and fluid milk value chains indicated that shortage of feed, high feed price, inefficient breeding and veterinary service delivery systems and shortage of land to be critical value chain constraints (100% of the respondents). Regarding on-farm dairy husbandry operations, women were indicated to be highly involved in milking (88%) and milk processing (92%). Farmers owned both local (1.83±1.71 and 0.63±1.71cows household^{-1} at Bako and Nekemte, respectively) and cross-bred dairy cows (2.67±1.88 and 7.29±8.12 cows household^{-1} at Bako and Nekemte, in that order). On-farm milk yield performance of both genotypes was observed to be very low (6.54 ± 2.32 for Bako site and 9.79 ± 2.04 for Nekemte) compared to on-station yield reports. Generally, no formal milk marketing system was observed to exist in both sites. Concerning dairy cattle diseases, reproductive disorders and mastitis were indicated to be pervasive across the surveyed farms. Similarly, the feed and dairy innovation systems study revealed institutional (both formal and informal), capability, infrastructural and weak inter-actor interaction problems to be the major problems embedding in the system diagnosed.

6.2. Recommendations

In forage germplasm selection programs, evaluation of potential materials under diverse agro-ecologies and production systems to finally select stable and best performing varieties for official release is vital. Further assessment of the forage legume accessions observed to perform well under on-station condition in the first three experiments, for their performance under diverse agro-ecological and on-farm production conditions is thus vital. Accordingly, Magna-788, FG9-09(F) and Magna801-FG(F) that had superior performance than the other two (FG10-09(F) and Hairy Peruvian) for the measured herbage traits (DMY, CP, leaf to stem ratio, ME and RFV) were selected for further evaluation. Similarly, three of the cowpea accessions: WWT, ILRI-9325 and ILRI-11976 which performed well for DMY, and CP, ME, IVOMD and RFV attributes compared to

the other accessions were suggested for further evaluation. In the same way, *C. Plumieri* ILRI-191, *C. Virginianum* ILRI-14541 and *C. pubescens* ILRI-12297 ranked top for the key yield and quality attributes and were thus suggested for further evaluation in the next germplasm selection stage. Moreover, it is important that data on herbage DMY potential and compositional attributes of the best bet genotypes finally be augmented by biological response data generated through animal based experiments in the future.

Based on the information generated in the value chain analysis, formulation of appropriate regional policies that would favor peri-urban dairy production and crafting of appropriate regional feed and dairy product quality and safety regulations were recommended for the way forward. Addressing deceptive and dishonest behaviors of some of the private sector actors (informal institutional problems) through training and appropriate regulatory mechanisms that would help control such behaviors were recommended. Lack of physical infrastructures such as electricity, feeder roads and water supply systems were also widespread in the system studied. In this regard, increasing public investment for strengthening these support infrastructures was suggested to be one of the strategies that need to be considered in the future.

In the same way, strengthening poorly functioning public feed and dairy research laboratories in the study area through improved research and development grant, improving access of researchers to diverse knowledge sources by improving financial support for training was also suggested as important steps to avoid such gaps of knowledge infrastructure. A careful assessment of the pinpointed feed and dairy innovation system problems also revealed that the systemic problems were not independent of each other, with one problem in one part of the system inducing another problem in the other part of the system. It is, therefore, vital that embedding systemic problems be addressed through putting in place integrated systemic policy instruments

that reinforce each other than attempting to address the systemic constraints in a piecemeal approach.

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APPENDIX

Appendix Table 1. Summary of variance ratios and levels of significance from the analysis of variance for various alfalfa traits

		Herbage traits		
Source of variation	DF	DMY	Stand height	Leaf to stem ratio
Cultivar	4	1.26*	10.81***	6.79***
Cutting cycle	7	109.36***	85.72***	20.7***
Interaction	28	0.96NS	1.42NS	1.28NS

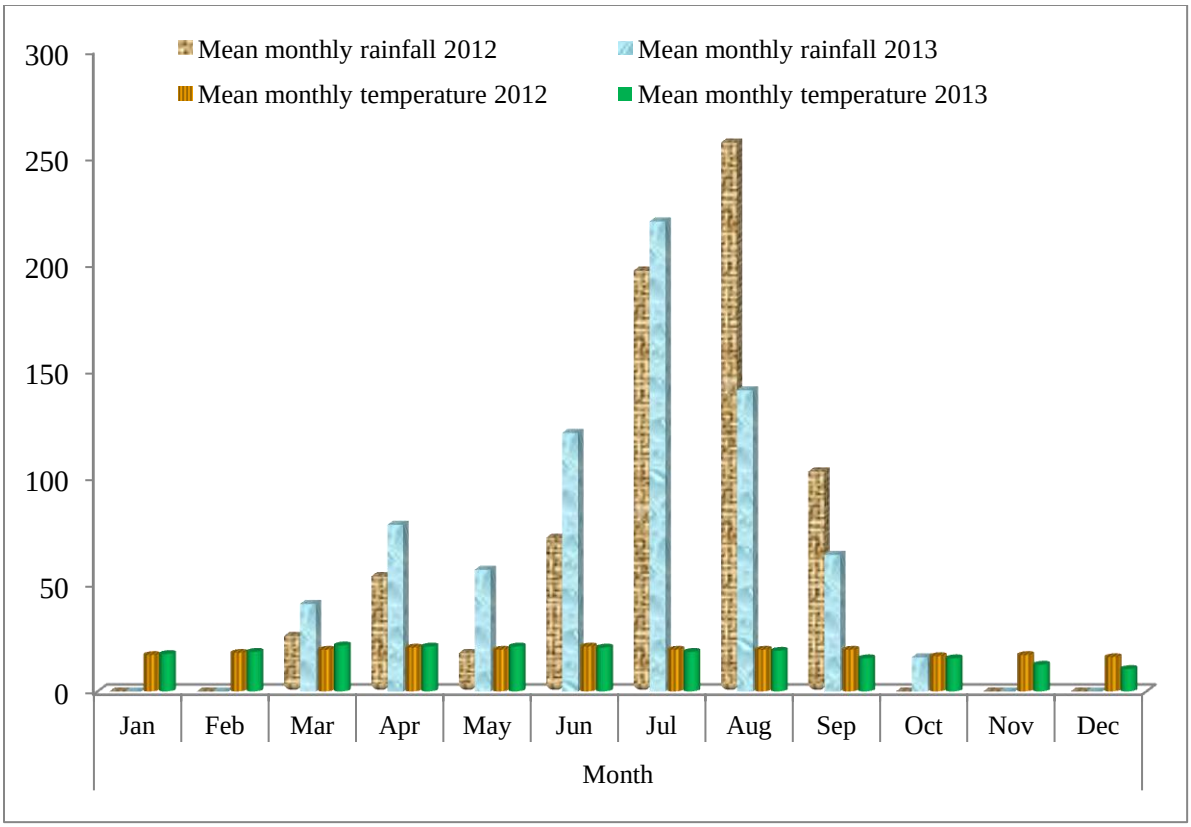
Note: DF, degrees of freedom; *, significant at P=0.05; ***, significant at P≤0.001; NS, not significant

Appendix Table 2. Mean squares and their significance levels from the analysis of variance for herbage DMY and CPY in cowpea and Centrosema accessions

Source	DF	Traits measured	
		DMY	CPY
Cowpea			
Year	1	16.07NS	20213.98**
Accession	4	23.32**	7188.98**
Year * Accession	4	16.18*	5248*
Centrosema			
Year	1	369.97**	168177.80***
Accession	4	4.08*	2966.57*
Year * accession	4	3.18NS	1955*

Note: DF, degrees of freedom; *, significant at P=0.05; ***, significant at P≤0.001; NS, not significant

Appendix Figure 1. Mean monthly temperature and rainfall of Debre Zeit Research Center



Curriculum Vitae

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MSc. Degree in Animal Production, November 1998 - July 2000, Haramaya University, Ethiopia

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Additional trainings attended

1. Area of Training: Principles and applications of Farmers' Field School for Livestock Researchers, organized by ILRI, Kenya, Naivasha, March 7-18, 2005
2. Area of Training: Animal Nutrition and Feeding Systems Research Group Training Course, organized by: ILRI, Addis Ababa, May 13 - June 26, 1997
3. Area of Training: Livestock Research Methods Training Workshop, organized by Oromia Agricultural Research Institute, June 17 - 21, 1996

Current Career Position: Researcher II: Feed Resources and Animal Nutrition, Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Centre

Membership and participation in other extracurricular activities

- Served as Director of Bako Agricultural Research Centre, January 2001- June 2006
- Served as Editor- in-Chief, Ethiopian Society of Animal Production (ESAP)
- Currently serving as Associate Editor-in-Chief of Ethiopian Society of Animal Production (ESAP)
- Served as member of the research team of ILRI/BMZ and Oromia Agricultural Research Institute Collaborative Research Project on "Improving the Livelihood of Poor Livestock Keepers in Africa Through Characterization of Indigenous Livestock Species Project"
- Served as member of the dairy production training and consultancy team at Ethiopian Meat and Dairy Technology Institute
- Member of the meat technology training and consultancy team at Ethiopian Meat and Dairy Technology Institute
- Active member of the Animal Production Society of Ethiopia
- Served as member of Oromia Regional Research-Extension-Farmer Linkage Advisory Council
- Served as member of the publication committee at Bako Agricultural Research Centre
- Served as co-chairman of Zonal Research-Extension-Farmer Linkage Advisory Council Based at Bako Research Centre, January 2001- June 2006
- Served as division head of the Animal Feeds and Nutrition Division at Bako Research Centre, October 2001 – June 2004

IV. Publications (Books, Journal articles, Proceedings, Research Reports and Book Chapters)

Books

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The information I have provided is true and correct.

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