The status of animal feeds and nutrition in the West Shewa Zone of Oromiya, Ethiopia

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Abstract

The resource base (animal and feed resources) of the various districts in the West Shewa Zone are summarised and synthesised from secondary data. The feed resource balance of each district is estimated from area coverage and average productivity of the major feed resources. Data generated from recent surveys of selected *weredas* in the zone are used as case studies to substantiate the secondary data and reflect the current reality on the ground. Technical information pertinent to the zone in terms of feed production, feed quality and feeding systems were reviewed and synthesised to identify challenges and opportunities in feed and animal industry. Estimates based on secondary data suggest that the available feed production (basal diet) per annum is 1.68t TLU^{-1}, which is about 70% of the requirement per TLU yr^{-1}. A substantial decline in availability of grazing lands, low productivity and quality of native pasture are major challenges in areas where natural pasture is the dominant basal feed. The use of crop residues as livestock feed is increasing from time to time in most of the districts and their optimal use is constrained primarily by their low nutrient concentration, digestibility and low intake. The use of industrial by-products is confined to peri-urban or urban livestock production, and to few households in the mixed crop-livestock production system adopting improved livestock breeds, mainly of dairy. The use of improved forage and pasture crops is limited to few households who adopted improved livestock breeds of dairy under smallholder's conditions. Opportunities for mitigating poor nutrition and transforming animal agriculture within the zone through the use of improved feed technology or information are identified and highlighted.

1. Introduction

Livestock production is an integral component of almost all farming systems in the west Shewa zone. In the highlands and mid-altitudes livestock is mainly used for the supply of draught power and provision of food. Foreign income generated through the export of hides and skin is also an integral part of the country's economy at the macro level. By-products of livestock in the form of manure are also of economic importance in the mixed crop livestock system for soil fertility improvement. The income generated from selling livestock and livestock products also forms the main income for the farming community in the highlands. In the low lands, livestock is the mainstay of the livelihoods of the pastoralists and agro-pastoralists. Despite its importance, the productivity and economic contribution of the sub-sector is challenged by various technical, socio- economic, political and institutional constraints.

Among the technical constraints, issues related to feed scarcity (quantitative and qualitative dimensions) are the overriding ones, primarily because of biological, economic and environmental issues. Biologically, the process of animal production is virtually a conversion of low quality products with limited alternative uses such as by-products into high quality products such as milk, meat and egg. In this process the quantity and quality of the livestock product is largely a function of the type of feed used and the art of feeding. There are substantial proofs that at the field level both production and reproductive performance are heavily constrained by the quantity and quality of feed. In economic terms, the feed cost usually accounts for 70% of the total cost of livestock production. This influences not only the productivity but also the feasibility of the enterprise. In terms of environmental issues, aspects of making livestock production compatible with resources are basically a function of provision of feed and an appropriate feeding system. Given appropriate management, livestock production is harmonious with the environment.

The current feed supply in the West Shewa Zone is very much lower than what is required. A situation analysis of the current scenario further indicates additional factors that are a burden on the demand side. Realizing the current market opportunities of livestock and livestock products, they are anticipated to double the volume of livestock products in the coming 3-5 years. Moreover, various livestock feeds (roughage and industrial by-products) are being exported, which leads to serious competition with local uses. In addition, the recurrent drought also exerts pressure on the feed resource base. This has partially led to an exorbitant price of feed. The allocation of pasture lands for some other uses (urbanization and expansion of flower production) is expected to reduce the supply of hay for Addis Ababa dairy farms. As a follow-up of this trend, dairy farmers around Addis Ababa have shifted the feeding practices of lactating dairy cows (the contribution of hay in a daily diet is currently about 30% and the usual level used to be as high as 70%). Such a level is not recommended from a ruminant nutrition perspective and has a negative influence on feed conversion efficiency.

Apart from various limitations, opportunities also exist to improve the feed industry in general and assist the livestock sub-sector to contribute to food security and poverty reduction. Technical interventions for improving the feed supply base and optimised utilization of various feed resources exist both from a research perspective and in terms of community innovations systems. Roughage sources such as native hay and crop residue were collected and conserved, while the availability of industrial by-products were mapped to account for their temporal and spatial distribution and made available to users at a reasonable price. Because of underdeveloped infrastructure and marketing system, some of the by-products are not efficiently utilised. Beyond technical and socio-economic issues, there are also institutional issues in connection with delivering services. Government institutions with the current set up and capacity are not in a position to fulfill all the needs in the areas of feed industry. The demand is much higher than the current capacity and there seems to be a need to fill the gap to improve the delivery of services in the provision of feed and guidelines for the feeding system. The decline in feed balance (feed availability per TLU) and the need to increase livestock production/productivity has a serious impact on natural resources. Deliberate decisions and strategic choices regarding feed production and utilisation have to be made in order to accomplish sustainable livestock production. In this review paper the features of the West shewa zone pertinent to natural resources, livestock and feed production are highlighted, research and development experiences in animal feeds and nutrition are reviewed and recommendations are made to guide sustainable livestock production.

2. Features of the West Shewa Zone

With its capital city 120 km west of Addis Ababa and consisting of 13 districts, the West Shewa Zone is one of the administrative zones of the Oromiya Regional State. With its variable agro-ecology and farming system the zone enjoys the following resources:

2.1. Agro-ecology

The West Shewa Zone encompasses low land, mid altitude and high land environments with respective shares of 25%, 30% and 45% (Table 1 and 2). Districts dominated by low land environment are Ginderberet, Nonno, Bako-tibie, Meta-Robi and Adeberga, while districts such as Ejere, Ambo, Cheliya, Danno, Dendi and Welmera are dominated by mid altitude. Districts representing typical highland environments are Jeldu and Tikurenchini.

2.2. Human population

With a population of almost 2 million, the West Shewa Zone accounts for 9% of the total population in the regional state (Table 3). The rural population accounts for about 96% of the total population in the zone, while the urban population accounts for 4%. The total population density of the zone is estimated at 127 persons km^{-2} and population density varied considerably among the districts. The most densely populated districts were Bakotiobie, Welmera, Ambo, Metarobi, Dendi, Ejere and Jeldu with a population density of > 130 persons km^{-2} each. Sparsely populated districts include Gindeberet, Nano and Adeberga with a population density of < 103 persons km^{-2} each.

2.3. Land-use pattern

The west Shewa zone has a total land area of 1.5 million ha. Cultivated land and grazing areas account for 49% and 22% of the total area of the zone, respectively (Table 4).

2.4. Livestock resources

Current estimates of the livestock resource base in the west Shewa zone suggest 1.23 million cattle, 43.000 sheep, 19.000 goats, 207.000 equines on a tropical livestock unit basis and 1.2 million poultry, accounting for 13% of the total grazing herbivore and 9% of poultry in the regional state (Table 5). Cattle accounts for 82% of the total grazing herbivore, while small ruminants and equines account for the rest. In terms of cattle population, the most densely populated *weredas* are Gendeberet, Cheliya, Dendi, Jeldu and Ambo, accounting for 56% of the total cattle population in the zone.

2.5 Feed resources

2.5.1. Basal diet

Accurate estimates of the zonal feed resource base are not yet available and attempts are usually made to make best approximation using estimates of production/productivity. The relative contribution and major sources of livestock feed were identified and their relative contribution has been approximated recently by the CSA (2003). The available information suggests that grazing/green feed, crop residues, hay, by-products and other feeds are the major classes of feed resources, with a relative contribution of 74%, 20%, 2%, 1% and 3%, respectively (Table 6).

The major sources of basal diet for the grazing herbivore are grazing pasture, crop residues and stubble grazing. Based on the land mass and average productivity and grain yield data of crops, better estimates of feed resource availability can be made (Table 7). As indicated in Table 7, grazing pasture accounts for 28%, while crop residues and stubble grazing account for about 62% and 10%, respectively. Total feed resources available per TLU vary from district to district, with an average of 1.35 t TLU^{-1}. The three districts that have a fairly adequate basal diet (1.7-2.96t TLU) are Danno, Bako-tibe and Nanno. The majority of the *weredas* (7) belong to the cluster representing modest feed availability (1.2-1.5t TLU^{-1}), which is about 70% of the threshold required for the maintenance of one TLU per annum. *Weredas* in this cluster include Cheliya, Adeberga, Metarobi, Ejere, Dendi, Jeldu and Gindeberet. *Weredas* with severe feed shortage (1.0t TLU^{-1}) include Tikur Enchini, Welmera and Ambo. The estimates suggest that most of the districts are operating under severe feed shortage, while only a few of them are securely provided with sufficient amounts of feed. Grazing herbivores depend on native pasture in some *weredas* (Adebega, Gindeberet), while in others (Cheliya, Welemera) crop residues are the main basal diet. The following sections comprehensively describe the status of each basal diet in the zone.

2.5.2 Grazing pasture

A total of 81.388 ha of grazing land are estimated to be available in the western Shewa zone (Table 8). The current scenario of grazing pressure on native pasture in the zone indicates an average stocking rate of 2.4 TLU within the range of 0.5 TLU ha^{-1} in Metarobi to 83 TLU ha^{-1} in Gindeberet. Districts with the highest grazing intensity include Gindeberet,Tikur enchini and Bako tibie, with a grazing intensity of 36-83 TLU ha^{-1}. Districts with the lowest grazing intensity include Metarobi, Adeberga, Nanno and Welmera with a grazing intensity of 5-16 TLU ha^{-1}.

2.5.3 Crop residues

About two million tons of crop residues are produced annually in the zone and these feed resources constitute nearly 50% of the basal diet of the herbivore livestock in the zone. Cereal straws account for 95%, while legume residues account for the rest. Among cereal crop residues, straws from large cereals (maize, sorghum) account for 43%, while small cereals account for 48%.

Estimates on the availability of crop residues usually depend on harvest indices under research conditions (Nordbloom 1988). The availability of crop residues varies from district to district. Under consideration of field losses and alternative uses, about 1.22 million tons of crop residues are annually available for livestock feed (Table 9). Six districts, namely Gindeberet, Cheliya, Danno, Ambo, Bako-tibie and Nano, account for about 70% of the crop residue available for livestock feed in the zone. These districts also account for more than 50% of the grazing herbivores in the zone. Residues of small cereals account for 54% of the total crop residues, while residues of large cereals and pulses account for 42 and 4%, respectively. Accounting for 41% of the total crop residues *tef* straw is the single most important crop residue, followed by maize stover and sorghum stover with respective shares of 28 and 14% of the total crop residues produced in the zone. The available crop residue per ruminant population per annum varies from 0.22 tons in Tikur Enchini to 0.81 to 2.1t TLU^{-1}

annum^{-1} in Danno, with a mean of 0.81 t TLU^{-1} annum^{-1} (Table 10).

2.5.4. Agro-industrial/industrial by-products and compound feeds

Various agro-industrial by-products are produced in the zone or adjacent sites (Table 11).

3. An overview of research findings

Institutions responsible for undertaking animal feeds and nutrition research include the Holetta and Bako Agricultural Research Centers. Research in this discipline like any other disciplines has started in the mid 1960's at the Department of Animal Sciences. In the mid 1980's, animal feeds and nutrition research was streamlined as a research division in both institutions. Later in the mid 1990's, with the new proclamation which established The Ethiopian Agricultural Research Organization (EARO), Animal Feeds and Nutrition was reorganised as a national Research Programme encompassing two projects ("Forage and Pasture" and "Animal Nutrition"). With the new set-up of the research extension "Farmer Linkage Advisory Council", the west Shewa zone falls under the mandate of the Holetta Research Center. The following review therefore mainly focuses on the findings of the Holetta Research center and other institutions deemed necessary. In the following sections findings are highlighted on the basis of feed categories.

3.1. Native pasture

3.1.1. Botanical composition

Seasonally water-logged grazing areas were noted to be dominated by grass species such as *Adropogon abyssinicus*, *Pennisetum* and *Cyperus/Sedge*. The proportion of legumes in this type of grazing land is very low (Table 12). The relative abundance of pasture species varies from place to place, depending on the intensity of water-logging. In seasonally water-logged areas *Andropogon abyssinicus* and *Cyperus/sedge* are highly dominating. But the proportion of legumes is increasing and has already improved in relatively drained and totally drained pasture areas (Table 12). The availability of this type of pastureland is very rare, as it was mostly utilised for the cultivation of crop rather than grazing in both districts. Humphrey (1978) has emphasised that some pastures and soils are more easily invaded by weeds than others. For instance, *Cenchrus ciliaris* is resistant to invasion under heavily stocked conditions; *Panicum maximum* is more vulnerable in this respect. As indicated by Lulseged (1985), overgrazed grasslands, particularly in the highlands, are dominated by Pennisetum schimperi, which is a coarse, unpalatable grass. Similarly, *Cyperus/sedge* species are more resistant to water-logging than other species. The overall proportion of legumes in commonly used pasture in both districts is very low.

3.1.2. Productivity of natural pasture

In the highlands there seems to be enough forage during the wet season and soon after. The average dry matter yields of relatively drained (not freely drained) natural pasture are 9.54, 0.65 and 0.16 DM ha^{-1}; 2.48, 0.58, and 0.56 DM ha^{-1} at Sululta-Mullo and Adeberga districts during the main, dry and "Belg" seasons, respectively. The reason why it seems high during the main season is that during this time the seasonally water-logged grazing area is preserved for hay preparation. After the hay harvest animals are allowed to graze. After the harvest of hay, the DM forage yield declines dramatically (Table 13). This conforms to the assessment made by Zinash and Seyuom (1991), who report a remarkable seasonality in the yield and quality of native pasture in the central highlands.

The DM yield of natural pasture is better in seasonally water-logged areas, which are reserved for hay preparation, than in the relatively drained areas. The average forage DM yields are 13.98t DM ha^{-1} at Sululta - Mullo and 11.36t DM ha^{-1} at Adaberga during the main season. This complies with the work of Alemu T. (1991), who reported that protected fallow lands reserved for hay preparation in Arjo Awraja give a herbage yield of 9t ha^{-1} and highly grazed old grasslands 5t ha^{-1} DM at altitude ranges of 2000 – 2500m The species composition of the relatively drained areas is good. Relatively drained and drained natural pastures have a better legumes composition than seasonally water-logged grazing areas (Table 13). As stated by IDRC (1985), in the highlands annual native pasture yields range from 1 to 2t DM ha^{-1} on freely drained, relatively infertile soils and up to 4-6t DM ha^{-1} from seasonally water-logged fertile areas. Similarly, in this study the mean annual yields of relatively (not freely) drained pasture were found to be 3.45t DM ha^{-1} in Sululta - Mullo and 4.35t DM ha^{-1} in the Adaberga district; whereby the seasonally water-logged pasture area shows 4.96t DM ha^{-1} at Sululta - Mullo and 4.35t DM ha^{-1} in the Adaberga district.

During the main season attempts were made to determine the forage DM yield of dominant pasture species mainly by grouping them into broad categories such as grasses, legumes and forbs. As indicated in Table 14, grasses constitute the highest proportion of the total forage DM yield across all the areas. In contrast to this, in all types of natural pasture assessed across the districts, the contribution of legumes to the total yield was very low.

3. 1.3. Quality of natural pasture

The productivity of natural pastures in seasonally water-logged areas in the highlands has a high potential for dairy production if properly managed. This type of pasture even has a relatively good quality. The problem is that the pasture is not used for hay preparation, especially in the Ada Berga areas. Therefore, the farmers in this area have to practice hay-making instead of using the pasture as standing hay. In other areas intervention in pasture management has to be carried out in order to support dairy production. The second major limitation is the inherently low nutritional quality of feed resources. Because of its seasonality in quality, native pasture cannot support the maintenance requirement and animals often lose about 20% of their live weight, especially during the dry season of the year (Figure 1).

3.2. Crop residues

3.2.1. Chemical composition

Crop residues are generally characterised by a low CP but high amounts of cell wall and cell wall constituents (Table 15). Their crude protein content is lower than the threshold required for a positive N balance in an animal. The fiber content is also higher than the value suggested to limit the intake of animals. Among cereal crop residues, the crude protein content of *teff* straw is higher than that of wheat straw and close to that of barley straw and native hay. By-products of food legumes have relatively higher amounts of crude protein and less total fiber as compared to cereal crop residues.

3.2.2. Digestibility and energy value

Cereal crop residues are normally characterised by low digestibility and energy value, which are both inherent in their chemical composition. The mean in vitro digestibility of some cereal crop residues shown in Table 16 is about 48%, which is lower than the minimum level required for quality roughage.

Because of their higher N content, most of the residues of food legumes have a better digestibility and a higher energy value. The in vitro digestibility and the energy value of *teff* straw are higher than those of the other cereal crop residues (wheat or barley straw) and closer to that of native hay.

3.2.3. Voluntary intake

The reported voluntary intake of cereal crop residues is summarised in Table 17. Oats straw has the highest voluntary intake followed by *teff* straw. The voluntary intake of *teff* straw varies from 1.63% to 2.5% and from 1.87% to 1.91% of live weight for small ruminants and large ruminants, respectively. The mean voluntary intake of teff straw reported so far is 48g kg^{-1} 0.75 for small ruminants, which is lower than the expected level (79g kg^{-1} 0.75) required for a good quality forage (Leng 1985). The fiber (cell wall) intake of teff straw varies from 30-42g kg^{-1} 0.75 which complies with the theory that sheep can consume about 40g cell wall per kg metabolic body size. The calculated cell wall intake for large ruminants is fairly constant (52.7g kg^{-1} 0.75) and higher than that of small ruminants.

3.2.4. Rumen degradability characteristics

The ruminal degradability profiles of crop residues and other roughage are given in Table 18. *Teff* straw has a higher potential degradability than barley straw but it is similar to that of native hay. Since ruminal degradability parameters of fibrous feeds can explain most of the variations (r=0.95) in feed quality and animal response (Orskov 1989), it is appropriate to expect more animal production from diets based on *teff* straw than on other crop residues.

3.2.5. Animal performance based on crop residue

Un-supplemented diets

Because of its low amount of N, high cell wall and slow digestion, animals kept on a sole *teff* straw diet cannot maintain their N balance. Especially growing animals may lose weight due to their high N requirements. Losses up to 75g day^{-1} have been reported for young calves fed on a sole diet of *teff* straw (Abule 1994). The estimated nutrient supply from *teff* straw when fed alone to ruminants is given in Table 19. The energy supply is marginal to maintenance requirement, while the protein supply is far below the maintenance requirement. The growth rate or production level of animals fed solely on *teff* straw is primarily limited by the supply of essential amino acids to the tissues.

Animals fed on a basal diet of wheat straw often fail to extract nutrients required for maintenance purposes. The nutrient supply from an average quality wheat straw covers only 90% and 45% of maintenance requirement in terms of protein and energy needs, respectively, while the nutrient supply from a teff straw diet is 70% of protein needs and 111% of energy needs (Table 19). Because of its low amount of N, high cell wall and slow digestion, animals kept on a sole wheat straw diet cannot maintain their N balance. Especially growing animals may lose substantial weight due to their high N requirement. The primary limitation in a straw-based diet is therefore N supply, both quantitatively and qualitatively.

Supplemented diets

Animal performances on diets based on supplemented crop residue vary considerably depending on the type and level of supplements (Table 20). Supplemented crop residue diets can support a mean live weight gain of about 555g day^{-1} for local animals, while the growth performance for crossbred cattle on similar diets varied from 820 to 940g day^{-1} with a mean of 907g day^{-1}. Experimental evidence on a teff straw based diet suggests a live weight gain of 629g day^{-1} for indigenous animals. This performance was about 78%, 56% and 32% higher than the performance of similar animals fed on a basal diet of wheat straw, oats hay and native hay.

In a series of trials where maize residue was used as a basal diet at the level of 35-50% of the daily intake and supplemented with concentrate, growth performances of about 750g day^{-1} and 913 g day^{-1} were obtained for native steers and crossbred bulls, respectively (Alemu *et al.* 1978, O'Donovan and Alemu 1978). At a 50% inclusion of maize residues, the reported figures suggest a daily gain of 650g for native steers.

3.2.6. Strategies to enhance the utilisation of crop residues as livestock feed

Animals tend to consume a lower amount of feed with low digestibility and a poor rate of digestion. This results in low consumption of nutrients. Digestibility and intake of straw can be increased by chemical treatment, and if accompanied by supplementation, better animal responses can be attained. Various chemical treatments have been used to overcome the problems of digestibility plus low feed intake and to increase the potential rate and extent of digestibility of fibrous feeds. Among the chemicals used to treat crop residues, the dominant ones are urea and sodium hydroxide.

The use of the fertiliser urea to upgrade the nutritive value of crop residue has been explored in various regions and quite encouraging results have been reported (Tables 21 and 22). In general, the benefits of urea treatment are increasing digestibility, voluntary intake, protein and animal performance. Changes in the chemical composition in response to urea treatment are variable, depending on the composition of the crop residue. The crude protein content of crop residue could be increased by 2.5 (from 4 to 10%) in response to urea treatment, while the improvement in voluntary intake is about 25% (from 78 to 98g kg^{-1} metabolic body weight).

A quite substantial amount of improvement in animal performance has been obtained, especially if the treated crop residue is supplemented by appropriate supplements. Results from experiments in Bangladesh and Sri Lanka have been reviewed by Preston and Leng (1984). Their review indicates that a treated residue can support a daily gain of 500g of young growing cattle with a small amount of by-pass supplement. Urea treatment of straw can also make the preservation of the straw possible. It causes ammonia decomposition with improved digestibility by the hydrolytic cleavage of the urea and the release of ammonia. With such a practice, the addition of easily soluble carbohydrate (such as molasses) to the straw, in combination with urea treatment, has a positive effect. The residual un-decomposed urea in the straw material can also serve as an ideal N source for rumen organisms. The use of urea treated crop residue is a biologically and economically feasible option for an optimised use of crop residue as perceived by farmers (Table 23).

An assessment of the economic viability of straw treatment has been investigated by Schere and Ibrahim (1989) for different types and levels of production and has led to the conclusion illustrated in Table 24.
The decision on the use of straw ammoniation, supplementation or a combination of both is governed by the input prices relative to each other, labour costs, the animals' productive state and production level, as well as the price for animal products.

3.3. Agro-industrial by-products

3.3.1. Availability

There is no resource base study undertaken so far to describe the quantity and distribution of agro-industrial by-products in Ethiopia. Estimates of MOA (1985) suggest a total of 680.000t of agro-industrial by-products to be annually produced in the country. This figure can be increased substantially because of an increase in cottage industries and an increase in raw material production over the last 15 years. The major agro-industrial by-products include oilseed cakes, flour mill by-products and grain screenings, molasses, brewer's grain, coffee pulp and slaughter by-products.

3.3.2. Nutritional characteristics

Table 25 illustrates research undertaken to characterise and assess the supplementary value of agro-industrial by-products produced in Ethiopia.

3.2.3. Improved forage and pasture crops

In the long term research endeavors of the forage and research activities of HARC, more than ten forage species were identified. Recommendations have been issued for different agro-ecological zones. The overall yield improvement was four to six times the productivity of native pasture (Table 26).

4. An overview of on-farm testing and technology transfer efforts

4.1. Forage development efforts on farmer's field

Promising forage and pasture crops for various agro-ecological zones have been identified. The best ones have been advanced to on-farm testing, demonstration and promotion. On-farm forage development efforts have been launched in four districts (two from west Shewa and the other two from south-west Shewa), involving a total of 57 farmers (Table 27). The biomass productivity of the selected forage crops and farmers' reactions are quite encouraging. Available information suggests that the economic benefit derived from the use of these feed resources is the major determinant for the adoption of the mixed crop livestock system. Strategic choices in terms of species and varieties coupled with an appropriate method of integration into the farming system need to be considered for a sustainable feed production in the zone.

4.2. On-farm testing of nutritional interventions in various farming system

Biological and economic benefits can also be attained by an optimal utilisation of available feed resources. This strategic choice helps to reduce the pressure on natural resources and serves as a basis for sustainable livestock development. Best bet technologies/knowledge have been tested in various farming systems of the country. Because of their wider application to similar environments, the results achieved thus far, the lessons learned and their implications for the west Shewa zone are described below.

4.2.1. Multi-nutrient block and supplementary protein source

The use of a multi-nutrient block and of a supplementary protein source have been tested in the mixed crop livestock, pastoral/agro-pastoral and peri-urban livestock production systems (Table 28). The results (Table 29) achieved so far suggest that this intervention can double the milk production of cross bred cows (in the mixed crop livestock system) and of local cows (pastoral/agro-pastoral). Responses in the peri-urban production system are marginal and depend on the feeding practices followed in each farm.

4.2.2. Use of urea treated crop residue in ruminant diet

Urea treated wheat and *teff* straws have been tested in the diet of lactating zebu cows at Adadi and crossbred cows at Kuyu, respectively, taking into consideration a total of 22 farmers and 44 experimental animals. The results suggest that it is possible to increase the milk production of zebu cows from 1.3 to 2.3l cow^{-1} day^{-1} and that of crossbred cows from 3.35 to 6.90l cow^{-1} day^{-1}. This implies a 105% improvement for crossbred and 77% improvement for local cows compared to farmers' practice. The use of urea treated crop residue in fattening diet also suggests that it is possible to increase the weight gain of zebu oxen from 0.71kg animal^{-1} day^{-1} to 1.0kg animal^{-1} day^{-1}, implying a 50% improvement in live weight gain of local oxen as compared to the farmers' conventional practice.

5. Conclusions and recommendations

Based on research and development experiences in the zone and in similar environments, the following conclusions and recommendation can be made:

- The diversity of the zone in terms of agro-ecology, farming systems and resource bases requires a thorough study supported by modern tools in order to characterise the environment.
- Cattle account for 82% of the grazing herbivore in the West Shewa Zone.
- The respective contribution of crop residues, native pasture, and aftermath grazing is 62%, 28% and 10 %, respectively.
- The current scenario of grazing pressure on native pasture in the zone is 24 TLU ha^{-1}, ranging from 5 TLU in Meta-robi to 83 TLU in Gindeberet.
- The current feed supply in the zone amounts to only 70% of the annual feed requirement for maintenance purposes.
- The three districts which have a fairly adequate basal diet (1.7-2.96t TLU^{-1}) are Danno, Bako-tibie and Nonno.
- Districts under severe feed shortage (less than 1t DM TLU^{-1}) include Tikurenchini, Welmera and Ambo.
- Experiences of on-farm testing of promising feed technologies carried out in this zone or in some others can be used to speed up the feed technology transfer.

References

Abule, E. (1994) *Performance of crossbred calves fed tef (Eragrosist tef) straw supplemented with graded levels of cow pea (Vigna unguiculata) and Dolichos lablab (Lablab purpureus) hay*. MSc thesis, Alemaya University of Agriculture, Alemaya, Ethiopia.

Alemu G.W., O'Donovan P.B., Hailu G.M, Beyene K. and Galal E.S.E. (1978) Fattening studies with crossbred bulls. Rate and efficiency of gain on diets of maize stover residues and concentrates. *J Agric Sci* (Camb), 90: pp. 431-434.

Bonsi M.L.K., Osuji P.O., Nsahlai I.V. and Tuah A.K. (1994) Graded levels of *Sesbania sesban* and *Leucaeana leucocephala* as supplements to tef straw given to Ethiopian Menz sheep. *Anim Prod*, 59: pp. 235-244.

Butterworth M.H. and Mosi A.K. (1986) The voluntary intake and digestibility of different combination of cereal residues and legume hays for sheep. *ILCA Bulletin*, 24: pp. 14-17.

CSA (Central Statistics Office) (2003) *Agricultural sample survey 2001/2*. Report on area and production for major crops (private peasant holdings, meher season).

Ghiad E.G., El-Nouby H.M., Gomaa M. and Mohamed A.H. (1989) Digestibility and acceptability of ammoniated rice straw by sheep. *Proceedings of the Egyptian-British conference on animals, fish and poultry production*.

Gupta B.N., Chopra R.C and Kisan J. (1986) Studies on the influence of different sources of dietary Nitrogen on its metabolism in crossbred cattle. *Indian J of Anim Nutr*, 3: pp. 8-12.

Humphreys, L.R. (1978) *Tropical pastures and fodder crops*. Longman Group Ltd, London.

Institute of Agricultural Research (IAR) (1976) *Result of experiments in animal production.*

1966/67 to 1975 Animal Production Report No. 1, IAR, Addis Ababa, Ethiopia.

Ibrahim M.N.M., Fernando D.N.S. and Fernando, S.N.F.M. (1984) Evaluation of different methods of urea ammonia treatment for use at village level. In: *Proceedings of the third annual workshop of the AAFARR Network held at the University of Peradeniya, Sri Lanka, 17-22 April 1983.* School of Agriculture and Forestry, University of Melbourne, Parkville, Victoria: pp. 131-139.

Kearl, L.C. (1982) *Nutrient requirement of ruminants in developing countries*. International Feedstuffs Institute, Utah Agricultural Experiment Station, Logan, Utah.

Leng, R.A. (1985) Determining the nutritive value of forages. In: Blatir G.J., Ivory D.A., Evans T.R. (eds) *Forages in South East Asia and South Pacific Agriculture. Proceedings of an international workshop held at Cisrura, Indonesia, 19-23 August 1985.* Australian Center for Agricultural Research, No 12: pp. 112-123.

Lulseged G.H.and Alemu T. (1985) Pasture Research and Development in Ethiopia. In: Kategile J.A. (ed) *Pasture Improvement Research in Eastern and Southern Africa, pp. 77 – 92. Proceedings of a workshop held in Harare, Zimbabwe, 17-21 September 1984.* IDRC, Ottawa, Ont., IDRC.

Ministry of Agriculture (MOA) (1985) *Livestock sector review*. Addis Ababa, Ethiopia.

Nordbloom T. (1988) The importance of crop residues as feed resources in west Asia and north Africa. In: *Proceedings of plant breeding and the nutritive value of crop residues workshop held at ILCA, Addis Ababa, Ethiopia, 7-10 December, 1987*. ILCA, Addis Ababa, Ethiopia: pp. 41-63.

Nuwanyaka M.Y. and Butterworth M.H. (1986) Effects of urea, molasses, noug cake and legume hay on the intake and digestibility of teff straw by highland sheep. In: Arnab (ed) *Utilisation of agricultural byproducts as livestock feeds in Africa, pp. 87-98. Proceedings of a workshop*, Malawi, September, 1986.

O'Donovan P.B. and Alemu G.W. (1978) Maize residue based fattening diets for Zebu and crossbred cattle proceedings of IV world conference. *Animal production.* Buenos Aires, Argentina.

Olayiwale M.B., Butterworth M.H., Sayers A.R. and Olornju J.A. (1986) The effect of supplementing cereal straws with urea, trifolium hay and noug meal on feed intake and live weight gain of growing crossbred heifers. *ILCA Bulletin*, 24: pp. 18-20.

Ørskov E.R. (1989) Evaluation of feed resources for ruminants. Paper presented for the first *Research coordination meeting and development of feeding strategies for improving ruminant productivity in areas of fluctuating nutrient supply through the nuclear and related techniques.* 13-17 March 1989, Vienna International Center, Vienna, Austria.

Sadullah M., Haque M. and Dolberg F. (1981) Treated and untreated straw for growing cattle. In: *Proceedings of maximum livestock production from minimum land.* Department of Animal Science, Bangladesh Agricultural University: pp. 136-155.

Schere J.B. and Ibrahim M.N.M. (1989) *Feeding of urea ammonia treated straw.* A compilation of miscellaneous reports produced by the straw utilisation project, Sri Lanka.

Seyoum B. and Zinash S. (1989) *The composition of Ethiopian feedstuffs*. Research report No 6. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Seyoum B. (2004) *The effects of level of urea and treatment duration on chemical composition of cereal crop residues*. Paper presented on the national review meeting. Addis Ababa, Ethiopia.

Trung L.T., Palo L.P., Atrga T.A., Bein R.R. and

Plapind R.R. (1988) *Dose response of goats fed urea treated rice straw with varying supplementation rates: intake and digestibility by markers. Ruminant feeding systems utilizing fibrous agricultural crop residues*, Cambera, Australia, International development programme of Australian Universities and College Ltd: pp. 245-251.

Wanapat M., Praserusk S., Chnthai S. and Sinaphagum (1982) Effect on rice straw utilisation with ammonia released from urea and supplementation with casava chips. In: *Proceedings of the utilisation of fibrous agricultural residues as animal feeds.* School of Agriculture and Forestry, University of Melbourne, Paliville, Victoria: pp. 95-101.

Walli T.K., Subba R. A., Mahendra S.D.V., Rangnekar P.K., Pradhan R.B. *et al*. (1995) Urea treatment of straw. In: Kiran S. and Schiere J.B. (eds) *Handbook for straw feeding systems.* Indian consul of Agricultural Research and Department of Animal Production Systems, Agricultural University of Wageningen, The Netherlands.

Wanapat M., Srwattanasombat S. and Chanthal S. (1985) The utilisation of diets containing untreated rice straw, urea ammonia treated rice straw and water hyacinth. *Trop Anim Pro*, 10(1): pp. 50-57.

Zinash S. and Seyoum B. (1991) Utilisation of feed resources and feeding systems in the central zone of Ethiopia. *Proceedings of the third livestock improvement conference, 24-26 May 1989, Addis Ababa, Ethiopia.* Institute of Agricultural Research, Addis Ababa, Ethiopia: pp. 129-132.

Table 1: Agro-ecological classification of the West Shewa Zone (area overage in percent).

District	Highland 2500-3000 masl	Mid highland 1500-2500 masl	Low land <1500 masl	Total area (ha)
Gindeberet	-	40	60	236.903
Jeldu	60	32	8	139.387
Ambo	23	60	17	149.094
Cheliya	15	55	28	181.781
Bakotibe	12	37	51	64.469
Danno	5	80	15	65.912
Nanno	22	23	55	125.096
Tikurenchini	76	24	-	53.806
Dendi	30	60	10	151.338
Ejere	45	55	-	56.981
Adaberga	29	34	37	98.076
Welemera	45	46	-	75.500
Metarobi	20	35	45	93.768
Average	30	45	25	

Source: Zonal basic data (2000)

Table 2: Clustering of districts by dominant agro-ecology.

Agro-ecology	District	Range of coverage (%)	Contribution to zonal livestock population
High land	Tikurenchini, Jeldu	45-76	13
Mid-highland	Ejere, Ambo, Cheliya, Danno, Dendi,Welmera	46-80	49
Low land	Ginderberet, Nonno, Bako-tibie, Meta-Robi and Adeberga	37-60	36

Source: Zonal basic data (2000)

Table 3: Human population and estimated density of the west Shewa zone.

District	Area (km^2)	Population	Density (number km^{-2})
Gindeberet	2369	196.014	83
Jeldu	1394	180.759	130
Ambo	1491	221.022	148
Cheliya	1818	208.863	115
Bakotibe	645	105.638	164
Danno	659	82.105	124
Nanno	1251	120.493	96
Tikurenchini	538	64.093	119
Dendi	1513	206.917	137
Ejere	570	75.767	133
Adaberga	981	100.774	103
Welemera	755	114.531	152
Metarobi	937	134.453	143
Average			127

Source: Zonal basic data (2000).

Table 4: Land-use pattern of different districts of the West Shewa Zone (`000 ha).

Wereda	Total area	Cultivated land	Grass land	Forest	Others
Adeaberga	98	36	26	7	29
Ambo	149	103	4	11	31
Bako	64	35	15	3	11
Cheliya	182	107	39	14	22
Danno	66	35	18	8	5
Dendi	151	71	42	13	25
Ejere	57	32	11	10	4
Gindeberet	237	102	87	25	23
Jeldu	139	66	37	11	25
Metarobi	94	46	26	8	14
Nonno	125	51	20	42	12
Tikurenchini	54	14	1	3	36
Welmera	76	32	11	20	13
Total	1492	730	337	175	250
% contribution	**100**	**49**	**22**	**12**	**17**

Source: Zonal basic data for 2000

Table 5: Livestock population by district (TLU = Tropical Livestock Unit).

Region	Cattle	Sheep	Goats	Horse	Asses	Mule	**Total TLU**	Poultry	Bee hives	**% contri-bution**
Gindeberet	144819	1883	2639	7966	7390	521	**165218**	77331	21593	**10.71**
Jeldu	117930	7089	1889	13108	5589	473	**146078**	95160	101613	**9.47**
Ambo	148180	4895	3215	13542	14864	424	**185120**	138156	15145	**12.00**
Cheliya	149595	2186	1216	10582	9038	499	**173116**	145354	16507	**11.22**
Bakotibe	72523	702	524	1120	4612	1498	**80979**	97205	13666	**5.25**
Danno	64904	523	515	1180	2042	889	**70053**	77803	8382	**4.54**
Nanno	80499	1895	1169	6876	4840	1027	**96306**	108402	7766	**6.24**
Tikurenchini	42618	2690	329	10978	855	258	**57728**	89923	1602	**3.74**
Dendi	132083	7490	1732	18994	11728	670	**172697**	146390	8507	**11.20**
Ejere	47742	2319	593	5300	5829	422	**62205**	53377	2986	**4.03**
Adeberga	82400	3676	1773	5354	8416	363	**101982**	59635	7916	**6.60**
Welemera	61914	3393	649	5542	13594	113	**85205**	64575	3197	**5.52**
Metarobi	85430	3857	2740	5095	5868	234	**103224**	67102	9893	**6.69**
Total	1230637	42598	18983	105637	94665	7391	**1499911**			**100.00**

Source: CSA (2003)

Table 6: Estimates of feed resource utilisation (percentage of total use).

Region	Green fodder grazing	Crop residue	Improved feed	Hay	By-products	Others
Gindeberet	79.84	15.30	---	2.01	0.06	2.79
Jeldu	71.34	20.68	----	1.41	0.84	4.53
Ambo	76.36	18.71	0.10	1.55	0.53	2.73
Cheliya	79.80	15.58	0.02	0.77	0.20	3.54
Bakotobe	85.53	9.88	0.13	0,29	1.38	2.29
Danno	83.67	10.40	0.08	1.15	0.41	4.10
Nanno	80.33	14,75	----	0.09	0.02	4.82
Tikurenchini	86.82	10.01	0.01	0.31	0.39	2.47
Dendi	74.54	18.48	0.05	1.42	0.45	4.57
Ejere	57.00	36.97	0.20	1.79	0.24	3.81
Aseberga	75.43	16.55	0.06	3.84	0.16	3.95
Welemera	63.46	29.40	0.03	2.95	0.97	3.18
Dawo	51.24	42.60	----	1.72	3.12	1.26
Metarobi	72.57	17.29	0.07	6.34	0.03	3.91
Zonal mean	74.17	19.82	0.06	1.87	0.63	3.43
Regional mean	69.36	21.73	0.09	3.39	1.26	4.23

Source: CSA (2003)

Table 7: Estimates of feed availability (basal feed) in the west Shewa zone by district (`000 ton per annum).

District	Aftermath grazing	Crop residue	Grazing land	Total	Feed/TLU (t yr^{-1})
Gindeberet	17	145	50	212	1.28
Jeldu	16	89	74	179	1.23
Ambo	24	135	9	168	0.91
Cheliya	23	169	79	271	1.46
Bakotibe	10	105	31	146	1.80
Danno	18	146	36	200	2.96
Nanno	14	106	41	161	1.68
Tikurenchini	7	13	1	21	0.36
Dendi	23	91	85	199	1.15
Ejere	10	48	22	80	1.29
Adaberga	13	67	53	133	1.30
Welemera	9	32	21	62	0.73
Metarobi	8	74	52	134	1.30
All	192	1220	554	1966	1.35
Percentage contribution	10	62	28	100	

Table 8: Estimates of grazing pressure on natural pasture in the west Shewa zone by district.

Region	Grazing land in ha	Grazing herbivore (TLU)	Grazing intensity (TLU ha^{-1})	Feed/TLU
Gindeberet	1978	165218	83	1.28
Jeldu	6407	146078	23	1.23
Ambo	10352	185120	18	0.91
Cheliya	9395	173116	18	1.46
Bakotobe	2522	80979	32	1.80
Danno	2676	70053	26	2.96
Nanno	5857	96306	16	1.68
Tikurenchini	1590	57728	36	0.36
Dendi	15608	172697	11	1.15
Ejere	3068	62205	20	1.29
Aseberga	8476	101982	12	1.30
Welemera	5178	85205	16	0.73
Metarobi	8281	42526	5	1.30
All	81388	1499911	24	1.35

Table 9: Estimates of crop residue production by districts (`000 ton).

District	Tef	Barley	Wheat	Maize	Sorghum	Pulses	Total	Contribution (%)
Gindeberet	75	1	5	33	28	3	145	12
Jeldu	26	10	11	12	30	0	89	7
Ambo	60	12	11	27	17	8	135	11
Cheliya	47	9	11	73	22	7	169	14
Bakotibe	15	1	2	82	5	1	105	9
Danno	80	0	2	31	24	9	146	12
Nanno	30	6	2	44	20	4	106	9
Tikurenchini	2	8	1	2	0	0	13	1
Dendi	41	18	10	14	0	8	91	7
Ejere	26	5	4	2	5	6	48	4
Adaberga	44	4	4	8	2	5	67	5
Welemera	18	9	2	0	1	2	32	3
Metarobi	31	3	5	9	24	2	74	6
Total	495	86	69	337	178	55	1220	100
Contribution %	41	7	6	28	14	4	100	

Table 10: Zonal availability of crop residue in relation to livestock population in West Shewa.

District	Available straw (10^3t)	Livestock population (10^3)	Residue t TLU^{-1} $annum^{-1}$
Gindeberet	145	165	0.88
Jeldu	89	146	0.61
Ambo	135	185	0.73
Cheliya	169	173	0.98
Bakotibe	105	81	1.23
Danno	146	70	2.08
Nanno	106	96	1.10
Tikurenchini	13	58	0.22
Dendi	91	173	0.53
Ejere	48	62	0.77
Adaberga	67	102	0.66
Welemera	32	85	0.38
Metarobi	74	103	0.72
	1220	1500	0.81

Source: CSA (2003)

Table 11: Estimates of agro-industrial by-products and compound feeds.

By-product	Quantity (`000 t yr^{-1})	Remark	Sources
Oilseed cakes	116	Various zones of Oromiya 95% from East Shewa	OESPO (1999)
Wheat bran	54	East/west Shewa from four mills in Oromiya	OESPO (1999)
Coffee pulp	35	From Oromiya regional state	OESPO (1999)
Brewery by-product	76	From breweries in Oromiya and Addis Ababa	OESPO (1999)
Molasses	125	From three sugarcane factories in Oromiya	OESPO (1999)
Compound feeds	185	From four feed mixing plants in Addis Ababa and Oromiya	OESPO (1999)
Total	591		

Table 12: The proportion of botanical composition of natural pasture in West and North Shewa districts.

District	Dominant vegetation (%) at various sites								
	Enclosure			Seasonally water-logged			Relatively drained		
	Grasses	Legumes	Others	Grasses	Legumes	Others	Grasses	Legumes	Others
Suluta – Mullo	48.80	47.12	4.08	92.05	4.00	3.95	40.03	51.01	8.95
Were-jarso	----	----	----	74.8	23.00	2.20	----	----	----
Wuchale	59.20	13.00	27.80	-----	----	---	----	---	----
Ada Berga	59.37	24.81	15.82	79.97	11.87	8.16	87.48	4.13*	8.39
Ambo	46.60	13.20	58.8	78.20	18.00	---	---	---	--
Gindeberet	78.40	15.40	6.20	74.2	18.00	8.00	---	---	---

Note: there was undergrazing at the time of sampling.

Table 13 Average productivity (DM t ha^{-1}) of natural pasture in selected sites of the West and North Shewa Zones.

District	Site	Mean	Range
Adeberga	Relatively drained	1.21	0.58 - 2.48
	Seasonally water-logged	4.35	0.45 - 11.36
	Enclosure	14.69	
Gindeberet	Enclosure	2.53	1.66 - 3.36
	Seasonally water-logged	1.50	1.09 - 2.40
Ambo	Enclosure	1.63	0.92 - 3.13
	Seasonally water-logged	1.38	0.39 - 1.96
Dendi (Galessa)	Seasonally water-logged	0.55	0.1 1 - 1.14
Ejere (dobbi)	Enclosure	1.62	0.80 - 3.20
Ejere (Addisalem)	Enclosure	4.26	3.00 – 6.20
Welmera (HRC)	Enclosure	4.35	2.80 – 5.10
Welmera (Sademo)	Enclosure	1.94	0.80 – 4.50
Wuchale	Seasonally water-logged	1.98	0.66 - 3.04

Table 14: Average productivity (DM t ha^{-1}) of different species of natural pasture under different conditions during the main season of the year.

Site description	Pasture species	Average forage DM yield (t ha^{-1})	
		Sululta – Mullo district	Adaberga district
Seasonally water-logged	Grasses	12.31	12.46
	Legumes	0.27	0.51
	Forbs	0.23	0.31
	Total	12.81	13.28
Relatively drained	Grasses	7.51	10.38
	Legumes	2.37	Nil
	Forbs	0.45	Nil
	Total	10.33	10.38
Enclosure	Grasses	9.68	11.42
	Legumes	1.41	0.45
	Forbs	0.31	1.27
	Total	11.40	13.14

Table 15: Chemical composition of crop residues and other dry roughage (% DM basis).

Feed	DM	Ash	CP	NDF	ADF	Lignin
Teff straw (21)*	92.4	7.1	6.0	74.5	42.4	7.7
Wheat straw (10)*	92.9	7.2	3.9	77.2	48.2	7.9
Oats straw (2)	92.5	7.1	2.4	75.7	56.9	6.6
Barley straw (10)*	93.1	8.3	6.2	73.2	45.0	6.3
Fingermillet straw (3)	92.06	7.0	6.6	60.1	33.1	6.5
Chickpea straw (5)	92.8	9.8	4.4	54.9	41.1	11.1
Pea straw (4)	91.9	6.0	7.9	68.7	54.8	17.9
Beans straw (2)	92.5	8.7	5.9	66.5	54.2	11.1
Native hay (9)*	92.2	9.5	6.6	73.8	45.5	8.3

* Number in parenthesis indicates number of samples analysed
Source: Seyoum and Zinash (1989)

Table 16: In vitro digestibility and energy values of some crop residues and other roughage.

Feed type	No. of samples	IVDOMD (%)	EME (MJ kg^{-1})
Teff straw	14	53.20	8.35
Wheat straw	8	45.50	7.14
Barley straw	10	48.03	7.60
Lentil straw	1	62.80	9.40
Fababean straw	1	34.43	5.16
Beans straw	2	49.65	7.45
Pea straw	4	56.40	8.8
Lathyrus pea	1	55.20	8.3
Native hay	9	54.50	8.60

Table 17: Reported voluntary intake of crop residues.

No	Crop residue	Animal	Live weight	Dry matter intake		NDF intake g/$kgW^{0.75}$	Source
				percent live weight	G/$kgW^{0.75}$		
1	*Teff* straw	Sheep	17.9	1.81	37.3	29.69	Nuwanyakpa and Butterworth (1986)
2	*Teff* straw	Sheep	20	2.39	48.6	37.68	Butterworth and Mosi, (1986)
3	*Teff* straw	Sheep	21	2.50	52.6	41.55	Bonsi *et al.* (1994)
4	*Teff* straw	Sheep	16.7	1.94	72.1	55.61	Abule (1994)
5	*Teff* straw	Heifers	210	2,14	84.5	59.9	Olayiwale *et al.* (1986)
6	*Teff* straw			2.30	48.6		Butterworth and Mosi, (1986)
7	Wheat straw	Heifers	210	1.88	71.5	51.62	Olayiwale *et al.* (1986)
8	Wheat straw			2.10	44.4		Butterworth and Mosi, (1986)
9	Oats straw			2.70	57.1		Butterworth and Mosi, (1986)
10	Maize stover			2.00	42.3		Butterworth and Mosi, (1986)

Table 18: Nylon bag dry matter disappearances of crop residues and other roughage (%).

Feed	Dry matter disappearances at different incubation hour						
	0	9	24	36	48	72	96
Teff Straw	22.2	30.9	45.3	54.2	58.2	67.9	70.1
Wheat Straw	22.6	27.6	34.9	38.7	45.3	47.6	50.5
Native hay	25.5	30.7	43.6	55.6	61.4	66.0	68.4
Oats hay	37.0	41.2	55.3	64.0	68.8	70.7	72.3

Table 19: Nutrient supply of crop residues when fed alone to ruminants.

Basal diet	Animal		Nutrient supply as % of maintenance*	
	Type	Weight	Energy	Protein
Teff straw	Sheep	15	92	55
		25	107	62
		35	115	68
	Cattle	250	122	80
		350	114	78
		450	114	77
Wheat straw	Sheep	15	75	36
		25	87	40
		35	94	44
	Cattle	250	99	52
		350	93	50
		450	93	50
Mean			90	45

* Maintenance requirement (Kearl, 1982)

Table 20: Growth performance of ruminants fed on a basal diet crop residues.

Basal diet	Level of supplement	Experimental animal			Source
		Type	Weight (kg)	Growth (g day^{-1})	
Teff straw	50	Native steers	186	628	IAR (1976)
Teff straw	50	Native steers	193	438	IAR (1976)
Teff straw	45	Crossbred calves	158	503	Abule (1994)
Maize cobs	50	Native steers	190	541	IAR (1976)
Maize cobs	60	Native steers	212	990	Alemu *et al.* (1978)
Maize cobs	65	Crossbred bulls	192	990	O`Donovan and Alemu (1978)
Maize cobs	65	Native steers	192	690	O`Donovan and Alemu (1978)
Maize cobs	50	Crossbred bulls	212	950	O`Donovan and Alemu (1978)
Maize cobs	50	Native steers	212	750	O`Donovan and Alemu (1978)
Maize stover	70	Crossbred bulls	212	920	O`Donovan and Alemu (1978)
Maize stover	50	Crossbred bulls	212	820	O`Donovan and Alemu (1978)
Maize stalk	50	Crossbred bulls	205	950	O`Donovan and Alemu (1978)
Maize stalk	50	Native steers	205	650	O`Donovan and Alemu (1978)
Maize stalk	50	Crossbred bulls	197	810	O`Donovan and Alemu (1978)
Maize stalk	50	Native steers	197	640	O`Donovan and Alemu (1978)
Maize stover	50	Native steers	192	405	IAR (1976)
Wheat straw	50	Native steers	185	352	IAR (1976)
Haricot bean haulms	50	Native steers	193	505	IAR (1976)

Table 21: The influence of urea treatment on the crude protein content of crop residues (percent DM basis).

Residue	Untreated	Treated	Increase	Sources
Barley	3.7	7.0	3.1	Seyoum (2004)
Rice	4.8	9.2	4.4	Ghiad *et al.* (1989)
Rice	4.0	8.0	4.0	Wanapat *et al.* (1985)
Rice	4.0	16.0	12.0	Gupta *et al.* (1986)
Rice	5.9	8.5	2.6	Trung *et al.* (1988)
Rice	2.9	6.7	3.8	Sadullah *et al.* (1981)
Teff	3.1	7.7	4.6	Seyoum (2004)
Wheat	2.4	7.3	4.9	Seyoum (2004)
Wheat	4.0	14.0	10.0	Gupta *et al.* (1986)
Average	3.16	7.67	4.51	

Table 22. The influence of urea treatment on the digestibility of crop residues (% DM basis).

Residue	Untreated	Treated	Increase	Sources
Barely straw	48.0	58.0	10.0	Seyoum et al. (2004)
Teff straw	45.0	55.0	10.0	Seyoum et al. (2004)
Wheat straw	38.0	48.0	10.0	Seyoum et al. (2004)
Rice straw	46.0	54.0	8.0	Wanapt *et al.* (1982)
Rice straw	48..0	52.0	4.0	Ibrahim *et al.* (1984)
Average	45.0	53.4	8.4	

Table 23: Scientists' and farmers' perception of urea treatment.

<table>
<tr><td rowspan="8">Scientists' perception</td><td></td><td>Parameter</td><td>Unit</td><td>Improvement</td></tr>
<tr><td rowspan="3">1. Feed quality</td><td>CP</td><td>%</td><td>4-5</td></tr>
<tr><td>OMD</td><td>%</td><td>5-10</td></tr>
<tr><td>DMI</td><td>%</td><td>25-50</td></tr>
<tr><td rowspan="4">2. Animal response</td><td>Milk yield</td><td>litres</td><td>0.5-1.0</td></tr>
<tr><td>Growth on sole residue</td><td>g day^{-1}</td><td>50-100</td></tr>
<tr><td>Growth on treated residue</td><td>g day^{-1}</td><td>100-150</td></tr>
<tr><td>Milk on treated straw alone</td><td>l day^{-1}</td><td>2-4</td></tr>
<tr><td>Farmers' perception</td><td colspan="4">Increase in straw consumption
Better growth performance
Health improvement
Increase in milk yield (0.5-1.5 cow^{-1}day^{-1})
Increase in butter fat</td></tr>
</table>

Source: Walli et al. (1995)

Table 24: Recommendations on the use of urea treated straw.

Type of animal nutrient need/level of prod.	Viable feeding option
Few nutrients/maintenance	Untreated straw + supplement
Milk yield > 3 l	Treated straw
Growing animals, high gain	Treated straw + supplement
Milk yield > 8 l	Treated straw + supplement
Draught animals	Untreated straw

Table 25: Chemical composition and nutritive value of agro-industrial by-products.

By-product	DM	EE	CP	NDF	IVOMD	ME
Cottonseed cake	92.56	6.9	26.9	65.1	59.0	8.9
Flax seed cake	94.30	9.9	26.8	36.9	75.7	11.4
Noug seed cake	93.2	7.5	32.7	32.8	62.1	9.3
Wheat bran	92.46	2.7	18.9	53.1	87.1	13.0
Wheat middling	92.90	4.4	18.3	45.0	79.6	11.9
Brewers grain	23.75	3.51	24.90	63.5		
Sugarcane molasses	66.45	2.42	5.18	-	95.0	

Table 26: Number of recommended forage species for various agro-ecologies and their productivity as compared to native pasture.

Forage species	Highland (>2000 masl)	Mid-altitude (1500 – 2000 masl)	Low land (<1500 masl)	DM range t ha^{-1}	DM mean	Increment over native pasture %
Grasses	5	6	4	8 - 18	13	225
Herbaceous legumes	4	6	4	6 - 10	8	100
Browse species	1	2	2	9 - 12	10.5	163
Total	10*	14*	10*		10.5	163
Native pasture	Seasonally water-logged (rested)			3 - 5	4	
	Under continuous grazing			0.5 – 1.5	1	

* - As most forage crops have a wide adaptation, the figures account for a double count of a given forage species for the different agro-ecologies

Table 27: On-farm forage development efforts.

Forage	District	No. of farmers	Area covered (ha)	Estimated forage yield (t DM ha^{-1})	Total feed production (t DM)
Oats- vetch	Jeldu	18	9	10	90
	Kersa-kondaltiti	12	6	8	48
	Weliso	12	6	8	48
	Tikur-enchini	15	4	Not sampled	--
Tree lucerene	Jeldu	10	1500 seedlings	Not sampled	
	Tikurenchini	15	1500 seedlings	Not sampled	
Total	4 districts	57 farmers	25 ha, 3000 seedlings		186

Table 28: The set-up for on-farm testing of a multi-nutrient block (MNB).

Production system	No. of weredas	Household	Experimental animals
Crop–livestock	1	12-15	24-30
Peri-urban/urban	4	5 (farm)	60
Pastoral/agro-pastoral	1	22	44
Total	6	39 - 42	128-134

Table 29: The influence of nutritional intervention on the average daily milk yield (l) of lactating cows.

Production system	Site	Control	Intervention	Increase (l)
Crop livestock	Kuyu	3.09	7.47	4.38
Peri-urban/urban	Holetta	12.70	13.49	0.79
	Burayu	7.90	7.83	0.07
	Sebeta	10.10	10.79	0.69
	Karakore	10.52	9.32	-1.20
	Sululta	9.80	11.68	1.88
Pastoral/Agro-pastoral	Fentale	1.98	3.14	1.16

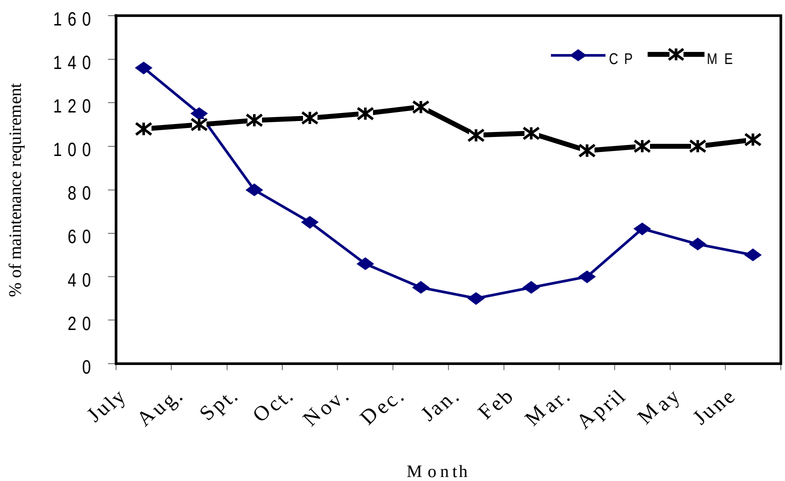

Figure 1: Amount of energy and protein provided by natural pasture expressed as percentage of the nutrient requirements for a 350kg steer.