INTEGRATING FODDER IN SMALL-SCALE FARMING SYSTEMS TO MEET CATTLE NEEDS IN SOUTHERN ETHIOPIA

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Contents

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Abbreviations

CP: Crude Protein (measured in grammes)

DCP: Digestible Crude Protein

DM: Dry Matter content of food (measured as a percentage)

DMI: Dry Matter Intake (measured in Kg)

IAF: Inter Aide France

ME: Metabolizable Energy (measured in MJ)

MJ: Mega Joules (quantity of energy available in food)

SUMMARY:

With the increasing pressure on land and natural resources, small-scale farmers of Wolayta and Kambata-Tembaro zones located in Southern Ethiopia are facing an acute fodder crisis, resulting in poor animal production performance: low milk quantity and quality, weak animals with low weight and uncertain survival rates for calves born.

Providing a balanced feeding to livestock all year long remains a critical challenge for most farmers. To overcome this major constraint, Inter Aide has promoted the integration of fodder grasses, and legume species, in southern Ethiopia during the last decade, according to farmers' needs and wishes.

This technical manual aimed at project technicians has been designed to support farmers in the process of **integrating diversified fodder production on their farms** while **minimizing interference with their traditional farming system,** in order to **preserve their land while responding to cattle needs** and **optimising milk and meat production**.

The first chapter presents the basic nutritional needs of cattle and the main measuring units used to measure the nutritive values of fodder as well as introducing various terminology related to animal nutrition. The second chapter presents the nutritive values of the various types of fodder and supplementary feeds available to farmers and explains how to estimate the energy and crude protein content of different rations. The third chapter introduces concrete examples of unbalanced and balanced cattle diets based on ration calculations according to observed local feeding practices.

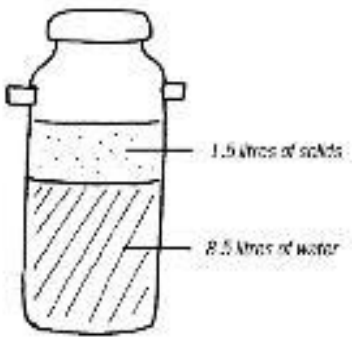
The fourth and fifth chapters give basic practical information on cultivated fodder production, explaining why, where and how various fodder species can be established within small-scale farmlands.

Finally, the 'References and Further Reading' section in appendix I provides useful links for additional information and bibliographical references with corresponding weblinks; and there is a useful section on practical recommendations to implement in appendix II: 'The ten golden rules of good feeding management for dairy cattle'.

CHAPTER 1: UNDERSTANDING BASIC ANIMAL NEEDS, RUMINANT PHYSIOLOGY AND FODDER CHARACTERISTICS

1 WATER AND FEED

Like all living beings, cattle need water and food to live.



a. Water

Water is necessary for:
1) Bodily functions (including maintaining a constant blood volume);
2) Animal digestion: microbes in the cow's stomach need water to live and break down plant fibres consumed;
3) Milk production: milk is made-up of 85-90% water;
4) Urine and faeces (to carry away toxic waste products from the body); and
5) To evaporate (mechanism of cooling the animal under hot conditions).

Cows and oxen need a lot of water. If they don't have enough water to drink, they will not eat as much as they can, and will produce less milk or meat. **Cattle need around 6L of water per 50kg body weight.**
Example: A traditional breed weighing 250 kg needs around 30L of water for its maintenance

Moreover, a milking cow needs around **5 liters of water for every liter of milk** it produces.
Example: a traditional breed producing 3 liters of milk per day needs 15 litres of water. A milking cow should always have available drinking water. If it is not possible, the cow should be provided with as much water as it can drink **2 to 3 times a day**.

Water is accessed in two ways: through the feed consumed and direct drinking. The amount of water needed by animals depends on several factors:

1) The **size of the animal**: large animals need more water
2) The **climate**: during the hotter dry season, animals drink 20 to 25% more water than in the cooler, rainy season.
3) The **type of feed**: animals fed with dry crop residues (straw, stover) need more water than animals fed with fresh fodder (grasses, tree leaves etc.).
4) The **way they are managed**: Animals staying outside in the sun get thirstier than cows staying indoors in a cowshed or barn.
5) Their "**activity**": Pregnant and milking animals, animals used for ploughing and improved breeds need more water.

b. Feed

Cattle need nutrients such as **energy, protein, minerals and vitamins** to perform basic bodily functions, reproduction and milk production.
Those nutrients are found in the **dry part of fodder** (i.e. part remaining after extraction of water).
Cows should be provided with a **balanced ration of forage 2 to 3 times a day**. The amount and quality of forage available to the animal will determine the amount of milk it produces

The amount of feed needed by an animal depends first on **its body size or live weight,** and on **its activity or condition:**

- ✓ Improved animal breeds, such as Holstein or Jersey cows, being bigger than traditional breeds and usually higher-yielding in terms of milk production, need to eat more food!

- ✓ Cows in lactation and/or pregnancy and oxen working in fields need more feed than animals resting or which are 'dry' (i.e. non-lactating) or not pregnant.

Moreover, **an animal should never be fed with only one type of fodder**. Different types of fodder should be combined together to satisfy the animals' needs.

2. BASIC RUMINANT PHYSIOLOGY

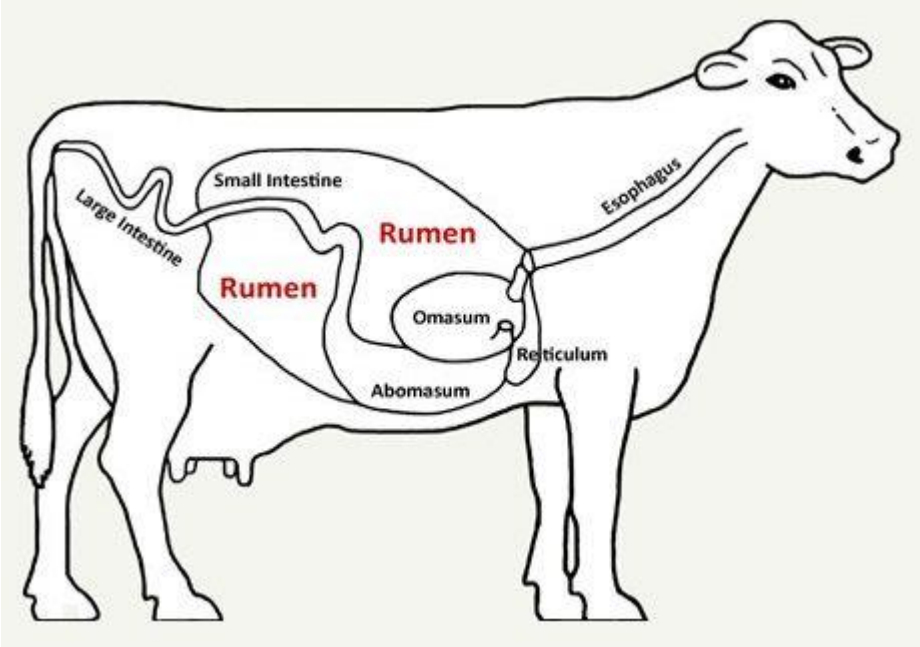
Cows are known as 'ruminants' because they 'ruminate' i.e.regurgitate food which has been consumed and passed into the stomach, and back from the stomach to the mouth again: this process faciliates the digestion of the complex fibrous compounds found in plants by the saliva (which contains digestive enzymes) as well as reducing the particle size of the fibre for the rumen microorganisms to act on.

a. The cow's digestive system

The cow has a complicated digestive system including the oesophagus (where food passes after being ingested), and four interlinked chambers or stomachs comprising:

- The **rumen**: the rumen can be considered as a large fermentation vat for holding the fibrous feeds and it is here where digestion properly starts to occur. It is large in size and can hold up to 150 litres of fluid (so necessitating a constant and accessible source of water to maintain the same volume). In this fibrous 'soup' are found millions of various microorganisms (bacteria, fungi and protozoa) which ferment and break down the fibrous complex plant wall structures (lignin, cellulose and hemicellulose) into smaller and simplified molecules ready for absorption and utilisation by the body.
- The **reticulum:** where fermentation by microorganisms continues.
- The **omasum:** here the food particles are reduced in size and water absorption occurs.
- The **abomasum:** the fourth compartment where food particles are digested by enzymes before being absorbed into the bloodstream and carried around the body to the various organs.

Figure 1: Simplified diagram of the cow's stomach



b. Rumen microorganisms

The rumen contains many billions of microorganisms such as bacteria, fungi and protozoa which live (and die) in the rumen, and whose principal role is to aid digestion of plant fodder sources by breaking down the complex fibrous compounds into smaller digestible particles (energy and protein) which can then be absorbed by the cow and used for various activities (growth, milk production, pregnancy etc.).

3. CRITERIA TO CHARACTERIZE THE NUTRITIVE VALUE OF FODDER

The quality of feed is measured by **the amount of nutrients that animals can take from the fodder**. This nutrient intake depends on **nutrient contents** and the **digestibility** of the fodder.

Nutrients content in fodder	The main nutrients are energy, protein, minerals and vitamins. They are contained **in the dry part of the fodder**, called **dry matter.**
Digestibility of the fodder	Only **part of the food** eaten by the cow **is digested**, and only the digested portion is used for body maintenance, reproduction and milk production
Intake	Animals can eat a limited amount of food. A simple rule for use on farms is that an animal can eat around **3% of its body weight in dry matter per day**

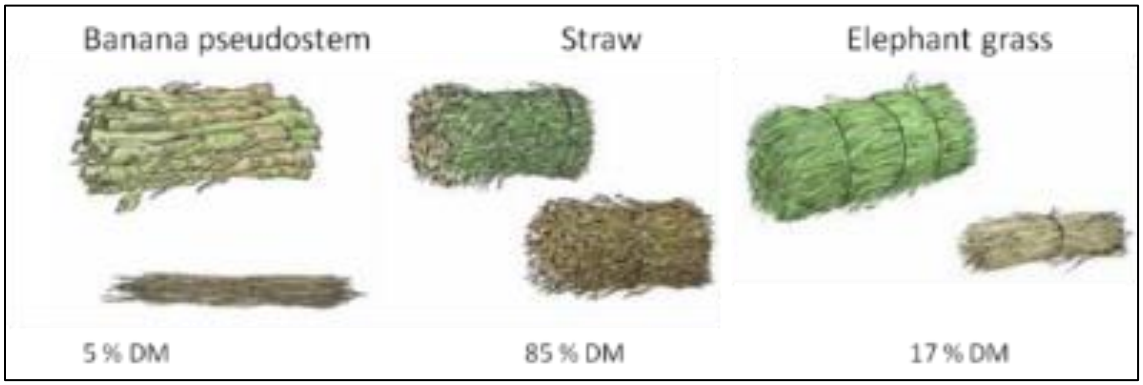
a. Understanding the concepts of dry matter (DM) and nutrient content (energy and protein)

The **dry matter is what remains in the forage after the water has been removed**. Dry matter is expressed as a percentage of fresh feed.

Example:

- Natural grass DM = 45 % => For 100 kg of natural grass, 55 kg are water and 45 kg are dry matter.
- Wheat straw DM = 90 % => For 100 kg of wheat straw, 10 kg are water and 90 kg are dry matter.

➔ **50 kg of natural grass** and **25 kg of wheat straw provide the same amount of dry matter**.



Animals must eat enough dry matter to supply them with nutrients essential for body maintenance, reproduction and milk production, in addition to water.

In order to simplify, only energy and protein are considered in the following paragraph as they represent the two major elements.

Forage content in nutrients is measured per kilogram of **dry matter.**

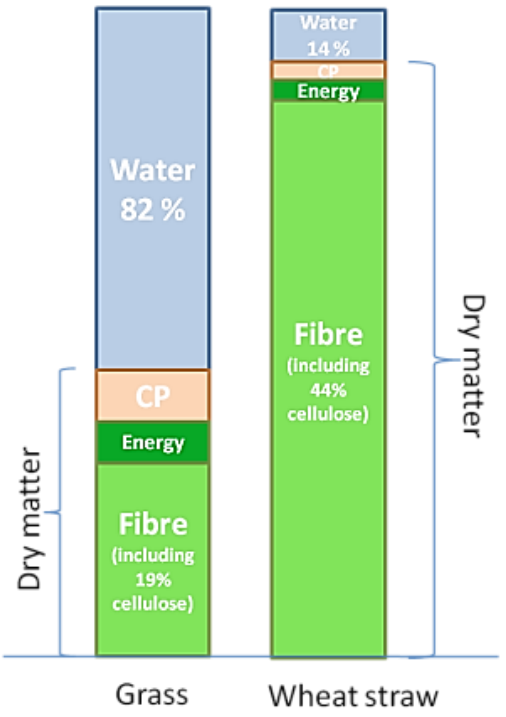


Figure 2: Graphs showing average food components of grass and wheat straw

Energy

The energy portion of feedstuff is used for all bodily functions, and for its activities such as milk production for dairy cows or ploughing for oxen. This is **the major nutrient, in terms of quantity, that cattle require**.

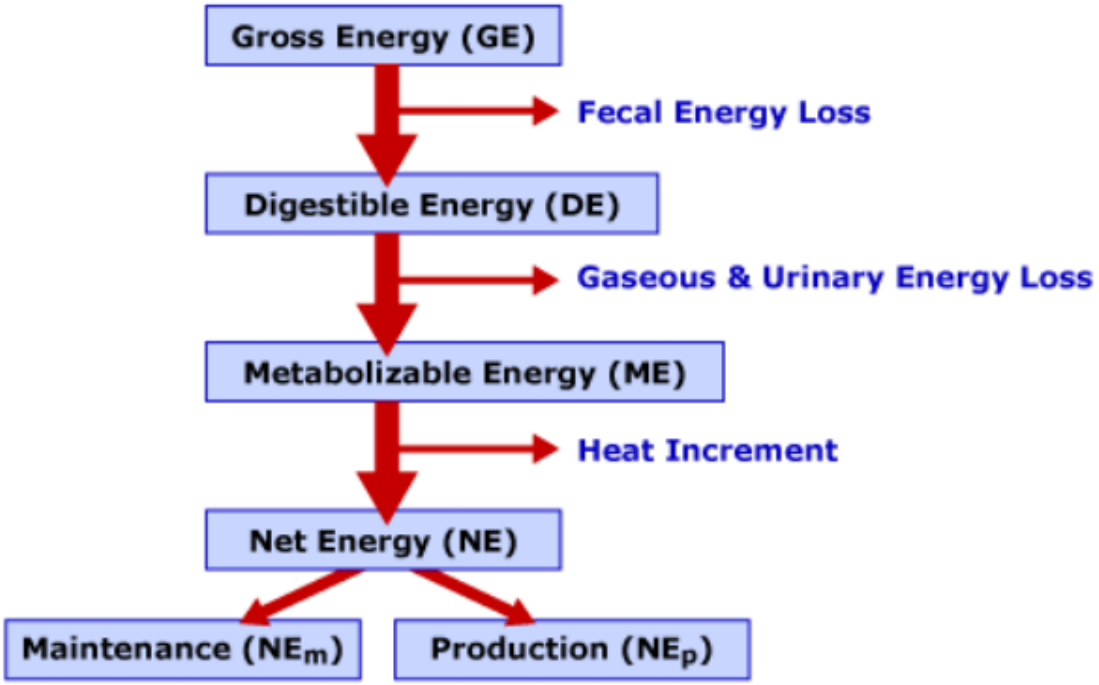
Energy can be obtained from several types of feedstuffs that contain either carbohydrates or lipids (fats and oils) or proteins. Carbohydrates are the major source of energy in the diet of dairy cows. Feeds contain three major types of carbohydrates:

- **Sugars**: Sugars are soluble in water, making them readily available to the animal. Sources are molasses or sugar cane.
- **Starch**: Starch is the main form of carbohydrate stored in cereal grains, fodder crops (e.g. maize) and some roots (potato tubers).
- **Fibre**: Forming the structural part of plants, fibre is present in large quantities in grasses, fodder crops and crop residues. Note: The fibrous content of the plant increases with the age of the plant.

Once food is consumed by ruminants it is digested (broken down) into digestible energy, metabolizable energy and net energy, with some of the food energy lost in faeces, urine, methane and even heat, as shown in the diagram below:

The common unit used to characterize energy needs or the energetic value of feedstuff is the **Metabolizable Energy (ME)** measured in megajoules (or MJ) per kilogramme of dry matter), which represents the amount of energy within the feedstuff that is digested and absorbed through the gut system of the animal for its bodily functions and eventually, for **production** (milk synthesis, growth of the foetus during pregnancy, draught power for ploughing etc.).

Figure 3: Partition of food energy in ruminants



Protein

Protein is **quantitatively the second most important nutrient in feeding cattle**. Proteins are also major components of milk and meat (muscle) and other tissues of the body, e.g. horns, hooves etc.

The measure of protein content is expressed in **Crude Protein (CP)**, which corresponds to the **nitrogen (N) content of digestible dried matter of the feed multiplied by 6.25**. It can be compared with the protein requirement of cattle which can also be presented in the form of CP; and is measured either as grammes **crude protein** per kilogram of dry matter (gr CP/kg DM) or as a percentage.

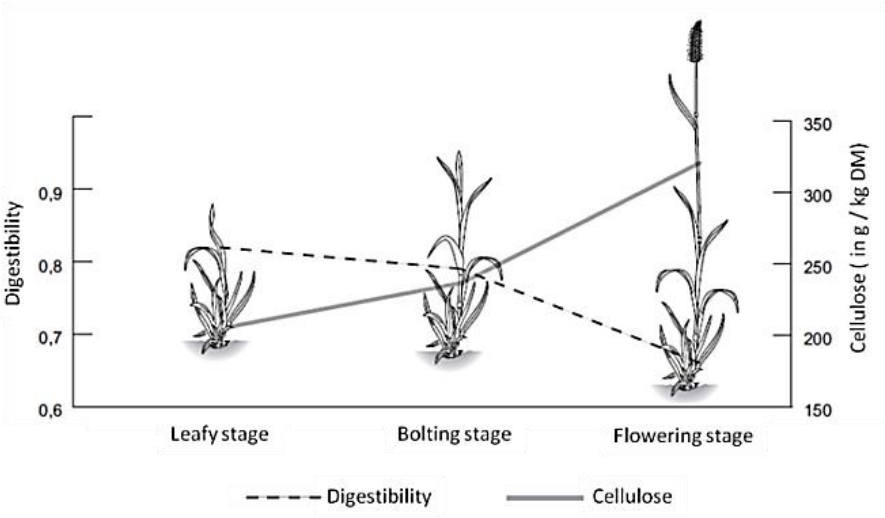
For most grasses and legumes species, the protein content increases with energy value. However, with an equal energy value, **legume species** present higher protein content than grasses; they are **one of the best natural sources of protein for feeding to cattle**.

b. Understanding the concept of Digestibility

The main factor causing variation of energy intake is **the digestibility of the energy** within the feedstuff. The decomposition of fibres is a long process and takes place within the cow's rumen or stomach. Long fibres such as those of grasses and cereal straws take a longer time to be digested than short fibres such as those of forage legumes and concentrate feeds. The longer the cell walls remain in the rumen, the less new feed can be eaten by the animal, so that **the bulk of the ration provides a physical control on feed intake**.

Figure 4: Graph showing increase in cellulose content and decrease in digestibility of fodder with time

*The **more the feed intake contains fibre, the longer the digestion**. **A good quality fodder has less fibre, so the cow eats more… and therefore produces more!***



The vegetation stage of fodder plays a significant role in digestibility: young grasses, which have many leaves but a small stem, are very digestible. When grasses become older, the proportion of stem (which contains a high amount of cellulose) increases, inducing a decrease in digestibility.

If the diminution of the energy value of fodder grasses and crops remains low during the leafy stage, it accelerates at the blooming stage (see figure 2 above). However, the decrease of digestibility of legume species with maturity is less important.

In this way, dry crop residues (wheat, teff straw, dry maize stover) have a low digestibility rate. A bundle of elephant grass harvested after 6 weeks' regrowth has less *lignin* than a bundle harvested after 8 weeks' regrowth, and thus has a better digestibility.

c. Feed Intake

A simple rule for use on farms for all types of animals is that **dry matter intake represents around 3% of the animal's weight**. A **traditional cattle breed** (250 kg) can eat maximum **7.5 kg of DM per day**, whereas an **improved breed's** intake can reach **10** to **12 kg DM a day**.

Cattle ingestion being limited, it is necessary to feed it with feedstuffs which are rich in nutrients and which take up little space.

Example: *Wheat straws are poor in nutrients and take up lots of space in the animal's digestive system. It is recommended to limit their ingestion and chop them in small pieces to facilitate digestion.*

CHAPTER 2: ANIMAL NEEDS AND FEEDING VALUES OF COMMON FODDER

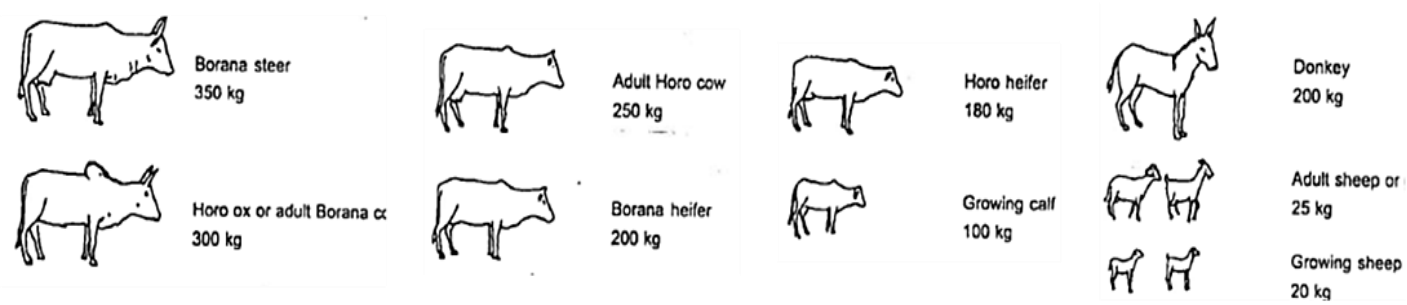
In order to optimize animal feeding and milk production, it is necessary to know the needs of the animal, and what nutrients different available fodder can bring.

1. Cattle needs for maintenance and production

a. Maintenance:

The first step consists in finding the energy and protein needs of the animal **for its body maintenance:** breathing, blood flow, movement etc. Those needs depend on the **live weight** of the animal:

Figure 5: Comparison of weights of various livestock



Knowing the weight of the animal, the energy and protein needs can be calculated using the following simplified formula:

$$\text{Energy needs} = \left(\frac{6 \times Body\ weight}{1000} + 1.4\right) \times 7.11 \text{ MJ/day}$$

$$\text{Protein needs} = \left(\frac{7 \times Body\ weight}{10} + 95\right) \text{ gr CP/day}$$

The average daily ME and CP allowance for maintenance for different cattle weights is presented in the following table:

Table 1: Daily ME and CP needs for maintenance for local and improved breeds of cattle:

	Live weight (kg)	Daily ME needs for maintenance (MJ/day)	Daily DCP needs for maintenance (gr/day)
Cow (traditional breed)	200 - 250	18 – 21	235 – 270
Ox (traditional breed)	300 - 350	23 – 25	305 – 340
Improved breed	400	27	375

b. Production:

The second step consists in adjusting the daily needs to get the required production. Milk and meat production are linked with the size of the animal, and thus with the quantity and quality of fodder intake.

For milk production: milk production requires additional energy and protein, which can be estimated using the following simplified formula:

$$\begin{cases} \text{Energy needs} = 3.2 \times \text{Number of liters of milk} & \text{MJ/ day x 50\%} \\ \text{Protein needs} = 50 \times \text{Number of liters of milk} & \text{gr DCP/day x 50\%} \end{cases}$$

For animal fattening: allow 9 MJ ME for every 100kg live weight per day for maintenance, plus 35 MJ ME/day for every 1kg of live weight gain.

Example: To fatten a traditional calf which weighs 150 kg and increase its daily weight by 2kg per day: 9+(9/2) = 13.5 MJ for maintenance + 35 x 2 = 70 MJ => 83.5 MJ/day are required.

Cross-breeds:

Cross breeds give more milk and meat than local cows: they are bigger and can therefore eat more feed. There are two main options:

- Larger cows can eat more of the same feed and produce more milk than local cows; or
- Larger cows can eat more feed of lower quality and produce the same amount of milk as local cows.

Note:

Holstein cows have been highly selected for milk yield; consequently, they tend to produce more milk, but of lower fat content. Prolonged under-feeding in the early lactation stage results in premature peak milk yields, inducing a rapid decline in milk production.

Jersey breeds are intermediate in size, so they eat less feed than Holstein, but need higher quality feed to reach their milk production capacity!

In any case, those selected breeds require important care, as they are more sensitive to disease than traditional breeds, especially if they are underfed.

2. Overview of common fodder types

Inter Aide France is promoting the multiplication and diversification of the following grasses and legume plants in the highlands and midlands shown below:

- **4** types of fodder grass for Soil and Water Conservation structures: Hard Desho, Soft Desho, Elephant grass and Bana grass.
- **3** other types of grass for improving diversification: Guatemala, Guinea and Surinam grasses.
- **8** species of legumes: Pigeon pea, Cow pea, Sesbania, Desmodium, Vetch, Lupine and tree lucerne.

Table 2: Grass and legume plants promoted in Highland and Midland areas

Highland		Midland	
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Hard Desho	Pennisetum riparium	Hard Desho	Pennisetum riparium
Soft Desho	Pennisetum pedicellatum	Soft Desho	Pennisetum pedicellatum
Bana grass	P. purpureum x P. americanum	Bana grass	P. purpureum x P. americanum
Elephant (Napier) grass	Pennisetum purpureum	Elephant (Napier) grass	Pennisetum purpureum
Guatemala grass	Tripsacum laxum	Guatemala grass	Tripsacum laxum
Guinea grass	Panicum maximum	Guinea grass	Panicum maximum
Surinam grass	Brachiaria decumbens	Surinam grass	Brachiaria decumbens
Vetch	Vicia villosa	Pigeon pea	Cajanus cajun
Tree lucerne	Chaemcytisus proliferus	Cowpea	Vigna unguiculata
Sesbania	Sesbania sesban	Sesbania	Sesbania sesban
Oat	Avena sativa	Greenleaf Desmodium	Desmodium intortum
Source: Inter Aide France Fodder Training Manual by C. Bistoni et al. (2020)		Silverleaf Desmodium	Desmodium uncinatum
		Alfalfa	Medicago sativa

In order to balance animals' needs with the supply, it is necessary to know the energy and protein content of the various available feedstuffs. The following table present an average ranking of the main fodder types, giving the average value of Dry Matter (DM), Metabolizable Energy (ME) and Crude Protein (CP).

Traditionally, farmers have access to three main types of fodder sources: natural vegetation, crops, crop residues and supplementary feed (concentrate). More recently, some farmers have introduced cultivated fodder within their farm, which enables them to improve and diversify yearly fodder supply.

Natural vegetation

Includes natural grass harvested in communal lands or in enclosures, trees and shrubs leaves, weeds removed from cropland and Enset plots. The composition and feeding values of natural grass or weeds are not easy to determine, as they differ from one place to another. But on average, a bundle of natural grass has good nutritive value. However, **energy and protein content are divided by two in old yellowish grasses**.

Local legume trees and shrub leaves (Erythrina brucei etc.) represent good balanced fodder sources and are easy to digest.

Cultivated grasses and legumes

Common cultivated grasses such as Desho (Pennisetum riparium) or Elephant grass (Pennisetum purpureum) present moderate to good feeding values. The major issue is the important decrease in feeding value with plant maturity.

Legume species introduced in farmland are an extremely rich source of protein and energy, which is used to balance daily rations.

Table 3: Feed values of fodder and legume plants and certain crop residues fed to cattle

Ranking	Name of fodder	DM (%)	ME (MJ/kg DM)	CP (% DM)
Excellent	Alfalfa green*	18.2	8.8	25.3
	Desmodium silverleaf (fresh)	25.7	7.4	15.1
	Sesbania sesban (fresh)	26	11.5	24.4
	Tree lucerne	40	9.7	22.2
	Vetch	20.3	10.6	23.0
Good	Pennisetum purpureum * (elephant/napier grass)	14.5	8.0	10.3
	Natural grass (rainy season)	45	7.4	?
	Local trees/shrub species	55	8.5	?
	Pigeon pea (Cajunus cajun)	32	9.6	19
	Sweet potato vine (Ipomoea batatas) fresh	13	8.8	16.5
Moderate	Banana stem	10	6.6	?
	Enset leaves (Ensete ventricosum) (flower bud stage)**	12.9	8.9	13.15
	Hard Desho	14	8.2	?
	Bean straw (Vicia faba)	89.7	6.4	7.4
	Maize stover (fresh)	29.6	8.4	6.8
Poor	Maize stover (dry)	92.8	6.9	3.9
	Enset corm (fresh)	21.5	10.8	3.5
	Enset pseudostem (fresh)	10.2	8.8	4.0
	Tef straw (Eragrostis tef)	91.6	7.9	4.1
	Barley straw	91	6.5	3.8
	Wheat straw	91	6.8	4.2

Sources: *Topps and Oliver (1993, cited in Chakeredza et al., 2008); **Mohammed et al. (2013); www.Feedipedia.org (all other data)

Three main elements to highlight and memorize from this data:

i. Straws are the poorest fodder types.
ii. Enset corm is high in energy but has the lowest content in terms of protein.
iii. Most fodder types are low in protein, except legume species.

Crops

Includes enset leaves, pseudo stem and corm, sweet potato vines, sugar cane heads, banana leaves and pseudo stem. As they are wet, fresh fodder sources, **their DM rates are low**.

Enset leaves, usually chopped and fed to livestock in addition to other feedstuff, present moderate feeding values; even if they have the **richest protein content** of the entire plant, their **energy intake is low.** On the other hand, Enset corms and pseudo stem are a good source of energy but are poor in CP **which can aggravate the problem of protein deficiency.**

Sweet potato vine has an acceptable rate of protein, and as it is not too fibrous, it has a good digestibility. Sugar cane heads are very poor in CP but are a good source of sugar and thus energy.

Crop residues

Crop residues (wheat and teff straw, bean pulse, maize stover) have common characteristics: as they are dry feedstuffs, their dry matter rate is high (65 to 85 % DM). Straws of all types are **coarse, high-fibre**, **low-protein** and **low-digestibility** forage. Consequently, **their feeding value is low**. They also remain in the rumen for a long time, limiting food intake.

Compared to cereal residues, legume residues have high protein content and better digestibility provided that they are mechanically processed (chopped) before feeding. By mixing cereal and legume residues in a defined proportion, it would be possible to meet maintenance requirements. But feeding only cereal residues does not even fulfil maintenance requirements and animals may continue to lose weight.

Dry maize stover available after grain harvest is also widely used. The major limitation is its high lignification. Immature maize plant thinning contains 6 times more crude protein than dry maize stover!

CHAPTER 3: RATION CALCULATION ACCORDING TO CURRENT FEEDING PRACTICES

1. Ration values according to traditional fodder calendar

According to farmers' rations, nutrients' supply and cattle needs have been estimated for different seasons (see tables below containing calculations for different feed rations).

a. Dry season until beginning of 'Belg': from November to March

Smallholder farmers usually feed cereal straws with different Enset fractions during the long dry season until the beginning of the *Belg* season.

However, there is an important pressure on those two feedstuffs:

i. Straws have other uses within the farm economy, and these must be taken into account when assessing availability and profitability in livestock feeding systems: straw is used for tukul maintenance; part is sold and part is left on the soil to protect it from erosion or for fertility.

ii. Enset is a staple food for household consumption.

Other crops or crop residues are sometimes available, such as sweet potato vines or maize stover.
The feed ration tables below show the possible options available for the farmers:

b. The feed and fodder gap: April

April is a critical period for small-scale farmers, as forage resources decrease substantially. Straw reserves are usually depleted, maize hasn't reached maturity and weeds have just started to germinate. Enset leaves, sweet potato vines and roots along with cereals (barley/wheat) and legume (bean/pea) residues (i.e. principally straws) are the main feeds at that time.

c. End of the Belg and the Meher season: May to October

During the '*Meher*' season, natural grasses, tree leaves, weeds or fresh crop residues are the main fodder sources.

A ration of 3.5 kg of natural grass + 2 kg of fresh maize stover entirely covers the daily maintenance needs of 1 bovine.

Farmers give fresh maize stem when they harvest corn for home consumption. Thinning green stover (from leaf stripping, plant tops or the entire green plant) introduces a significant benefit in terms of fodder availability and quality during the rainy season, thereby promoting an increase in milk production. However, harvesting natural grass is a long and physical work, becoming even longer and more difficult with the increased pressure on land and resources.





d. Supplementary concentrate feed

Wheat bran (known locally as 'frushka') is the agro-industrial by-product from wheat flour mills most widely used by farmers. As most concentrates, it is rich in nutrients and provides far more energy and protein than the other available feedstuffs. As it is already ground, it is very easy to digest. Farmers who have enough capital resort to feeding wheat bran especially for milking cows. On average, 0.3 kg – 0.5 kg of wheat bran per animal may be given daily.

Cereal grains, molasses, sunflower cake, soyabean meal, oil seed cake, noug seed cake, forage maize and residues from breweries ('atela') are other concentrates rich in nutrients. The main limitations in using these types of concentrate are affordability and quality: the price is dictated by the availability of raw materials, which are also used for human feed. Consequently, farmers who can afford wheat bran use about 0.5kg per day per animal, which is only ¼ of the recommended rate.

Table 4: Feed values of different supplementary and concentrate foods fed to cattle

Food type	Name of foodstuff	DM (%)	ME (MJ/kg DM)	CP (gr/kg DM)
Cereal & crop grains				
	Maize grain *†	86 - 90	13.9 – 14.2	94 - 98
	Sorghum grain *†	86 - 90	12.6 – 13.4	108 - 118
Concentrate	**Wheat bran ('frushka') ****	**87**	**11**	**17.3**
	Soyabean meal *†	90 - 92	12.2 -12.3	440 - 503
	Noug / Niger (Guizotia abyssinica) oilcake **	92	12.0	313
Supplements	Brewers grains (residue from beer processing, 'aleta') **	91	9.9	258
	Blood meal *†	90	9.0 – 13.2	937 - 942
	Meat & bone meal *†	90 - 96	9.7	507 - 590
	Molasses †	75	12.7	410

Sources: *Topps and Oliver (1993, cited in Chakeredza et al., 2008); †Matthewman (1993); ** www.feedipedia.org

e. Examples of different feeding rations fed to dairy cattle

Option 1: Straw + Enset (leaves and pseudostem)

	Feedstuff	Kg fresh feed fed	Kg DMI (Kg)	ME (MJ/day)	CP (gr/day)
Supply	Wheat straw	**2** kg	0.91 x 2 = **1.82**	1.82 x 6.8 = **12.4**	1.82 x 42 = **76.4**
	Enset leaves	**6** kg	0.129 x 6 = **0.77**	0.77 x 8.9 = **6.9**	0.77 x 131.5 = **101.3**
	Enset pseudostem	**1** kg	0.10 x 1 = **0.10**	0.10 x 8.8 = **0.9**	0.102 x 40 = **4.0**
	Total supply			**20.2**	**181.7**
Needs	Needs for maintenance (local cow of 250 kg) (see table 1 above)			**21**	**270**
	% required to cover maintenance needs			**96.2 %**	**67.3%**
	Remaining/missing nutrients for milk production			20.2 – 21 = **-0.8**	181.7 – 270 = **-88.3**
	Possible milk production			**0 Litre**	**0 Litre**

In this scenario of option 1, it can be seen that both the energy and protein provided in the diet are insufficient either for basic maintenance needs let alone for any additional milk production. In practice, the cow would need to mobilise her existing body reserves to make-up the shortfall, and consequently would lose weight.

Option 2: Straw + Enset leaves + Enset pseudostem + sweet potato vine

	Feedstuff	Kg fresh feed fed	DMI (Kg)	ME (MJ/day)	CP (gr/day)
Supply	Bean straw	**2** kg	0.897 x 2 = **1.8 6**	1.8 x 6.4 = **11.52 .3**	1.8 x 74 = **133.2**
	Enset leaves	**7.5** kg	0.129 x 7.5 = 0.97	0.97 x 8.9 = **8.63**	0.97 x 131.5 = **127.56**
	Enset pseudostem	**1** kg	0.102 x 1 = **0.102**	0.102 x 8.8 = **0.90**	0.102 x 40 = **4.08**
	Sweet potato vine	**2.5** kg	0.13 x 2.5 = **0.325**	0.325 x 8.8 = **2.86**	0.325 x 165 = **53.63**
	Total supply			**23.91**	**318.47**
Needs	Needs for maintenance (cow of 250 kg) (see table 1 above)			**21**	**270**
	Needs for producing 1 kg milk/day (assuming 3.0% butterfat & 2.8% protein)			**4.5**	**36**
	% required to cover maintenance needs			**113.86%**	**117.95 %**
	Remaining/missing nutrients for milk production			23.91 – 21 = **+2.91**	318.47 – 270 = **+48.47**
	Possible milk production			**2.91/4.5 = 0.65 Litres**	**48.47/36 = 1.35 Litres**

In this scenario of option 2, it can be seen that the cow's energy needs are completely covered by the feed ration for basic maintenance with some surplus energy for production of **0.65 litres** of milk. The protein needs for maintenance are also met for milk production, with the potential to produce **1.35 litres**; however, as the energy absorbed from the food is only sufficient for producing about 2/3 of a litre of milk, then the maximum amount of milk that can be produced is **0.65 litres**.

In this case, it is the energy component that is the **limiting factor** (see also section 2c below) and which needs to be addressed before the amount of milk production can be increased. Any extra protein which cannot be used for milk production will be used for muscle production instead.

***** Reference: ME tables from UK Ministry of Agriculture, Fisheries and Food, 1984

Option 3: Straw + Enset + Enset pseudostem + wheat bran

	Feedstuff	Kg fresh feed fed	DMI (Kg)	ME (MJ/day)	CP (gr/day)
Supply	Mixed wheat and bean straw (50:50)	**2** kg	(0.91 x 1) + (0.897 x 1)/2 = **1.90**	1.90 x ((6.8+6.4)/2) = **12.5**	1.90 x ((42+74)/2) = **205.2**
	Enset leaves	**7.5** kg	0.129 x 7.5 = **0.97**	0.97 x 8.9 = **8.63**	0.97 x 131.5 = **127.5**
	Enset pseudostem	**1** kg	0.102 x 1 = **0.102**	0.102 x 8.8 = **0.9**	0.102 x 40 = **4.08**
	Wheat bran ('Frushka')	**2** kg	0.87 x 2 = **1.74**	1.74 x 11 = **19.1**	1.74 x 173 = **301.0**
	Total supply			**41.1**	**637.8**
Needs	Needs for maintenance (cow of 250 kg) (see table 1 above)			**21**	**270**
	Needs for producing 1 litre milk/day (assuming 3.0% butterfat & 2.8% protein)*			**4.5**	**36**
	Remaining/missing nutrients for milk production			41.1 – 21 = **+20.1**	637.8 – 270 **+367.8**
	Possible milk production			**20.1/4.5 = 4.5 Litres**	**367.8/36 = 10.2 Litres**

In this scenario of option 3, it can be seen that the addition of wheat bran concentrate to the cow's diet significantly increases the energy and protein supplies to ensure a daily production of about **4.5 litres** of milk (the energy requirements for 4.5 litres of milk are met but even though the protein supply is sufficient to produce more than double this, i.e. 10 litres of milk, the energy component limits the maximum amount of milk that can be produced).

Note 1: The figures given in the above tables for 'needs' of the cow will depend on various factors, including the age and breed of the animal, the nutritive values for the different components in the milk produced, the stage of milking and the stage of pregnancy that the cow is in etc. and are intended for illustrative purposes here.

Note 2: When calculating feed rations for cattle, the Dry Matter values for each dietary component must be converted to **fresh weights** to determine the amount of the fresh food which must be fed.

Note 3: Ideally cows should be allowed to consume as much forage as possible since they are more adapted to digesting fodder plant material. Also, higher quality forages will lead to a higher feed intake; and a higher feed intake will result in higher milk production etc.

***** Reference: ME tables from UK Ministry of Agriculture, Fisheries and Food, 1984

2. Limiting factors

a. The major problem of water supply

During the dry season, farmers face important problems of water scarcity. Water consumption by cattle depends on several factors, as indicated in chapter 1. As water has a great influence on animal intake and digestion, water scarcity leads to:

i. A **decrease in animal intake**: even if the animal has more feed available, it will not eat more,
ii. A **"loss" of nutrient digestion**: instead of being used for animal maintenance, part of the nutrients is extracted in manure.

b. Irregular fresh fodder availability along the year

From November until February, cattle are mainly fed with dry feedstuff. Enset is the only fresh fodder available at that time, competing with household consumption. Most farmers cannot meet their cattle's needs for maintenance:

i. Vulnerable families don't have enough crop residues to properly feed their animal
ii. Better off farmers usually have more animals than available fodder to get the maximum performance. They usually resort to concentrate (wheat bran) to balance nutrient requirement.

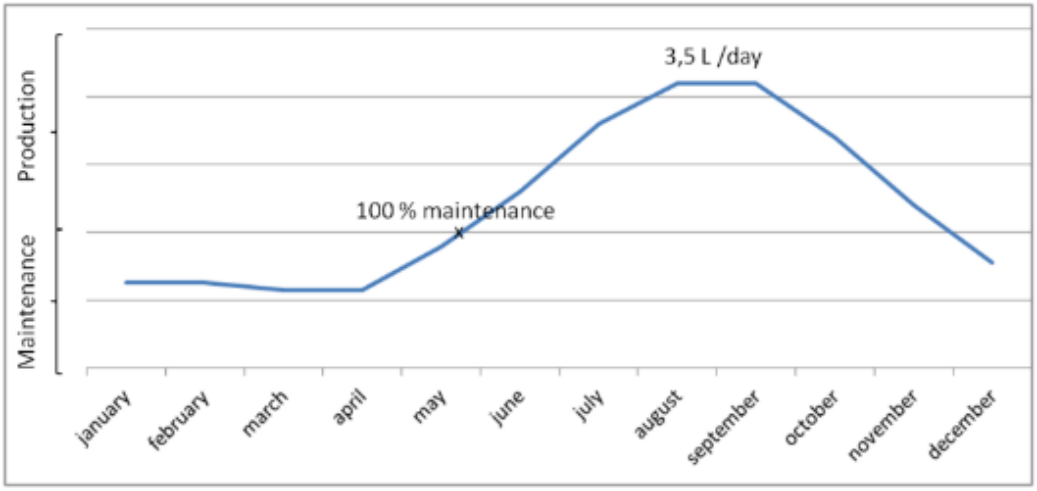


Figure 7: Evolution of nutrient availability for maintenance & milk production according to annual fodder calendar

c. Primary limiting nutrient

One of the key principles to understand animal nutrition is the **principle of the primary limiting nutrient**. When animals graze, attaining a particular production goal can be restricted by inadequate supply of one or more nutrients: protein, energy and minerals. But animal performance is primarily limited by the availability of the most limiting nutrient (called the primary limiting nutrient).

The supply of nutrients other than the primary limiting nutrient will have no effect on performance until the primary limiting nutrient deficiency is corrected.

As shown in the previous graph, **protein is usually the primary limiting nutrient** in most of the available fodder sources. Enset corm is particularly poor in protein; consequently, giving Enset corm without any protein-rich feedstuff can result in the "loss" of the energy contained in the corm.

Conclusion: Small scale farmers have limited land and capital, so they face difficulties in properly feeding their livestock. Animals are usually given inadequate water quantities and low-quality forages which do not meet the daily requirements for good growth and milk production.

CHAPTER 4: INTEGRATING DIVERSIFIED FODDER PRODUCTION IN THE FARMLAND

1. Interests of integrating fodder production in small-scale farms

With the increase of population density, natural pasturelands are progressively converted into croplands, and the biomass production remaining on communal lands cannot support the growing animals' requirements. Both factors are expanding the gap between available resources and small-scale family farms' needs. Meanwhile, the reduction of farmland size after each generation is causing a decrease in available crop residues, widely used as a fodder source.

This "feed and fodder gap" has become even more critical with the recurrent late arrival of rains at the *Belg* season. Even if during the *Meher* season fodder sources are easier to find, the available choice remains limited, and numerous farmers resort to supplementary feed during the milk peak.

Economic benefits

- The association of high biomass productive grasses with nitrogen-fixing plants as high-protein forages helps supply balanced animal feeding, increase farmers' livestock, milk production and animal fattening
- On-farm production of good quality fodder reduces the cost of supplementary food bought at the market
- The sale of fodder bundles, seeds or seedlings proved to be an interesting source of income for families who have no or few animals to feed.

Environmental benefits

- Fodder planted on anti-erosive structures plays a determinant role to control soil erosion as it provides soil cover, avoiding bare soil, while stabilizing the structures.
- Introducing various fodder species within the farm contributes to increasing farmland biodiversity
- Legumes forage improves soil fertility through their ability to fix nitrogen
- Animals fed with a good balance of fodder grasses and legumes species produce high quality manure, which is crucial to nutrient recycling

Social benefits

- Producing fodder within the farmland reduces the burden of gleaning natural grass
- The regular availability of cultivated fodder along the year contributes to the decrease of the pressure on Ensete plot, traditionally intensively used for cattle breeding during the dry season. Ensete plots are healthier and provide more food for family consumption.

These chronic feeding constraints have a direct impact on livestock population, animal production performance and farmers' expenditures.

In this context, integrating diversified fodder production including grasses, legumes, trees and shrubs within the farming system presents a significant set of advantages.

2. The necessity of controlling open-grazing

The introduction of cultivated fodder within small-scale farms has to go along with local **restrictions on open-grazing.**

Traditional farming systems allow animals to roam at will and browse for their feed. This system, although seen as economical and labour saving, is often a nuisance and a source of conflict, damaging crops, communal pasturelands and incompatible with on-farm fodder production.

Consequently, a feeding system based on **the cut-and-carry practice** is necessary. A general rule is to give freshly cut forage to an animal equivalent to about 10% of its body weight each day. Ideally, half should be given in the morning and the remaining half in the evening, so the animal can make more efficient use of the forage.

The cut-and-carry system presents various advantages: having animals penned allows an easier control and management of the herd. It also permits regular monitoring of disease, breeding cycles and parturition. Also, the centralized production of manure eases the task of its collection to spread on the farm.

3. Example of possibilities to introduce good quality forage in traditional farming systems

At least four main strategies can be used to integrate fodder in small-scale farmland, minimizing the interference with traditional farming systems: 1) Diversified fodder production in underused spaces of the farm; 2) Live hedges; 3) Diversified permanent grass-legume pasture and 4) Natural pasture improvement.

a. Diversifying fodder production in underused spaces of the farm

Unused spaces of the farm which are inappropriate for crops can act as biomass production support, maximising land productivity, while bringing various benefits:

On soil and water conservation structures

Anti-erosive structures count for 6 to 8 % of the total land surface. Growing fodder on soil bunds (or 'fanya juu') is an efficient way to strengthen the structure and increase vegetative cover, limiting the erosion process.

- *Example of grass species grown: different types of Pennisetum*
- *Associated legume species: Cajanus cajan, Alfalfa (Medicago sativa), Vetch (Vicia), Tree lucerne (Cytisus), Gliricidia sepum, lupin (annual)…*

Under coffee or trees

The practice consists in growing shade tolerant legumes such as Desmodium species (*Desmodium uncinatum* and *Desmodium intortum*) under coffee trees. Both varieties perform well under the shade of the coffee trees; they are easy to establish and multiply using stem cuttings. This practice complements legume forage availability and helps control noxious weeds.

Farmers usually need the space under coffee trees to be free of grasses during the harvest; therefore, they usually prefer to harvest Desmodium in October and November.

This practice can also be applied under mango or avocado trees.

b. Around the field as live hedges

Fences are omnipresent in the Wolayta and Kambata landscape. They are mainly established around the 'tukul', home garden, and sometimes around cash crop fields. In most of the cases, they are made of dead wood or Juniperus and they do not have other purpose than to play the role of a fence and prevent animals from grazing crops. But some farmers also grow hedges, mainly constituted of local trees and shrubs, for other purposes:

- To fertilize the soil: leaves are harvested and spread on crop fields during soil preparation
- To feed animals: leaves are used as fodder, despite their low fodder potential (except for the local *Erythrina brucei*).

Introducing new perennial legumes within live hedges provides good quality fodder all year long, especially during the dry season, increasing rations' nutritional values. They also increase the vegetative cover, limiting bare soil vulnerable to erosion, and also act as wind breaks.
Example of grass species grown: Elephant grass or Bana grass
Associated legume species: Cajanus cajan, Gliricidia sepium, Calliandra in the midlands; Sesbania sesban, Tree Lucerne (Cytisus proliferus) in the highlands

Those three legume species can remain for years once established and do not require much management, except pruning.

Above: Hedges of Sesbania sesban (associated with Pennisetum riparium on the right)
Below: Hedges of Cajanus cajan with Pennisetum riparium (left) and gliricidia (right)

c. Diversified permanent grass-legume pasture

As producing fodder is an interesting source of good quality feed for animals but also an interesting regular source of income, some farmers dedicate plots to permanent fodder production. They generally use fields with low fertility or difficult access as fodder doesn't require as much care as crops. The cultivated "pasture" produces a large amount of high quality fodder, easy to use for cut-and-carry practices. Moreover, fodder act as a vegetative cover protecting soil from erosion.

Example of grass species grown: Pennisetum riparium, and more rarely Elephant grass or Bana grass
Legume species associated: Desmodium and Cajanus cajan (in mid-altitude areas) and vetch and alfalfa (in high altitude)

d. Natural pasture improvement

The main goal of natural pasture improvement is to mix legume fodder species within enclosed natural grasslands plots kept for cut-and-carry purposes. This field left not cultivated being maintained by owners to use for different social ceremonies; however, farmers traditionally grow natural grass on such places by enclosing an area next to their house to let natural grass grow and feed their animals using the cut-and-carry system. However, the quantity of biomass produced and its nutritional value are usually not satisfactory. In order to overcome those deficiencies, legume forage species are integrated in natural pasture plots.

Legumes should be planted at the onset of rains, either in rows, or over sown inside the natural grass, once natural grasses have been cut down. If annual legumes are used, part of the fodder should not be harvested until the legume sets seeds and disperses them naturally. This practice requires time and patience but it increases soil seeds bank and the probability of future regrowth.

Example of associated legume species: Desmodium (in mid-altitude areas) and vetch (in high altitude areas).

Left: Desmodium germinated in the row inside natural pasture, Right vetch over sown and mixed with natural grass

4. Basic practical steps to produce and maintain good quality fodder

As mentioned above, different types of fodder grasses and legumes species can easily be integrated in the farm. Pennisetum grasses are quite drought resistant but they have basic needs to grow properly: fertilization, warm temperature, sun, well-drained soil, and water. They tolerate light shade but it may diminish their growth performance.

However, due to inappropriate management, farmers usually notice a decrease in fodder grass productivity after 3 to 4 years. To keep a sustainable high-quality grass production and avoid soil nutrient depletion, fodder plots have to be properly managed using the following advice.

a. Fertilization management

Pennisetum grasses are known to require N and P to ensure their viable productivity, especially for cut-and-carry purposes. Fertilization not only affects grasses' productivity, but also their longevity and their nutritional value.

Applying soil on the grass:

Some farmers move some soil around the grass, 7 to 10 days after each harvest. There are two ways to manage soil application, depending on grasses' location:

- **For fodder grown on anti-erosive structure:** the soil from the upper field or silts that is accumulated in the ditch is spread on top of the cut grasses. The soil is not hoed between the clumps to avoid bunds' degradation.
- **For fodder cultivated on dedicated plots or around the field**: the soil between clumps is hoed, as, in those areas, weeds grow faster as the space between seedlings is wider than on anti-erosive structures.

Organic fertilization:

Farmers also add manure or compost on the side of the grass after the harvest, when young leaves start growing. Organic fertilization practices depend on animal dung availability. Compost or manure is loaded and carried in a wheelbarrow or a stretcher. As it is a physical time-consuming work, it is mainly applied on anti-erosive structures or plots close to the house.

Chemical fertilization:

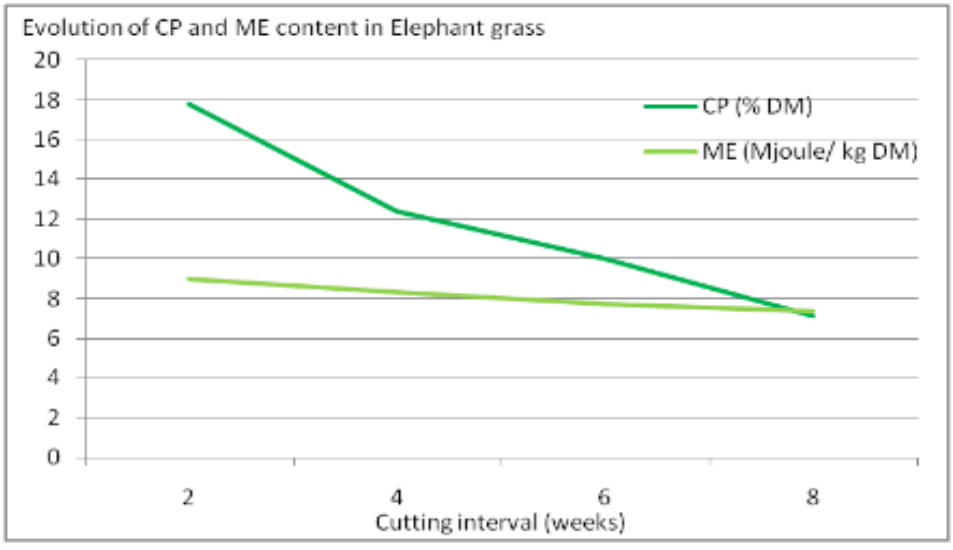
In some cases, when farmers have enough capital to buy chemical fertilizer, they also apply urea to complement manure application.
The application of chemical fertilizer is done in two ways:

- At planting time: at the beginning of each crop establishment, chemical fertilizer is spread on the soil. At that time, a small quantity is also applied on anti-erosive bunds.
- After each cut: such as organic fertilization, chemical fertilizer is applied after each harvest, mainly on the structures or dedicated plots next to the cash crops (far from the house), as it is easier to carry and apply than manure.

b. Harvest management

➲ **Respecting the interval between two harvests**: as shown in the following graph, the feeding value of grasses rapidly declines as fodder grasses become older, as the amount of lignin increases. The protein content is the most affected: it decreases by 1/3 after 4 weeks of regrowth!

Figure 8: Feeding values (CP and ME) of Pennisetum purpureum with time



Quantity doesn't mean quality: high biomass production doesn't mean high nutritive value. Although longer intervals between two cuttings may result in higher DM yields, animal production usually remains poorer. Consequently, **the interval between two harvests** should not exceed **3 months for P. riparium** and **2 months for Elephant or Bana grass**.

Figure 9: Pictorial representation highlighting the importance of quality fodders

➲ Cutting the grass properly

Some farmers harvest the grass at root level to get the maximum biomass in their bundle. However, this practice has negative effects on the grass productivity for several reasons:

- It damages the roots, as they are directly exposed to the sun, dry wind or heavy rains.
- Severe cuttings (or heavy grazing) result in delays in active growth. Indeed, the regrowth rate is initially directly related to the amount of leaf remaining to intercept light and support photosynthesis.

Fodder grasses should be cut 5 to 10 cm above roots' level to ensure an optimal new regrowth.

➲ Maintenance

As most perennial plants stay several years in the same place, *Pennisetum* species with creeping root growth character tend to develop and spread out, interfering with crops fields and competing for nutrients with nearby crops. The space where seedlings were planted becomes too small and soil fertility is insufficient to satisfy grasses' needs.

→ **Clump division is a good way to lighten the plantlets** and improve their productivity, giving them more space and light and reducing the competition for nutrients and water. Clump division should preferably be done at the end of the Belg (May-June)

→ **Weeding** should be done **after each harvest** to maintain high productivity

→ **Intercropping fodder grasses with legumes** presents various advantages:

- It contributes to diversifying and improving animal feeding: 3kg of legume leaves is equivalent to 1 kg of wheat bran concentrate.
- It helps maintain soil fertility.
- It supports fodder grass productivity and avoids competition with neighbouring crops for nitrogen.

CHAPTER 5: IMPROVING CATTLE FEEDING RESSOURCES, PRACTICAL EXAMPLE

1. Description of the initial situation: basic land occupation and available fodder

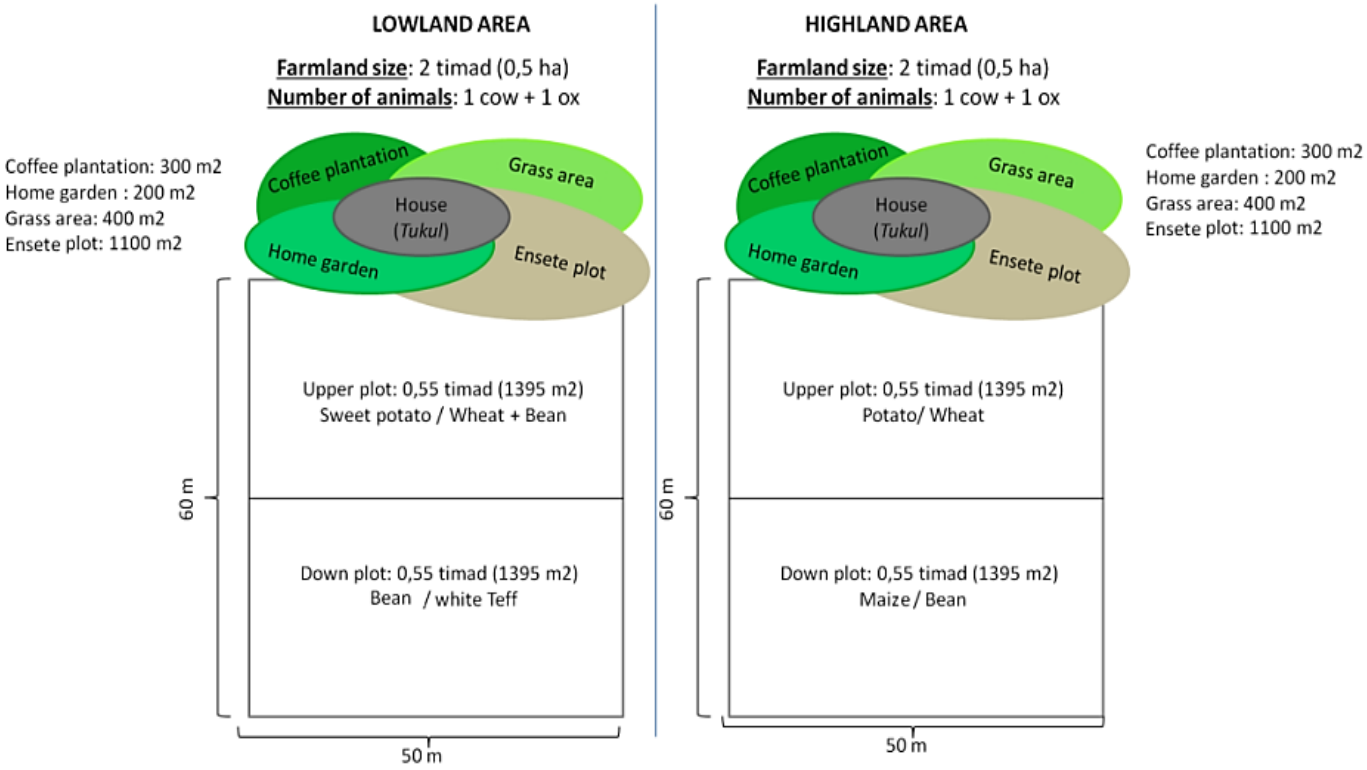
The following table presents the average quantity of crop residues available in the case study (for lowland and highland).

Table 5: Average quantity of crop residues available for households in lowland and highland areas

Available fodder	Lowland (kg)	Highland (kg)
Sweet potato vine (1390 m2)	1600	-
Wheat straw	551	1100
Bean /haricot straw	820	550
Maize stover	-	1200
Teff straw	900	-

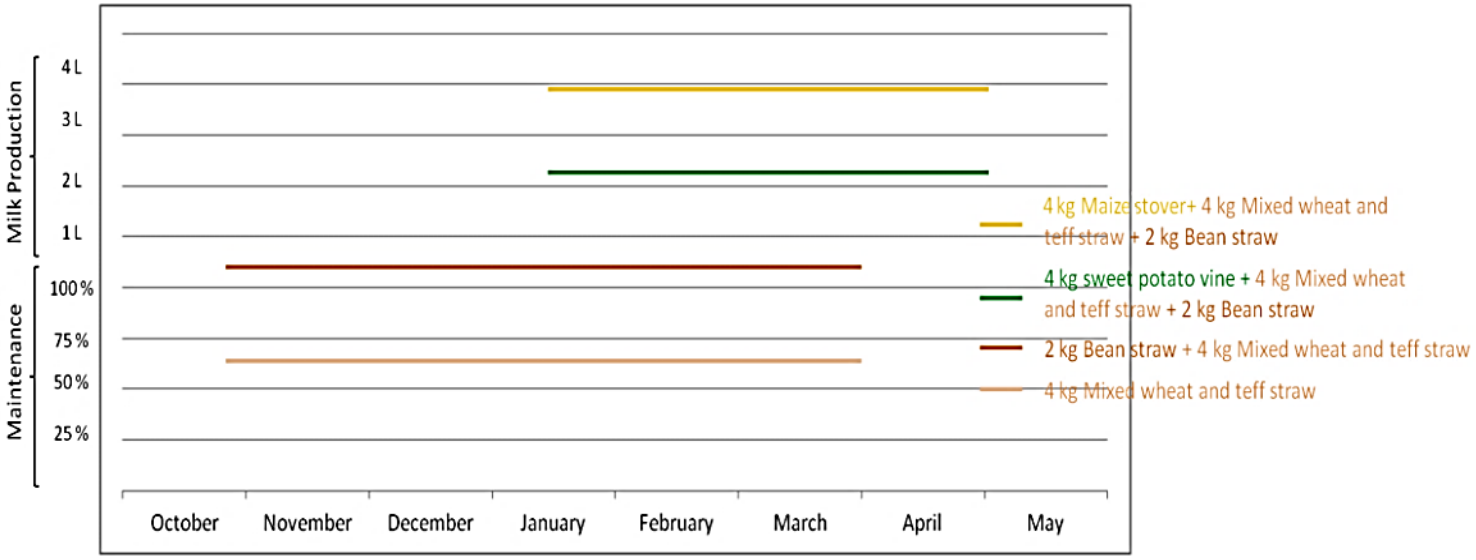
It can be considered that part of the teff straw is kept for house (tukul) maintenance or is sold for cash; thus, the estimated average amount of straw (wheat + teff) in the lowland is about 1000 kg.

Figure 10: Diagrams showing smallholder farm layouts in lowland and highland areas



Taking into account the fact that 2 animals should be fed during the dry season with those available crop residues, the graph below presents different rations with their corresponding values for maintenance and production. The duration along the month considers the potential period during which the 2 animals can be fed with the available crop residues until the stock ends.

Figure 11: Average quantity of daily ration for one animal and corresponding performance for maintenance and production



2. Improving animal feeding and production

a. Providing cattle with the appropriate frequency and quantity of water

Animals should get drinking water **at least twice a day**; during the dry season especially, an animal which gets **20L of water in the morning** and **20L at night** can maintain its body weight and **increase its daily milk production by 25%**!

b. Introducing diversified fodder species within the farming system

One of the key strategies for all producers who periodically need emergency forage is "drought anticipation" with proper planning and execution of an annual forage program. They can design a plan for their small plot and manage their various cultivated fodder to maximize animal supply along the seasons.

➲ Fodder grass

Fodder grasses such as P. riparium or Elephant grass can be harvested three times a year on average. The average yield of P. riparium is 4 kg/m^2 per cut, varying from 2 kg/m^2 during the dry season up to 7 kg/m^2.

With **200m^2 of well managed rain-fed cultivated grass**, a farmer can feed **2 animals** in addition to common fodder sources, considering that each animal is fed with a bundle of **5 kg/day.**

To overcome the fodder depletion between March and April, grasses should be cut between October and November, allowing for 3 months of regrowth (the growth rate is slower during the dry season due to the rain shortage). The third cutting can start at the beginning of July.

➲ Legume species:

As fodder grasses are bulky and low in nutrient content, they should be supplemented with legumes. Those protein-rich feedstuffs help animals to produce as much milk as they can and to use other feeds that are low in protein more efficiently.

To be able to cover 1 animal's needs throughout the year, a farmer needs to plant:

- About **500 legume trees per cow**, which would occupy about **250 meters of land** if planted in a single row hedge, either in association on SWC structure, or as a live hedge around the field.
- About 250 linear meters of alfalfa (Medicago sativa).

Caution: Under rain-fed cropping systems, herbaceous legume species don't have a high biomass production.

Adding legume species at a rate of 25 to 30 % (about 1 part protein source to 3 to 4 parts) of the main forage is recommended. NOTE: An exception to this rule is alfalfa (an excess of which can cause bloating) and Leucaena (maximum of 10% inclusion to avoid any potential metabolic disorders due to ingestion of the enzyme mimosine).

➲ Associating grass and legume on SWC structures

A farmer building 4 anti-erosive structures has 200 linear meters of embankment to plant, which enables a production of:

- 100 m^2 (200 m x 0.5 m) of fodder grass
- 200 m of Pigeon pea (400 trees, 0.5 m space between 2 trees).

➲ Around the field and Enset plot

100 m2 ((60m + 50m + 60m + 30m) x 0.50m) of fodder grass can be cultivated around the field associated with 50 m of Pigeon pea (100 trees)

➲ Under coffee plantation

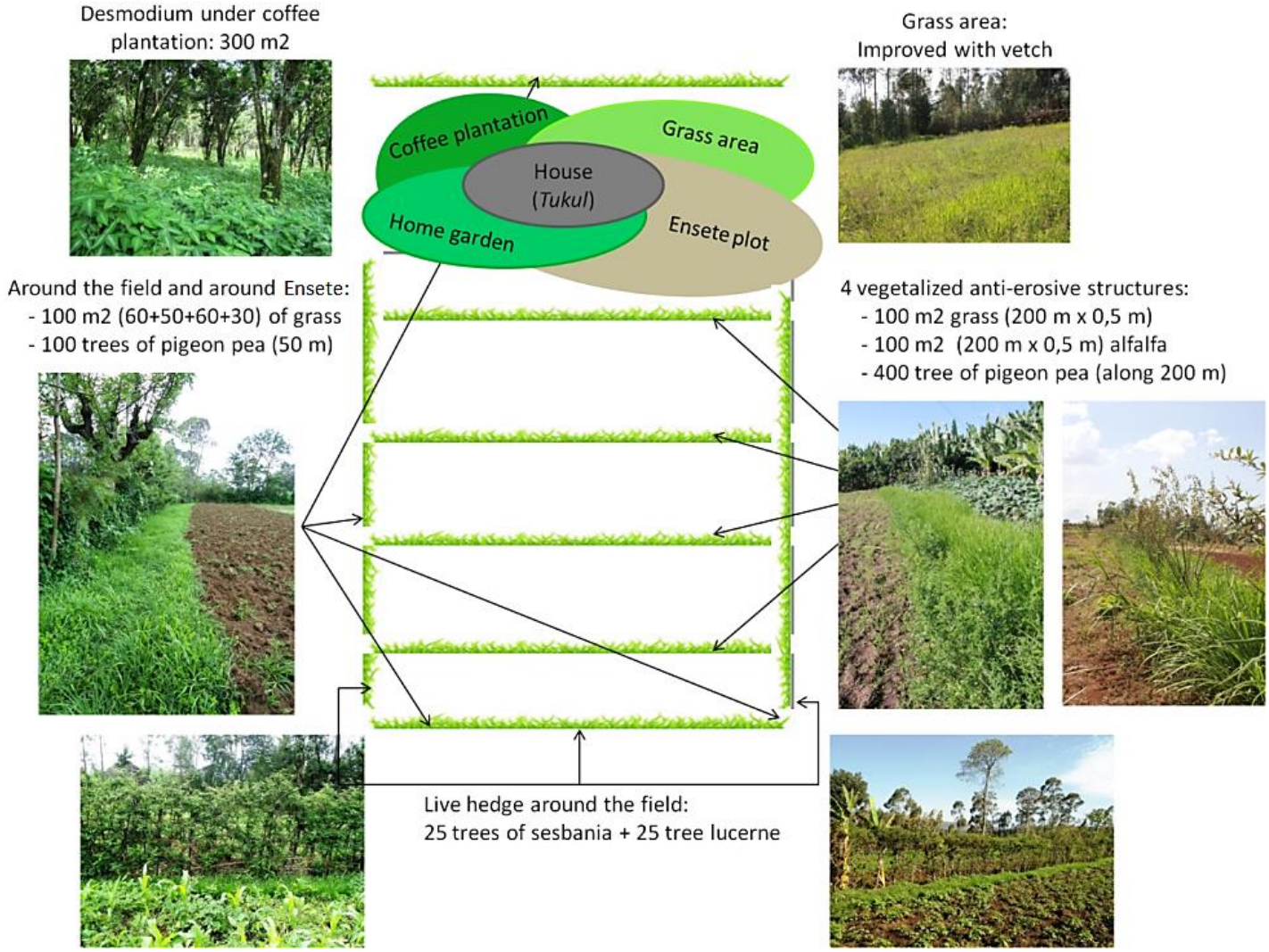
300 m² of **Desmodium** grown under coffee trees can provide 650 kg of fresh fodder per year. Considering that 3 harvests can be done, it corresponds to 2.5 kg per animal per day during 1.5 months (i.e. 3 times).

➲ Diversified live hedge

The total perimeter of the land is 220 m (60 x 2 + 50 x 2). Assuming 1m spacing between 2 trees:

- 220 trees of Sesbania sesban can be planted.
- In the mid to highland areas mixed forage tree species can be planted 110 trees of Sesbania and 110 tree Lucerne.

Figure 12: Diagram showing smallholder farm layout with inclusion of various legumes varieties



c. Legumes as an alternative to concentrates

At higher milk production levels or during ploughing times, dairy cows and oxen need a supplement of concentrate feed, which can be complemented or replaced with legumes species.

Supplementation of the base diet during the dry season (crop residues + Enset) with high-quality forage or concentrates helps to overcome the problem of low digestibility of the fodder base (straw), improving significantly feed intake, animal health and performance (milk production, meat).

On average, **3kg of fresh leaves of legume trees** such as Calliandra, Sesbania or tree Lucerne give about the same milk yield as **1 kg of concentrate!**

Farmers who are buying concentrate can give ½ ratio of concentrate (2kg) and ½ ratio of legume tree leaves for a good mixed ration (2kg).

Farmers who cannot afford commercial meals such as wheat bran can design homemade rations consisting of both tree and herbaceous forages: 6 kg of Sesbania leaves mixed with 6 kg of Alfalfa give approximately the same nutritive supply as the daily ration of wheat bran.

Managing crop residues

An easy and efficient way to improve crop residues' quality as feed is **to strip the dry leaves of maize stover or to chop the stalk after harvesting**. Some tests have shown that chopping does not improve straw digestibility but does increase intake, reduce wastage and make it easier to mix the straw with other feed components.

It is also advisable to give a 20% excess of crop residues so the animal can select the nutritious parts.

NB: The base of the maize stem should be left in the field after the dry leaves have been stripped to protect the soil against erosion and maintain its fertility.

3. Other options to be explored

There are of course several other options that would deserve to be tried with interested farmers. As previously mentioned, the end of the dry season (between March and May) is a critical period for the farmers to at least maintain their cattle. Trying to make some fodder stock during the Meher season might be a possibility by producing hay composed of grass and legume (such as alfalfa). Another option could be silage, which is not practiced in south Ethiopia. The promotion of fodder trees could also offer alternative resources during the dry season.

The application of **urea** to cereal residues has been proven to increase the proportion of dietary nitrogen for cattle and can help maintain or increase their protein requirements, especially during the dry season. However, care must be taken when applying the urea to the straw to avoid excess application and avoid any possible poisoning of the animals, so it is better to consult a local Ministry of Agriculture official.

Molasses is a source of readily fermentable energy, and In areas where access to molasses is readily available, home-made molasses-urea blocks can be prepared, or else liquid molasses with urea mixed-in, and fed to cows in conjunction with cereal residues to maximise the low feed potential of straws by rumen microbes, with urea again as a source of nitrogen.

APPENDIX I: REFERENCES AND FURTHER READING

1. **Field Training Manual** by Charlotte Bistoni, Pierre Perrault, Getamesay Demeke, François Bourgeois, Mesfin Desalegn, Tarekegn Kaliebore, Tsegaye Mathewos (Inter Aide France 2020).
   Description: This field training manual details training programmes aimed at both project technicians and key beneficiaries (peer educators) in midland and highland areas in south Ethiopia and covers topics such as fodder diversification, agroforestry activities, soil water conservation, soil fertility improvement, and community fodder multiplication sites.

2. **Integrating soil conservation and fodder production as climate adaptation strategy in Ethiopia** by Lolita Guyon, Getamesay Demeke, Philippe Redon, Francois Bourgois, Tadesse Mega, Abebe Tilahun, Mesfin Desalegn, (2018, CTA Publication):
   www.cgspace.cgiar.org/bitstream/handle/10568/97900/2042_PDF.pdf?sequence=4&isAllowed=y
   Description: Manual produced by Inter Aide France which has developed an innovative approach that consists in combining fodder production and soil and water conservation, with fodder plants planted on anti-erosive structures and in unproductive places on the farm.

3. Biomass production and market value of two types of grasses (Pennisetum purpureum and riparium) grown on anti-erosive structures by François Bourgeois (Inter Aide France 2020):
   www.interaide.org/pratiques/content/biomass-production-and-market-value-two-types-grasses-pennisetum-purpureum-and-riparium?language=fr
   Description: This note details on-farm measurements that have been taken continuously over 15 months among 64 plots on 57 farms in order to quantify (i) the fresh biomass of the grass produced on the soil and water conservation structures throughout the year, and (ii) its economic value.

4. Feedipedia website: www.feedipedia.org
   Description: A free online reference encyclopaedia supported by FAO, INRA, AFZ and CIRAD, detailing different feed resources for livestock including fodder and legume feed resources with information on the characteristics of each item, description, botanical classification, nutritive values and links to research articles.

5. **Dairying** by R.W. Matthewman (1993, CTA Publication in the 'Tropical Agriculturalist' series). References used for feed tables 2 and 3 in the manual.

6. **A simple method of formulating least cost diets for smallholder dairy production in sub-saharan Africa** by Sebastian Chakeredza et al. (Aug. 2008, African Journal of Biotechnology Vol. 7 (16))

7. **Nutritive values of the drought tolerant food and fodder crop enset** by Mohammed B., M. Gabel and L. Karlsson (May 2013, African Journal of Agricultural Research Vol. 8 (20), pp. 2326-2333).

8. **ILRI on-farm adviser ration formulation tool for dairy cows:** www.ilriofa.com
   Description: A free practical smartphone tool which can help advise farmers to balance major nutrients in feed ration diets of dairy animals. After inputting all the data on feeds, feed prices etc. it generates an advice sheet with recommendations to improve diets.

9. **FAO ration Formulation Tool for dairy cows**
   www.feedipedia.org/content/fao-ration-formulation-tool-dairy-cows
   Description: This free online application calculates least-cost rations for dairy cows using locally available resources and has been specifically designed for technicians looking for a simple and easy-to-use formulation tool to create a balanced diet vital for enhancing animal production and farm profitability. It is based on nutrient information of different locally available feeds which must be manually inputted into the Excel database. Unlike the ILRI application it is not available as a mobile-phone application.

Figure 13: Screenshot of ILRI 'On-Farm Advisor' mobile phone application

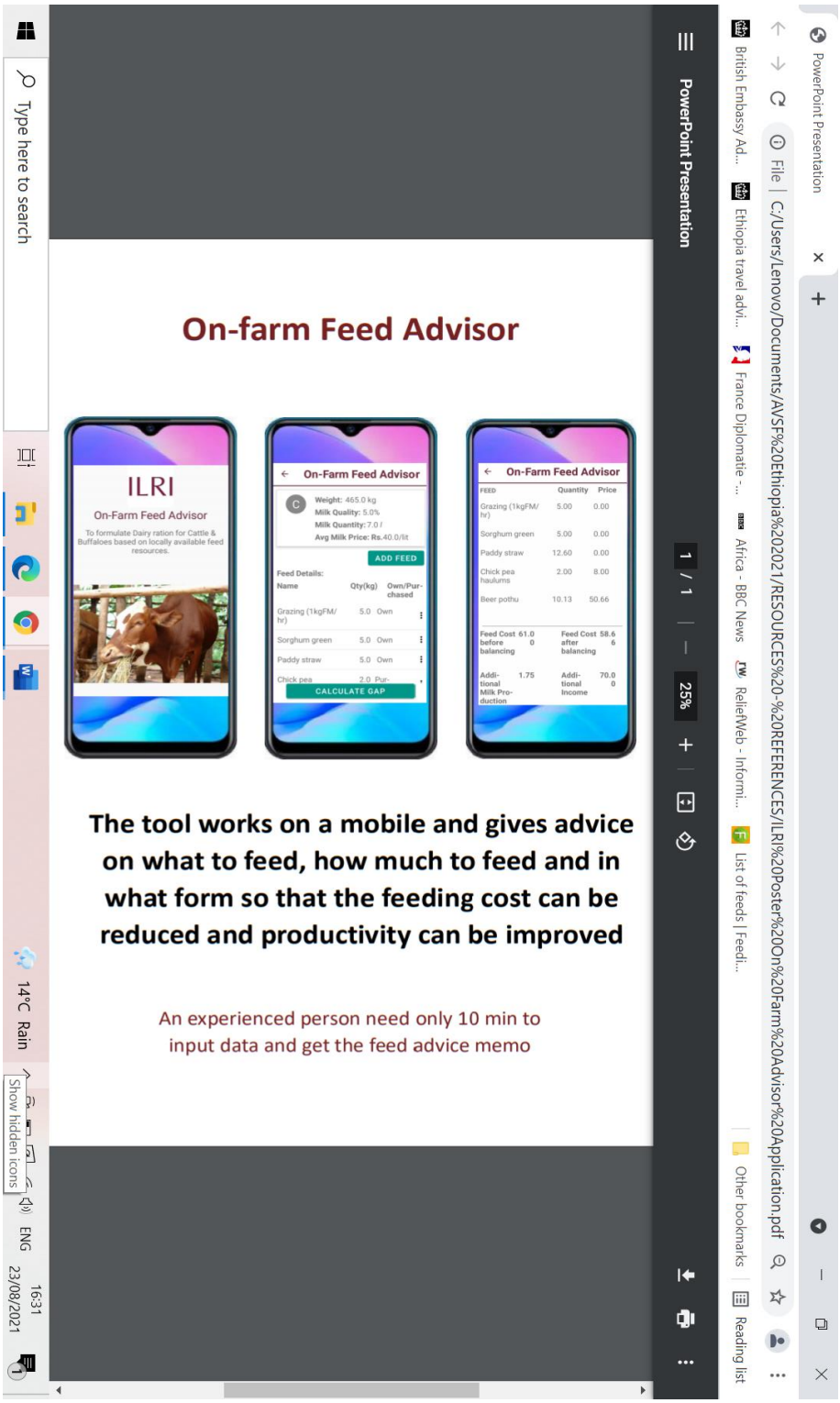
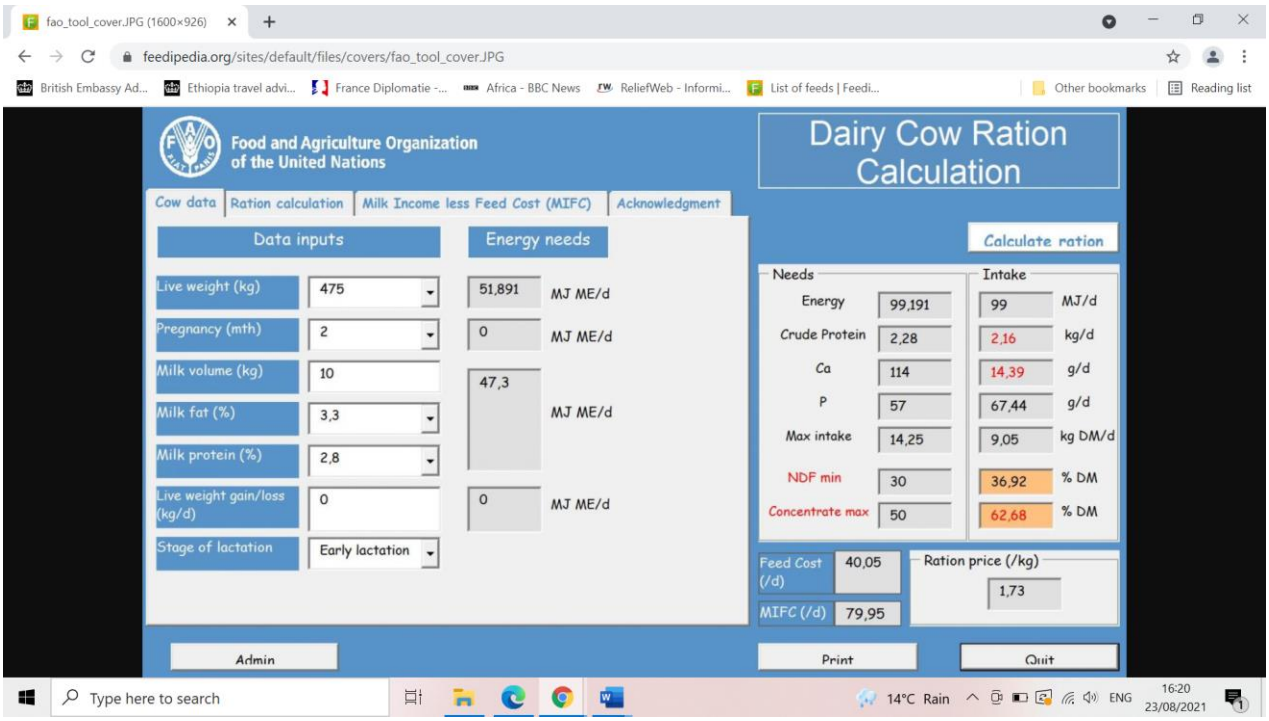


Figure 14: Screenshot of FAO online ration tool



APPENDIX II: TEN GOLDEN RULES OF GOOD FEEDING MANAGEMENT FOR DAIRY CATTLE

1. Cows need to drink a lot of water especially when they are being milked and also when they are suckled by their calves: the water should be available at all times and should be **clean and fresh**. Ideally there should be a water-trough placed in the cowshed and which is constantly filled.
Note: Cows like to drink straight after being milked therefore the farmer should ensure that they have access to clean, fresh water after milking is finished.

2. Forages and fodder plants should **always** be available for cows, ideally in a feed trough (which can be cleaned daily to avoid any dirt or bacterial build-up); they should be clean and free from dirt.
Note: If there is no feed, then the Dry Matter Intake will be low and therefore less milk is produced: i.e. the more feed they eat, the more milk they will produce.

3. It is good practice to provide a permanent multipurpose mineral lick-block for the animals especially during the dry season to ensure that basic minerals and vitamins necessary for maintenance requirements are provided even during times when food is scarce.

4. Even for low yielding cows, food must be given generously in early lactation and the first few weeks after calving to: (i)produce enough milk not only for the calf but also for human consumption; (ii) have sufficient food to produce milk up to and at the peak lactation curve requirements (ranging from 1 – 2 months post calving depending on the cow breed); and (iii) avoid any drastic loss in body condition arising from the sudden increased demands of energy for milk production, since the cow will be obliged to use her own body reserves to meet such increased energy demands.

5. Consider application of urea to low value feeds (e.g. straws) to supplement low protein diets (by increasing the non-protein nitrogen content of the diet). **Caution:** Urea should only be applied after consultation with a feed technician to avoid any incorrect treatment before feeding to cattle.

6. Consider planting legumes browse and shrubs (e.g. sesbania, leucaena, calliandra, tree lucerne etc.) on the edges of fields or other under-exploited areas of the farm as live hedges and a means of increasing **plant protein** produced on the farm at a minimal cost (**see also figure 12 on page 31**).

7. Greenleaf Desmodium can produce increased yields of up to **3 times** as much if intercropped with maize and allowed to 'climb-up' the maize stalks, compared to just planting in the soil and left to multiply as a sward on the ground.

8. Regularly deworm and detick cattle (e.g. every quarter) and at least twice a year to ensure elimination of gastrointestinal parasites and ectoparasites which can divert food resources (energy, protein) otherwise destined for production and growth for the animals, and may also cause disease, This is especially important for cattle which graze on communal grazing land where other cattle graze and may contaminate the pastures with internal and external parasites.

9. Any new feed or ration fed to cows should be introduced **gradually over 1 week to 10 days** to allow the rumen microorganisms to adapt to the new diet and avoid any possible stomach upset.

10. If possible, it is a good practice to note down the daily milk production from each cow; ideally each cow should have its own separate milk record so that its milking pattern can be regularly monitored. This can help to identify any potential problems with the cow if any anomalies appear. It can also help to identify which cows are the good milkers which should be kept, and which are poor milkers which should be removed from the farm.