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# Modern dairy farming in warm climate zones

Volume 1

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# Foreword

This series is about modern dairy farming in warm climate zones as defined in chapter 1 of this volume.
The idea was to give the content **a practical orientation;** in principle only that **which is of direct importance on the farm** has received attention.

The series consists of **three** volumes:

**Number 1**
- Dairy cattle feeding
- Pasture and fodder crops

**Number 2**
- Milking (by hand and machine)
- The milking machine
- Milk quality and handling on the farm

**Number 3**
- Animal health
- Calf rearing
- Herd administration
- Housing
- Suggestions for practicals in dairy farming training

A very important aspect of dairy farming, namely **reproduction** (including reproductive performance and reproduction management) is dealt with in a separate AGROMISA guide named *Reproduction in Dairy Cattle (2 parts).*
Also the very important **financial-economic aspects** of dairy farming have received attention in separate AGROMISA guides named *The Farm as a Commercial Enterprise and Farm Accounting.*

The text often refers to the farmer as ‘he’, ‘him’ or ‘his’. We would like to assure the reader that it is only for the sake of textual convenience that we have chosen not to mention the woman farmer explicitly.
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# Dairy cattle feeding

# 1 Introduction to ‘modern dairy farming’

Milk production techniques are quite different in various parts of the world. The word MODERN in the title of this series is not meant to imply that all other methods of dairy farming are old-fashioned and out-of-date. It rather refers to a method of dairy farming characterized by mechanization, fertilizer application, the use of concentrates and relatively high milk yields per cow.
Many people looking at such a system from outside, are struck first of all by the high milk yields. They may therefore be led to believe that successful dairy farming has to start with the type of cow prevailing in Europe or North America.
This however, is not necessarily so because, in general, a dairy farmer is not primarily interested in the level of the milk yield but **in the level of his/her income.** If the milk price is fixed, a farmer can increase his income either by producing more milk, or by lowering the production cost of his milk, or by both methods. For instance, if roughage is cheap and of reasonable quality, and the price of concentrates is high, the farmer may find it cheaper to keep 20 cows that produce 7 kg of milk per day on roughage only, than 10 cows yielding 14 kg of milk per day by using also concentrates. In other words, high milk yields per cow do not always lead to the lowest cost price of milk.

Another remark.
High-yielding dairy cows may be compared to high-yielding plants such as the modern cereal crops (rice, wheat). Just like these new, high-yielding crops the **high-yielding dairy cow will also produce a lot of milk only under optimum management conditions.** Without this high level of management (particularly feeding and disease control/prevention) this cow produces little more, or even less than a local cow, while on the other hand it is more susceptible to disease than local cows, so that the farmer incurs more risks.
Therefore, before one decides to introduce high-yielding cows, one has to be sure that the level of feeding and management these animals require, can be supplied. High-yielding cows, and a high level of management belong together like a pair of shoes. And who buys one shoe only?

The major difference between a low- and high-yielding cow lies in the difference in feed intake. Although the amount of feed required per kg of milk is less for a high yielder than for a low yielder, **the total amount of feed required is always high for a high yielder.** The **quality** must be better too. Moreover, dairy cattle have to be fed **regularly** and without sudden change in the composition of the ration.
In general, we can say that the better the ‘environment’, the more will the improved animal live up to its (genetic) potential.

### What makes up this ‘environment’?

We must distinguish between **farm management** (e.g. milking and heat detection) and **socio-economic** factors such as farmers’ organizations, infra-structure, extension and training and supply of services (roads, credit, veterinary services a.o.).

#### *1 Management of feeding and feed supply*

Milk production of cows is largely a hormone-induced process. A short-term drop in milk yield, particularly in the first part of the lactation period, will lead to a low overall lactation yield.
In fact many yields are so low, because the cows never reach their potential maximum after calving due to lack of feed even if only temporarily.

As a **reliable** feed supply is an absolute necessity, the introduction of improved dairy cows should be preceded by an assessment of the feed supply paying particular attention to the problem: the assurance of not only initial supply, but that of a **continuous** supply over a longer period.

A regular feed supply is not easy and often expensive to assure, as it may require **irrigation** or feed conservation in the form of **silage** or hay. Especially the production of silage will often pose difficulties.
The ensiling process may be unfamiliar, the machinery may not be available, use of urea to improve the feeding value of the silage may not be possible. An additional difficulty will be the production of **small quantities of silage** as required by the small farmer. He will have to organize labour and/or machines and the percentage of waste from small pits will be higher than from large pits.

Moreover, a high-yielding cow cannot produce milk on roughage only. With increasing milk yields a disproportionately larger part of the ration has to come from concentrates. Very good grass will probably support a milk yield of 2500 kg, but most tropical grasses will very likely be good enough for only 1500 kg.
In other words, the introduction of high-yielding cows also requires a **reliable supply of concentrates.** This, in turn, means availability of cereals and high-quality offals, and also a feed manufacturing industry, transport, roads, etc..

As milk yield is first of all a function of feed supply, the number of animals to be kept should always be related to the expected feed supply.
Planning and realization of feed supply should start well ahead of the arrival of the cows.

*2 Housing*
The major aspect of housing of dairy cows in the tropics and subtropics is that it can be comparatively simple and cheap. In fact, only a roof is required, first of all to provide shade. But the consequence of a roof is that we need a solid floor as well. Investment in housing for dairy cows is often high in practice. On the other hand, housing of **calves** is often neglected.
Shade should be provided to reduce heat loads and thus to increase feed intake. Provision of shade without simultaneous provision of feed is of little use.

*3 Milking*
Milking is one of the key points in dairy cattle management. Good milking means maintaining milk yield, maintaining udder health and maintaining milk quality.
Apart from the actual milking, the milker has an important task in keeping a keen eye on the cows in order to detect heat or disease.

*4 Animal care*
In addition to the veterinarian, the farmer plays a major role in health care for the individual cow.
Dairy farming is a highly developed form of agriculture and the **dairy farmer must possess quite a number of different skills. For instance:**
- ability to check health situation and decide whether a veterinarian is required
- keep the cow clean and functional
- heat detection
- adjustment of feeding levels and feed composition to milk yield and fertility needs
- milking
- calving care
- parasite control (dipping;rotation)
- calf rearing

*5 Fertility*
Milk production and profitability depend largely on regular calving to induce a new lactation. We would like each cow to calve every year. In practice we often find calving intervals of more than 15 months instead of 12 months. Moreover, often the highest yielders are affected, thus lowering the net value of these cows. Regular calving requires a high level of management with regard to calving hygiene, heat detection and breeding/insemination.

*6 Calf rearing*

Calf rearing is time-consuming and expensive.

The loss of rearing may be so high as to take the profit of the whole first lactation away. Calves of improved cows require extra care and are more risky, because they are weaker and more susceptible to local diseases, but also because they present a higher value.

In the first few weeks of a calf's life the two major risks are diarrhoea and respiratory problems. Draught, a sudden drop in ambient temperature, incorrect feeding and lack of hygiene are the major predisposing factors.

An additional problem is that the colostrum for calves from recently introduced cows contains insufficient immunity factors against local pathogens. Mortality amongst these calves is often high. Colostrum from local cows or from cows which have been in the area for one year or more is sometimes used with good results.

Gastro-intestinal parasites are the second danger in the life of a calf. Although an infection is usually not lethal, it may postpone the development of the calf by as much as one year.

Measures against these parasites should be based first of all on management rather than on the use of drugs that kill worms.

Depending on the locality, a number of immunizations will be required.

*7 Health and disease*

Although the farmer himself is the first line of defence against disease and disorder, he must have the support of a functional veterinary service to integrate all aspects of veterinary care, particularly the organization of disease eradication campaigns, but also to cater for the health of the individual cow.

*8 Marketing*

Usually the introduction of improved dairy cows aims at a better supply of fresh milk. As fresh milk deteriorates very quickly, a reliable marketing system is required. Major aspects are capacity of production, organization of production, quality controls, collection and transport, form of marketing and price.

Factors like national socio-economic policy, technical possibilities, climate, etc., may affect many of these items.

On the consumers' side the following factors may be mentioned:

- buyers' requirements
- purchasing power
- eating/dietary habits
- price of substitutes
- dairy imports
- geographical distribution of buyers

A practical difficulty may be to find an optimum relation between the processing capacity of the factory and the production capacity of the farmers.

***To summarize, we can say that if high-yielding cows in principle can be kept profitably somewhere, a high level of management will be required. The study of this series about modern dairy farming should be useful in achieving this high level of management.***

# 2 The composition of feedstuffs and their digestion

Feedstuffs for cattle consist of water and dry matter. For example, if the water content of a feedstuff is 75%, the dry matter content DM is 25%.
Although water is very important for a cow, it is the **dry matter** which contains the nutrients the cow needs.

## 2.1 Water

Feedstuffs contain more or less water. Examples of dry feedstuffs are hay and concentrate; young grass and silage are examples of wet feedstuffs.
**Water** is vital to the body of any animal.
The bodies of young animals may consist of water for as much as 80% of their live weight. Older, and especially fat animals, have less water in their bodies.

Dairy cows need water for:
- chewing and swallowing (saliva)
- transport of nutrients around the body
- formation and maintenance of body tissues
- milk production
- disposal of waste products
- regulation of the body temperature

Water leaves the body with the faeces, the urine and the milk and as vapour via the lungs (respiration) and the skin (sweating).

The **daily water requirement** of dairy cows depends on the composition of the feed (DM content), the amount of milk which is produced and on the climate (temperature and humidity).
For a dairy cow in the (sub)tropics the daily water requirement lies between 30 and 100 litres or more plus 2 litres for every kg of milk which the cow produces.

**Good water** (which means not contaminated; without colour, smell or taste; total soluble salts content less than 2 ppm), in sufficient quantity, is needed for optimum production.
Try to supply **cool** water in hot climates.
It is best when cows can drink whenever they want to and whatever quantity they want to.
If it is not possible to give cows permanent access to water, they should at least be watered twice a day. In hot climates dairy cows certainly benefit from having access to water more than twice a day.

## 2.2 Dry Matter (DM)

Dry matter consists of:
1 organic matter
2 inorganic matter

All valuable feed substances are contained in the dry matter.

### Organic matter (OM)

*Crude Protein (CP)*
Protein is needed for growth, maintenance, reproduction and lactation.
In general, every animal needs a constant supply of a certain amount of protein in order to remain healthy.

In the case of dairy cows, a shortage of protein will result in small calves at birth and/or slow-growing young stock.
Other effects of a shortage of protein, on adult dairy cows:

- low milk production
- less protein in the milk
- loss of body weight
- increased risk of infectious and metabolic diseases
- low fertility (hence a longer calving interval)

'Crude protein' is made up of 'true' protein (chains of amino-acids) and of inorganic nitrogen salts, amides and other substances.
'Amides' can be seen as substances which become true protein or as broken-down true proteins.
In green, flushy products (for instance, young grass) a large part of the crude protein consists of amides. In full-grown vegetable products the amide content is normally low.

The nitrogen in a feed which does **not** come from protein is called non-protein nitrogen (NPN).

Ruminants such as dairy cows can very well utilize non-protein nitrogen (see digestion). Hence, instead of feeding dairy cows expensive (true) protein, cheaper sources of nitrogen can be used as well. Urea which is a relatively cheap chemical product, is such a non-protein nitrogen. However, certain precautionary rules must be observed when feeding non-protein nitrogen to dairy cows.

*Carbohydrates*

Carbohydrates in feedstuffs are sugars and starches (e.g. derived from cereals, tubers and roots) and substances derived from plant cell walls, vessels and woody tissues, mainly cellulose and lignin.

Part of the carbohydrates in feedstuffs is called 'crude fibre' (CF) and the rest 'nitrogen-free extract (NFE); the latter consists of sugars, starches and sugar-like substances.
Sugars and starches are much easier to digest than crude fibre.

In the animal body carbohydrates are only present in the stomach. They are mainly used to provide energy covering the direct needs of the animal. If more energy is provided than immediately needed, the surplus is stored as body fat.

Fibre is very important for rumination and for the production of milk rich in butterfat. The feed of dairy cows should therefore contain a good quantity of crude fibre; 30% is considered a minimum.
Non-ruminants such as poultry can hardly digest crude fibre and for that reason the crude fibre content of their feed should be quite low.

*Fat (oil) or Ether Extract*

Fats also provide energy; in fact a certain amount of fat provides much more energy than the same amount of carbohydrate.

Some vitamins (for instance, A and D) are found in the fat fraction of the feedstuffs.

Roughages have a low fat content. Feedstuffs derived oilseeds (e.g. soybean, cotton) have a relatively high fat content.

Some fat should be present in the feed given to animals because of the vitamins.
Too much fat in the ration lowers the feed intake of the ruminant and disturbs the functioning of the rumen; for instance, not more than 2-3 kg/day of whole cotton seedcake should be fed to dairy cows.

### Inorganic Matter (IOM)

IOM is also called ash, because the IOM content is determined by burning samples of feedstuffs until they are free of carbon.

A high level of ash in a sample often indicates contamination with soil.
In the ash are the minerals. Minerals are very important for building-up the body; for instance, think of bones and teeth.
Minerals are also needed as constituents of the proteins etc. making up the soft tissues of the body. Numerous enzyme systems of the body require minerals as well.

Consequences of a shortage of minerals can be:

- low fertility
- poor growth
- diseases
- deformation of the skeleton
- low production

Generally speaking it is advisable to provide livestock with good mineral bricks/blocks (grazing livestock) or with a mineral mixture in the feed that is provided (housed livestock).
Another possibility is to correct mineral deficiencies in the soil by the application of appropriate fertilizers.

The minerals are divided in macro and micro elements. The only difference between macro and micro elements is that of the macro elements the animals need larger quantities.

### Vitamins

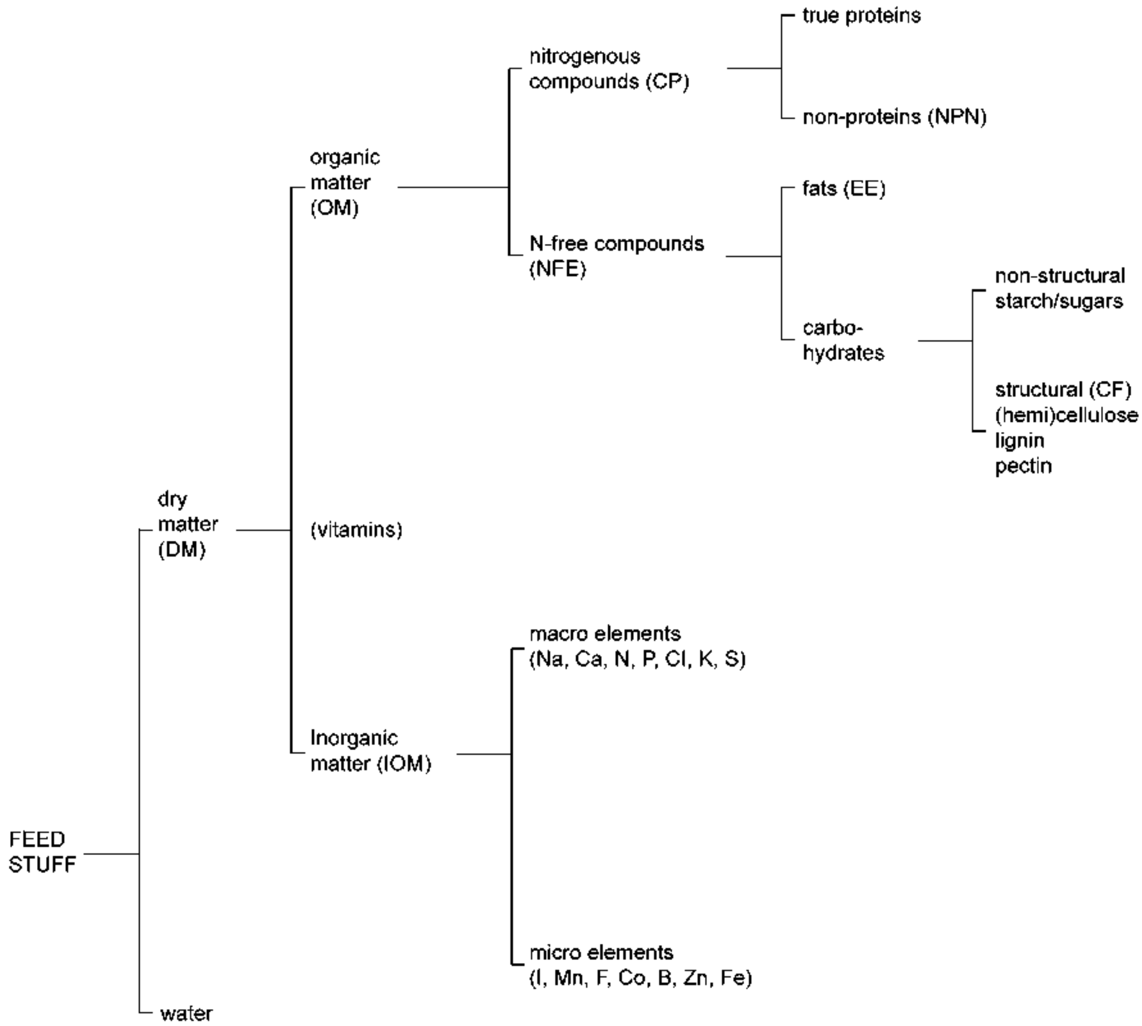
Vitamins are indispensable, but the animal body only needs them in **very small** quantities.

The most important vitamins are:

- **vitamin A:**
  With cattle, a shortage of this vitamin causes a dry skin, infections of the skin and the eyes, the digestive tract (diarrhoea) and the genitals (infertility).
  When farm animals get enough young green feedstuffs, they will not suffer from a shortage of vitamin A.
- **vitamin B:**
  This is a group of vitamins that **ruminants** can produce themselves, in their rumen.
  Poultry may suffer from deficiencies. Here a shortage may cause various disorders of the nerves, diarrhoea, reduced fertility, affections of the skin, etc..
  Bran, milk and liver products are sources of these vitamins.
- **vitamin C:**
  All farm animals can synthesize this vitamin (make it themselves).
- **vitamin D:**
  When animals are out in the open air, vitamin D is produced by the action of sunlight on the skin.
  A shortage causes retarded growth of the bones, especially in young, growing animals; this is called rachitis (rickets).

**Summary**

The composition of feedstuffs can be resumed as follows:



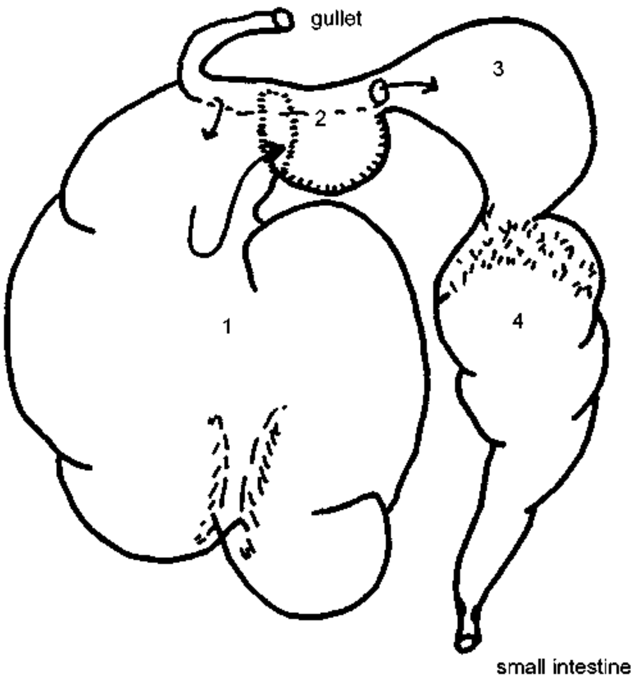

DM = dry matter
OM = organic matter
IOM = inorganic matter
CP = crude protein
NPN = non-protein nitrogen
EE = ether extract
NFE = nitrogen-free extract
CF = crude fibre

Na = sodium
Ca = calcium
N = nitrogen
P = phosphorus
Cl = chlorine
K = potassium
S = sulphur
I = iodine
Mn = manganese
F = fluorine
Co = cobalt
B = boron
Zn = zinc
Fe = iron

*Figure 1: The composition of feedstuffs*

## 2.3 Digestion

Digestion means the breaking down of the different components in a feedstuff in such a way that they can be taken up by the bloodstream and transported to the places in the body where they are needed. The process of digestion in non-ruminants as well as in ruminants takes place under the influence of **enzymes.** Enzymes are substances which stimulate or facilitate certain chemical processes.




1 = rumen (paunch; first stomach)
2 = reticulum (honey comb; second stomach)
3 = omasum
4 = abomasum (rennet stomach, rennet sack; true stomach)

*Figure 2: Ruminants have more than one stomach.*

The **abomasum** is comparable to the stomach of non-ruminants; the other stomachs (the so-called fore-stomachs) are specific for the ruminant.
Due to the relatively large volume and specific action of the fore-stomachs, the cow is capable to absorb quite a lot of bulky vegetable feed.

Just after birth the fore-stomachs are still underdeveloped. The milk which the calf drinks goes directly to the abomasum. However, the fore-stomachs develop quite rapidly and at six weeks the volume of the fore-stomachs is about that of the abomasum. This development is (and should be) stimulated by the feeding of roughage and concentrate.
In adult cows the volume of the fore-stomachs is about 15 times that of the abomasum; the rumen on its own has then a volume of 100-150 litres.

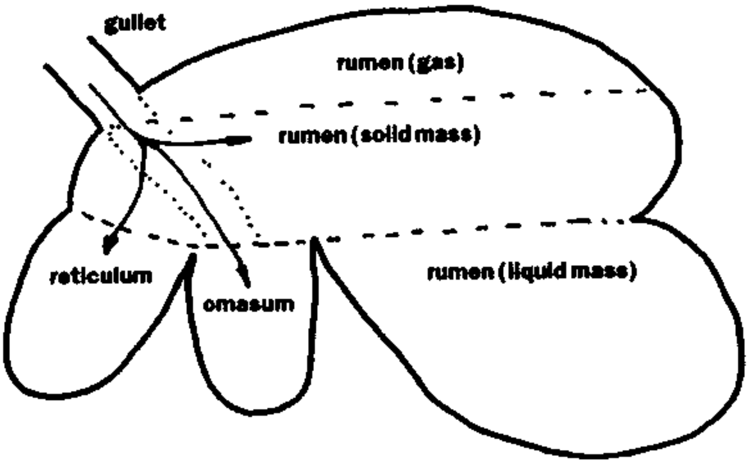



*Figure 3: Schematic representation of the fore-stomachs*

The rumen content is made up of three layers. At the bottom is the liquid layer. On this layer floats a solid mass of roughage particles and in the space above is the rumen gas.

**Digestion in the fore-stomachs**
The feed mixed with some saliva enters the fore-stomachs.
In the rumen the micro flora (billions of bacteria and protozoa) starts the digestion process.
What do the fore-stomachs to the feed:

- they break down part of the **carbohydrates,** mainly into:
  - acetic acid, which is needed in the butterfat-making process; especially cellulose contributes to the formation of acetic acid
  - propionic acid, which provides energy to the animal and which is needed for the formation of milk sugar; especially starches and sugars in the feed contribute
  - butyric acid
- they break down **part of the protein** in the feed into amino acids. These amino acids are either used in the formation of protein made by the micro flora in the rumen (rumen microbial protein = RMP) or broken down still further into ammonia, carbondioxide and volatile fatty acids.

However, the micro flora in the rumen not only **uses** the amino acids from the feed, it is also capable of **making** all essential amino acids out of **non-protein** nitrogen. For example out of **urea.** The non-ruminant animal does not have this capability.
The micro flora in the ruminant will only do this under certain conditions:

- there must be sufficient easily digestible carbohydrate in the feed (energy)
- there must be a clear shortage of 'natural' protein in the feed
- the urea should be supplied in small quantities and at regular intervals

There is a limit to what the dairy cow can take up in the form of non-protein nitrogen.

Digestion liberates the gases carbondioxide and methane which makes the cow belch regularly.

**Fibrous material** in the feed of a cow is very important. It stimulates rumination and saliva production and is necessary to bring about the 'solid' layer in the rumen. Without this solid layer the rumen does not have its regular contractions which are necessary for the proper mixing of the rumen contents.
Sometimes the layers in the rumen do not come about and the rumen then contains a mixture of gas, fluid and fibrous material. In this case the rumen contractions may stop; the rumen gas is no longer expelled and the cow may become ill; this is called bloat or tympanism.

### Digestion in the abomasum and the small intestine

Some time after eating the cow starts ruminating the (solid) feed from the rumen.
With the saliva which is added during the process the solid feed becomes almost wholly liquid. It then enters the abomasum via the omasum.
If the animal takes liquid feed, this passes directly into the abomasum.
Digestion continues in the abomasum, just as with animals having one stomach only (non-ruminants).

### To summarize

It will be clear that the digestion of carbohydrates and proteins in the ruminant is quite different from the digestion of carbohydrates and proteins in the non-ruminant.
In the **ruminant,** carbohydrates are transformed into fatty acids in the rumen, while in the non-ruminant carbohydrates are transformed into simple sugars in the intestinal tract.
Thanks to rumen fermentation, **a ruminant can utilize roughage** (crude fibre) and convert it into milk and beef.
In the **ruminant,** part of the protein from the feed first undergoes a change in the rumen, before passing on to the intestinal tract. It is because of this process that a ruminant does not require such a large amount of high-quality proteins in its ration as a non-ruminant. The micro flora builds up the proteins the ruminant needs, as long as there are enough (easily digestible) carbohydrates (NFE) and nitrogen in the ration. This nitrogen may also be non-protein nitrogen.

If the protein in the ration is of rather poor quality, the **ruminant will upgrade it** in the rumen to meet its requirements. The non-ruminant does not have this capability.

## 2.4 Digestibility

Not all the feed an animal eats is digested. The part that is not digested will leave the body as **faeces** and is not used by the animal.

The digested part of the feed can be expressed as a percentage of the total feed intake. This percentage is called the **digestibility coefficient.**

### Example

A cow eats 12 kg DM per day, of which 3 kg is later found in the faeces. This means that 12!3 = 9 kg DM has been digested. The digestibility coefficient of the DM is then $\frac{9}{12} \times 100 = 75\%$. In other words, 75% of the DM has been digested.

Depending on the feedstuff, the digestibility may vary very much. Some products such as most feeds of animal origin, young grass and other green roughages are very easily digested (high digestibility coefficient) while other products such as late-harvested hay, straw and chaff are difficult to digest (low digestibility coefficient).

**Other factors are:**

- the kind of animal (goat, sheep or cow; local or ‘European’ breed of animal)
- the level of feeding (in general, the more feed the animal consumes, the lower the digestion of this feed is)
- the structure of the feed (‘fine’ feed is digested more easily than ‘coarse’ feed; it is most unwise to feed whole grains to cows)
- palatability (i.e. whether pleasant to the taste)
- the age of the animal; very young and very old animals digest the feed somewhat less efficiently.

# 3 The nutritive value of feedstuffs

The biological value of a feedstuff is determined by:
- dry matter content
- protein content
- energy content
- digestibility (also palatability)
- amount and kind of minerals in the feedstuff
- amount and kind of vitamins

## 3.1 Intake of DM of dairy cows

In general, how much a cow will eat depends on the bodyweight and the milk yield of the cow, and on the type of feed.
Cows of 500 kg live weight, producing 2000 kg milk per lactation, on a diet made up mostly of average quality average, will consume 9-12 kg DM in early lactation.

In the following examples we will assume that the DM intake is 2 kg DM/day per 100 kg live weight (but it is important to remember that a cow producing 3000-4000 kg milk will consume 11-14 kg DM of a good quality diet made up of roughage and concentrate).

What does this mean in actual consumption:

| | | |
|---|---|---|
| Friesian cow | 500 kg l.w. | consumes 10 kg DM per day |
| Ayrshire/Guernsey | 450 kg l.w. | consumes 8-9 kg DM per day |
| Jersey | 350 kg l.w. | consumes 7 kg DM per day |
| small (local) cow | 300 kg l.w. | consumes 6 kg DM per day |

How much fresh product is then required:

| | |
|---|---|
| 1 kg grass (wet season) | with 20% DM = 200 g DM |
| 1 kg grass (dry season) | with 50% DM = 500 g DM |
| 1 kg hay | with 80% DM = 800 g DM |
| 1 kg sweet potato vines | with 15% DM = 150 g DM |
| 1 kg Napier grass | with 20% DM = 200 g DM |

So, a Friesian cow in the wet season would consume $10 \times {}^{100}/_{20} = 50$ kg fresh grass per day.
For hay this figure would be $10 \times {}^{100}/_{80} = 12\frac{1}{2}$ kg.

**N.B.:** How much does the (school) herd **in fact** consume when fed to appetite? (this little investigation could turn into a very good practical lesson!). Bear in mind that the 'field behaviour' of grazing cows may be different.

The consumption of concentrate will **lower** the consumption of roughage **if** the roughage is of high quality. If not, the roughage consumption may increase slightly.
It is therefore wasteful to feed too much concentrate to low to medium producing cows eating high-quality roughage. But a small amount (2-3 kg per day) of a high-quality concentrate given to cows grazing average to poor pasture should give good results.

To prevent disorders in the functioning of the rumen, it is advised that **at least one-third of the total DM** in the daily ration consists of good-quality roughage (long fibrous material).

## 3.2 Protein and energy in the feed

The protein requirements of cows and the protein content of a feedstuff are expressed in grams crude protein (g CP) or in grams **digestible** crude protein (g dCP). 'Protein' has already been discussed in the previous chapter.
The protein requirements of cows can **only** be met by the nitrogenous compounds in the feed (true proteins and non-proteins).
A shortage of nitrogenous compounds in the feed cannot be compensated by carbohydrates or other substances and will therefore result in lower production.

### Energy

A dairy cow needs **energy** for her maintenance and production (which means milk). The energy is supplied by the organic matter in the ration:

- carbohydrates (including crude fibre)
- proteins and non-protein nitrogenous compounds
- fats

The cow uses proteins to supply energy when there are not enough carbohydrates and fats in the ration to meet the cow's requirements, or when more protein is fed than is needed. 'Proteins for energy' should be avoided because proteins are usually expensive!

The energy in the feed is liberated in the digestive process.

The **amount of energy** which a cow needs, and the amount of energy which a feedstuff supplies, can be expressed in several ways (which can lead to confusion).
In this guide we will use a system which was originally widely used, namely the **total digestible nutrients** system, in brief **TDN.** Since then more 'refined' systems have come into use, which will hardly be discussed in this guide.

In the TDN system energies of digestible carbohydrates, digestible proteins and digestible fats of the feedstuff concerned are totalised. TDN of a feedstuff are expressed as a percentage of the fresh material (or the material as such) **or** of the dry matter of that feedstuff.
If, for instance, a certain green (fresh) forage has a TDN value of 12%, this means that 1 kg of that forage contains: 12% of 1000 g = 120 g of TDN. If that forage has a dry matter content of 20%, the dry matter (DM) of it will contain $^{100}/_{20} \times 120 = 600$ g of TDN per kg, which means a TDN of 60%.
TDN percentages on dry matter base of different feedstuffs can be better compared with each other than TDN values on fresh base, certainly when DM contents of these feedstuffs are completely different.

TDN values can also be expressed in **energy units:** calories or Joules and is then called digestible energy (DE).
1 kg of TDN represents about 4400 kilo calories (Kcal) or 4.4. mega calories (Mcal) of digestible energy. Because 1 calorie equals 4.184 Joule, 1 Mcal thus equals 4.184 mega Joules (MJ). Consequently, 1 kg of TDN also represents 4.4 × 4.184 = 18.4 MJ of digestible energy.
For instance, the above mentioned forage with a TDN of 12% has a DE content of 12% of the DE of 1000 g (1 kg) of TDN = 0.12 × 4.4 = 0.52 Mcal or 0.12 × 18.4 = 2.20 MJ (on fresh base). On dry matter base (TDN of 60%) the DE content again is 5 times higher than on fresh base: 5 × 0.52 = 2.60 Mcal or 5 × 2.2 = 11 MJ

The DE value of the dry matter can also be calculated as follows: 60% of the DE of 1 kg of TDN: 0.60 × 4.4 = about 2.6 MJ as well (or 0.60 × 18.4 = about 11 MJ).
DE thus is the digestible part of the gross energy (GE) of a feedstuff. The animal excretes the indigested part of the gross energy with the faeces.

Not all DE is used by the animal for maintenance and production purposes. During fermentation in the rumen some energy gets lost as methane (expired) and with urine: in total between 12 and 18% of the DE. The rest or balance is called **metabolisable energy** (ME), which in some countries is also used as energy unit. The ME value of the just mentioned Napier grass therefore is about 85% of the DE: about 0.85 × 2.6 = 2.21 Mcal per kg of DM, but it can also be calculated with the following formula:

ME (Mcal per kg DM) = 1.01 DE – 0.45.

The result of this calculation is: 1.01 × 2.6 = 2.62 – 0.45 = 2.17 Mcal per kg of DM.

However, this metabolisable energy is only partly used for maintenance and production purposes of the animal. About 43-45% of the ME is lost as heat by dairy cows and they can only use 55-57% of it for maintenance and production. This part of the energy is called **net energy for milk production** NEL, which is also used as energy unit in some countries.

The net energy of feedstuffs can vary substantially in dependence of the digestibility and the utilisation of the gross energy. Of the gross energy of barley straw, for instance, only about 20% is used for maintenance and production purposes, whereas this percentage amounts to about 36% for maize silage and even to about 43% for grains.

As an example, in the following table the different energy values of a few feedstuffs are presented.

*Table 1: Approximate energy values of a few feedstuffs*

| | **TDN** | **DE** | **ME** | **NEL** |
|---|---|---|---|---|
| | **(%)** | **(MJ per kg DM)** | | |
| wheat or rice straw | 40 | 7.4 | 5.8 | 3.0 |
| Napier grass | 55 | 10.0 | 8.1 | 4.5 |
| Lucerne hay | 60 | 11.0 | 8.5 | 4.8 |
| temperate grass silage | 70 | 12.9 | 10.7 | 6.1 |
| maize silage | 73 | 13.4 | 11.3 | 6.5 |
| maize grain | 80 | 14.7 | 13.0 | 7.7 |

The data in this table clearly show the big differences in energy values that exist between different forages. Straws, of course, belong to the lowest quality forages, whereas temperate grass and maize silage are the best forages in this respect. Maize silage in the tropics has about the same E-value as in temperate climates!

## 3.3 DM base or 'fresh' base

In books and magazines, the composition of feedstuffs is sometimes expressed on DM base (per kg DM) and in other cases on the base of the fresh feedstuff (per kg feedstuff).
It is possible to calculate the composition of feedstuffs from the data on DM base or to change the data from the fresh feedstuff to DM base.

### Examples

1 A grass with 20% DM has a TDN content on DM base of 25%.
What is the TDN content of the fresh grass?

The grass contains 20% DM which means 200 g DM/kg grass.
25% of this 200 g DM is TDN which means 50 g.
So, in 1 kg of this grass there is 50 g TDN and this is 5%.

2 A grass with 20% DM contains 20 g dCP/kg grass.
What is the dCP content on DM basis of this grass?

The grass contains 20% DM or 200 g DM/kg grass.
We know that all the nutrients are contained in the DM, so the grass contains 20 g dCP per 200 g DM.
If 20 g DM is found in 200 g DM, then 20 × 5 = 100 g dCP is found in 1000 g DM (100 g dCP/kg DM).
In percentage, $^{100}/_{1000} \times 100 = 10\%$ dCP in the DM.

3 Fresh milk has 15% DM, of which 24% is crude protein.
What is the crude protein content on fresh base?

$^{24}/_{100} \times 15 = 3.6\%$.

To make a good comparison between different feedstuffs in terms of feeding value, it is necessary to compare equal amounts of dry matter of each feedstuff, or in other words, to express the composition of the feedstuffs on DM basis. Only then a conclusion can be drawn as to which feedstuff has the best quality in terms of energy and protein.

**Example**

*Table 2: Per kg product*

| | % DM | TDN(g) | dCP(g) |
|---|---|---|---|
| grass I | 20 | 100 | 20 |
| grass II | 25 | 110 | 22 |
| hay | 80 | 380 | 70 |

To be able to draw a conclusion as to which of the three feedstuffs has the best quality, the data are changed to DM base; as follows:

*Table 3: Per kg DM*

| | % DM | TDN(g) | dCP(g) |
|---|---|---|---|
| grass I | 20 | 500 | 100 |
| grass II | 25 | 440 | 88 |
| hay | 80 | 475 | 90 |

Looking at the data on DM base, it can be concluded that grass I has the highest TDN and dCP content. So, grass I has the best quality of the three feedstuffs; this was not obvious at first.

*Table 4: List of common feedstuffs in the (sub)tropics and their nutritive value for cattle*

| | in 1 kg product | | | in 1 kg DM | | source |
|---|---|---|---|---|---|---|
| | DM g | TDN g | dCP g | TDN g | dCP g | |
| **1. Cereals and other concentrates** | | | | | | |
| maize grain - white | 900 | 840 | 47 | 930 | 52 | E/C Africa |
| maize grain - yellow | 880 | 845 | 80 | 955 | 52 | Trop.Feeds |
| maize grain | 900 | 775 | 80 | 860 | 90 | -- |
| sorghum grain | 900 | 755 | 68 | 840 | 76 | E/C Africa |
| wheat grain | 875 | 770 | 95 | 880 | 110 | Trop.Feeds |
| wheat grain | 900 | 705 | 100 | 785 | 110 | -- |
| barley grain | 985 | 625 | 70 | 695 | 80 | -- |
| barley grain | 900 | 695 | 90 | 770 | 100 | -- |

| | in 1 kg product | | | in 1 kg DM | | source |
|---|---|---|---|---|---|---|
| | DM g | TDN g | dCP g | TDN g | dCP g | |
| maize bran | 900 | 695 | 40 | 770 | 44 | E/C Africa |
| wheat bran | 900 | 585 | 99 | 650 | 110 | -- |
| wheat bran | 900 | 445 | 90 | 495 | 100 | -- |
| wheat pollard | 900 | 685 | 103 | 760 | 115 | -- |
| rice bran | 900 | 505 | 95 | 560 | 105 | -- |
| rice bran | 880 | 615 | 79 | 700 | 90 | -- |
| brewer's grains (sorghum) | 320 | 230 | 77 | 720 | 240 | -- |
| brewer's grains, wet | 225 | 155 | 45 | 690 | 200 | Trop.Feeds |
| brewer's grains, dry | 500 | 185 | 80 | 370 | 160 | -- |
| corn and cob meal | 880 | 775 | 40 | 860 | 46 | E/C Africa |
| cassava meal (tapioca) | 900 | 595 | 2 | 660 | 2 | -- |
| blackstrap molasses | 760 | 560 | 0 | 735 | 0 | Trop.Feeds |
| molasses | 800 | 495 | 8 | 620 | 10 | -- |
| molasses | 750 | 540 | 0 | 720 | 0 | E/C Africa |
| citrus pulp | | | | | | |
| beet pulp | | | | | | |
| maize gluten | | | | | | |
| **2. Legume seeds and oil seeds** | | | | | | |
| cowpea seed | 860 | 765 | 168 | 890 | 195 | E/C Africa |
| cotton seed (whole) | 920 | 830 | 163 | 900 | 177 | -- |
| cotton seed (whole) | 945 | 640 | 140 | 670 | 145 | -- |
| soyabean seed (whole) | 900 | 865 | 279 | 960 | 310 | -- |
| soyabeen seed | 900 | 785 | 290 | 870 | 320 | -- |
| soyabean seed with hulls | 910 | 810 | 205 | 885 | 225 | Trop.Feeds |
| sunflower seed with hulls | 920 | 755 | 124 | 820 | 135 | E/C Africa |
| sunflower heads, entire | 900 | 585 | 53 | 650 | 59 | -- |
| velvet beans | 900 | 810 | 171 | 900 | 190 | -- |
| velvet beans, in pods | 890 | 720 | 105 | 810 | 118 | -- |
| groundnuts | 900 | 1295 | 250 | 1440 | 275 | -- |
| **3. Oil seed cakes and meals** | | | | | | |
| cotton seed cake | 930 | 690 | 279 | 740 | 300 | E/C Africa |
| Egyptian cotton cake | 880 | 500 | 180 | 565 | 205 | Trop.Feeds |
| groundnut oil cake, without hulls, solv.extract | 920 | 745 | 460 | 805 | 495 | -- |
| soyabean meal | 920 | 755 | 322 | 820 | 350 | E/C Africa |
| sunflower cake (without hulls) | 940 | 660 | 282 | 700 | 300 | -- |
| **4. Animal protein feeds** | | | | | | |
| blood meal | 900 | 540 | 598 | 600 | 665 | E/C Africa |
| fish meal | 940 | 725 | 606 | 770 | 645 | -- |
| fish meal | 900 | 565 | 550 | 625 | 610 | -- |
| meat and bone meal | 960 | 625 | 453 | 650 | 472 | E/C Africa |
| **5. Dry roughages (not pasture)** | | | | | | |
| sweet potato vines, hay | 865 | 500 | 90 | 575 | 105 | Trop.Feeds |
| cotton seed hulls | 900 | 370 | 3 | 410 | 3 | E/C Africa |
| cowpea hay (with seeds) | 910 | 500 | 83 | 550 | 91 | -- |
| cowpea straw (no seeds) | 910 | 380 | 20 | 420 | 22 | -- |
| Dolichos lablab hay (with seeds) | 900 | 515 | 82 | 570 | 91 | -- |
| groundnut hay | 920 | 470 | 51 | 510 | 55 | -- |
| lucerne, good average | 900 | 470 | 98 | 520 | 109 | -- |
| lucerne, stemmy mature | 900 | 405 | 77 | 450 | 86 | -- |
| lucerne hay, early bloom | 900 | 510 | 115 | 565 | 125 | Trop.Feeds |
| lucerne hay | 850 | 400 | 110 | 470 | 130 | -- |
| maize cobs | 940 | 440 | 0 | 470 | 0 | E/C Africa |
| maize husk (cob sheath) | 950 | 435 | 4 | 460 | 4 | -- |
| maize stover | 900 | 450 | 1 | 500 | 2 | -- |
| sorghum stover | 900 | 450 | 1 | 500 | -- | |
| soyabean hay (mature) | 920 | 525 | 50 | 570 | 54 | -- |
| soyabean pod husks | 870 | 350 | 10 | 400 | 11 | -- |

| | in 1 kg product | | | in 1 kg DM | | source |
|---|---|---|---|---|---|---|
| | **DM g** | **TDN g** | **dCP g** | **TDN g** | **dCP g** | |
| soyabean straw | 870 | 330 | 15 | 380 | 17 | -- |
| velvet bean hay | 900 | 480 | 77 | 530 | 86 | -- |
| wheat straw | | | | | | |
| rice straw | | | | | | |
| **6. Dry roughages (pasture)** | | | | | | |
| Rhodes grass hay (early cut) | 910 | 490 | 21 | 540 | 23 | E/C Africa |
| Rhodes grass hay (first cutting) | 870 | 425 | 10 | 490 | 12 | Trop.Feeds |
| Rhodes grass hay (late cut) | 910 | 430 | 0 | 470 | 0 | E/C Africa |
| Star grass hay | 890 | 445 | 36 | 500 | 40 | -- |
| Guinea grass (full seed) | 910 | 410 | 11 | 450 | 12 | -- |
| natural pasture hay | 930 | 455 | 4 | 490 | 4 | E/C Africa |
| pasture hay (average) | 850 | 255 | 45 | 300 | 55 | -- |
| Rhodes grass/Siratro hay | 880 | 440 | 66 | 500 | 75 | E/C Africa |
| Stylo hay (2 months'regrowth) | 760 | 440 | 84 | 580 | 110 | -- |
| berseem hay (good quailty) | 900 | 555 | 110 | 615 | 120 | Trop.Feeds |
| **7. Fresh pasture and roughages** | | | | | | |
| sweet potato vines, fresh | 150 | 100 | 15 | 665 | 100 | -- |
| sweet potato vines, fresh | 85 | 60 | 15 | 705 | 175 | Trop.Feeds |
| maize, fresh, 8 weeks | 160 | 100 | 8 | 625 | 50 | -- |
| green maize | 200 | 120 | 10 | 600 | 55 | -- |
| sorghum, fresh, mature | 230 | 115 | 10 | 500 | 45 | Trop.Feeds |
| sorghum, fresh, before flowering | 200 | 115 | 16 | 575 | 80 | -- |
| sorghum, ditto | 250 | 120 | 13 | 480 | 50 | -- |
| Napier grass, fresh, vegetative, less than 1 m high | 200 | 115 | 10 | 575 | 50 | Trop.Feeds |
| Napier grass, 1 month' regrowth | 230 | 130 | 21 | 570 | 91 | E/C Africa |
| Napier grass, 7 months' regrowth | 260 | 115 | 5 | 440 | 21 | -- |
| Rhodes grass, 1 month' regrowth | 200 | 128 | 18 | 640 | 90 | -- |
| Rhodes grass, 2 months' regrowth | 230 | 135 | 11 | 590 | 50 | -- |
| Rhodes grass, 3 months' regrowth | 260 | 115 | 5 | 440 | 20 | -- |
| Rhodes grass, fresh, pasture | 280 | 185 | 15 | 660 | 55 | Trop.Feeds |
| Rhodes grass, fresh, young | 250 | 120 | 30 | 480 | 120 | -- |
| Rhodes grass, fresh, medium | 300 | 130 | 20 | 435 | 65 | -- |
| Rhodes grass, fully flowering | 350 | 140 | 10 | 400 | 30 | -- |
| Star grass, 2½ months' regrowth | 230 | 120 | 10 | 520 | 45 | E/C Africa |
| Star grass, 3½ months' regrowth | 260 | 125 | 8 | 480 | 32 | -- |
| Star grass, 4½ months' regrowth | 260 | 120 | 8 | 470 | 31 | -- |
| Star grass, fresh, medium | 300 | 130 | 20 | 430 | 65 | -- |
| Nandi Setaria, fresh, young | 200 | 120 | 25 | 600 | 125 | -- |
| Nandi Setaria, medium | 250 | 130 | 20 | 520 | 80 | -- |
| Nandi Setaria, fully flowering | 300 | 140 | 5 | 465 | 15 | -- |
| rye grass, fresh, medium | 200 | 130 | 30 | 650 | 150 | -- |
| berseem, 1st cut, irrigated | 110 | 70 | 20 | 640 | 180 | Trop.Feeds |
| lucerne, fresh, 1 year old stand | 200 | 145 | 30 | 725 | 150 | -- |
| lucerne, fresh, young | 180 | 100 | 35 | 555 | 195 | -- |
| lucerne, fully flowering | 250 | 120 | 30 | 480 | 120 | -- |
| lucerne | 180 | 105 | 34 | 590 | 188 | E/C Africa |
| silver-leaf Desmodium | 200 | 125 | 22 | 630 | 108 | -- |
| soyabean, flowering | 270 | 145 | 43 | 530 | 161 | -- |
| natural grass, E/C Africa, early growing season | 300 | 190 | 19 | 630 | 62 | -- |
| ditto, early growing season | 400 | 195 | 0 | 490 | 0 | -- |
| ditto, mid-growing season | 300 | 145 | 9 | 490 | 29 | -- |
| ditto, mid-dry season | 550 | 135 | 0 | 250 | 0 | -- |
| **8. Silages** | | | | | | |
| Rhodes grass silage | 240 | 120 | 2 | 500 | 5 | Trop.Feeds |
| ditto, early flowering | 230 | 135 | 14 | 580 | 63 | E/C Africa |
| ditto, full bloom | 250 | 135 | 12 | 550 | 49 | -- |
| ditto, mature grass | 300 | 140 | 5 | 460 | 16 | -- |

| | in 1 kg product | | | in 1 kg DM | | source |
|---|---|---|---|---|---|---|
| | DM<br>g | TDN<br>g | dCP<br>g | TDN<br>g | dCP<br>g | |
| maize, silage, good, high DM | 400 | 280 | 19 | 700 | 47 | -- |
| ditto, average quality | 330 | 210 | 14 | 640 | 42 | -- |
| ditto, poor quality | 270 | 150 | 7 | 550 | 26 | -- |
| ditto, milk stage | 220 | 120 | 10 | 545 | 45 | Trop.Feeds |
| sorghum silage | 260 | 145 | 10 | 560 | 40 | E/C Africa |
| Napier grass silage, 2 m high | 240 | 115 | 5 | 480 | 21 | -- |

### Discussion

- Most of the data come from research stations in East and Central Africa (indicated by E/C Africa). Other data have been derived from the FAO publication Tropical Feeds.
  Various other sources have been used as well.
- The list is not at all exhaustive.
  Our advice to trainers would be: consult locally established research stations or other sources of information of local importance and try to collect feeding value data for all products that are **locally available.**
  And students should learn to recognize locally available products and know their feeding value and comparative price.
- **Feeding value data must not be taken too rigidly.** Products known under one and the same name are seldom quite comparable and analyzing techniques and standards may not be exactly the same everywhere. This is reflected in our list. Advice: rely on the data which locally established research stations use.
- Grazing cows generally choose the most nutritious vegetation (i.e. 'selective grazing') when plant growth is relatively abundant. Feeding value data apply to the **average** product. Therefore cows may actually eat a product that is better than we assume it to be.
  Also keep in mind that the TDN system has been designed for assessing fodder quality in **temperate** climates. It is not necessarily well suited to tropical green fodders.
  On the other hand, **it is most unwise to feed dairy cows more or less 'blindly',** i.e. without having a good appreciation of the qualities of the product(s) which the cows eat and students should be made very much aware of this.
- Bear in mind that the data refer to the 'pure' product and not to mixtures including a large portion of weeds!
- Presumably the data refer to products grown on well-fertilized soils.

**NB: Certainly in Western Europe the TDN protein evaluation method is outdated; more 'refined' evaluation methods have come into use.**
**Where the TDN system is not in use (or no longer used), the user of this guide should adapt our text and let the students work with the method which is locally used.**

## 3.4 General description of important commercialized feedstuffs

(from Feeding Management I brochure, of VEEPRO HOLLAND)

### Roughages

Good-quality roughages are the best sources of fibre for optimal functioning of the rumen. This relates to their influence on the rumen flora. In order to maximize the nutrient value of forages, it is important to harvest (graze) at the right stage of maturity. Nearly all forages have their highest nutrient content before the flowering stage. The nutrient value as well as digestibility declines after this stage. Maize/sorghum to be ensiled should be harvested at the dough stage of the grain to obtain the highest nutrient value.

**Wet brewers'grains** is a by-product of the brewing industry. It is a medium-protein and medium-energy feed. It is very palatable and is best fed at a rate of 5 to 10 kg per dairy cow per day. It must be fed fresh or obtained from ensiled storage. If ensiled, the wet brewers'grains take about 4 to 6 weeks to ferment properly. It is important that the silage clamp has proper drainage to prevent the feed from rotting.

### Energy-rich feeds

Cereals have a high energy and low protein content.

**Barley** should be milled moderately fine or rolled for maximum utilisation by dairy cows; otherwise it will pass through the digestive tract partly undigested. It has about 95% of the energy value of maize and is very palatable and an ideal feed for cattle.

**Maize** is highly palatable and supplies a large amount of energy economically. However, it is low in protein, crude fibre and minerals.
Maize may be used as the main source of energy. In order to use the high energy content of maize efficiently it should be properly balanced with other ingredients. It should be milled or rolled or be fed as a high moisture ensilaged grain.
Maize meal on its own should not be stored too long as it easily becomes rancid and its carotene content will decrease considerably.

**Oats** are very rich in crude fibre; therefore it is advisable to mix oats with other cereals in rolled form for maximum utilisation.
Oats have a positive effect on milk and butterfat production. The rolled form is a very good feed for calves. The high crude fibre content contributes to early rumen development.

**Sorghum** grain is an excellent feed for livestock when supplemented with other palatable ingredients. It should be milled moderately fine, since too finely ground sorghum results in reduced consumption.
It is important to remember that the red sorghum varieties have a high tannin content and lack carotene. Tannin is a toxic substance if eaten in large quantities.

**Corn and cob meal** are the complete milled maize cobs (includes grains, spills and husks). Corn and cob are much lower in TDN and crude protein than maize itself, but is known for its easily digestible high crude fibre content.

**Hominy feed (maize germ and bran meal)** is a by-product of the dry maize milling industry and consists of the bran coating and maize germs. Hominy feed is very palatable and its nutrient content is nearly the same as that of maize grain. However, it contains more oil when the germs are included.

**Rice bran** is a by-product of the rice-milling industry. It is made up of the bran layer, rice germs and pieces of broken rice.
Rice bran is similar to oats as regards crude protein, energy, oil and crude fibre content, but contains more phosphorus.

**Wheat bran** is a by-product of flour wheat milling and is highly palatable. It is poor in calcium, but tends to be higher in phosphorous than most other cereals and their by-products.
It is a bulky feed, rich in crude fibre and has a laxative effect.

**Sugarbeet pulp** is also available in dried form (pellets). It is an ideal energy source for dairy cows producing large amounts of milk. Molasses may occasionally be added to increase its palatability.
The crude fibre is very digestible and the sugarbeet pulp can be fed to milking cows at a rate of up to 3 kg per day.

**Tapioca** (made from cassava roots) is produced in tropical and subtropical zones. Tapioca is quite palatable and relatively inexpensive. It is high in TDN content but low in protein. Its starch is highly digestible.

**Cane molasses** (thick brown syrup that is produced during the refining of cane sugar) makes feed more palatable and serves as a dust-settler and binder in dry feed. It is an inexpensive and excellent source of energy. Up to 10% by weight may be used in mixtures.

### Protein/energy-rich feeds

The majority of the protein-rich feeds are derived from oilseeds. They consist of the residues remaining after oil has been extracted. Whole oilseeds may also be used as feed.

**Alfalfa pellets** are produced in dehydration plants from standing alfalfa.

**Dried brewers'grains**.

**Cottonseed**. The whole kernel of cottonseed without the lint (fuzzy cotton) may be used as a good feedstuff for adult cattle. This feed is often used in tropical and sub-tropical regions. It is rich in protein, oil, crude fibre and energy.
An amount of up to 2.5 kg per day for high-yielding cows may be fed in early lactation.
It has a positive effect on the butterfat percentage of milk and is known for its enduring effect on milk production.

**Cottonseed cake (meal)** is an excellent protein supplement for dairy cattle. It is important to avoid overfeeding because the cottonseed cake may contain a toxic substance called gossypol. Gossypol has an inhibitive effect on digestive enzymes in the cow's intestine.
Heating to above 100 °C alters the chemical composition of gossypol and removes its toxicity.

**Soyabeans** are rich in protein, oil and energy. The beans should be milled or crushed and not be stored longer than one week. Milled or crushed soyabeans will rapidly become rancid due to their lipase content. Furthermore, soyabeans contain an enzyme called urease, which converts urea into ammonia and may have an adverse effect on the cow's digestive system.
Lipase and urease are inactivated by heating. Dairy cows fed with heat-treated (flaked) soyabeans produce more milk than cows fed on untreated soybeans.

**Soyabean cake (meal)** is one of the most valuable sources of vegetable protein and energy available. It is very palatable and may be used as the main protein source in dairy rations without restriction.

**Sunflower cake (meal)** is the by-product remaining after most of the oil has been extracted from sunflower seeds.
The nutritional composition varies widely due to differences in the amount of hulls (fibres) present. Decorticated cake is a most useful protein source for dairy cows.

### Animal protein feeds and by-products

These products are very rich in protein and are the by-products of slaughterhouses and seafood industries. Some products are very low in palatability and they should be used in limited amounts.
Caution is recommended because of the risk of salmonella contamination by some of these products.

Lately the use of meat and bone meal (obtained from ruminants) in animal feeding has become a hot issue in the European Union. The infectious agent of BSE disease is thought to be transmitted by meat and bone meal; it is not destroyed in the customary manufacturing process (heating). As from January 2001 meat and bone meal from ruminants may (temporarily?) not be used in animal feedstuffs in the countries of the European Union.

# 4 Digestibility, palatability and roughage quality

The **'digestibility'** of the OM of roughage gives an indication of the production which can be expected, as long as the energy and protein contained in the roughage are in balance.
The 'D' (Digestibility) value of grasses is about the same as the TDN value given as a percentage, because in general grasses have a low fat content.
Grasses (or other forages) which have a 'D' value of approximately 50 should contain enough nutrients for maintenance when fed to appetite, while those with a 'D' value of 60 or more should enable milk yields of 10-12 litres to be produced.
This method cannot be used for maize silage which has a high TDN value but a low protein value i.e. the energy and protein are not in balance.

**'Palatability'** (i.e. how much the animal likes eating a particular feed, measured usually by DM intake) is closely related to digestibility. Usually plants which produce a lot of young leafy material are highly palatable.
Grasses are usually more palatable than legumes at the same stage of growth, but as grasses become more fibrous, legumes become relatively more palatable.

In general **roughages** have:
- a low TDN content (below 65% on a DM basis) and
- a high CF content (30% or above).

Roughages may be grouped as follows:
1 Grass and grassland products (hay, silage)
2 Green fodder (e.g. lucerne and other legumes)
3 Straw (e.g of wheat, soya, rice, maize stover)
4 Maize and sorghum.

## 4.1 Grass

The protein content of tropical grasses is rather low compared with that of grasses of temperate climates.
Even young regrowth in the tropics has only 5-10% dCP in the DM.
The fat content is between 2 and 10% in the DM while the NFE content is usually between 40 and 50%. The CF content usually varies from 30 to 40% and the mineral (ash) content from 3 to 10%.

Animal production (milk) is first determined by the amount of forage eaten and the proportion which is digested.
If there are no shortages of protein, minerals or vitamins, then the **energy content** will control the performance.

The **overall feeding value** of grass (with respect to energy, protein and mineral/vitamin content) depends on several factors; for instance:
- growth stage
- soil fertility
- type of grass

*Growth stage*
In table 4 we can see how the feeding value of Rhodes grass changes with the growth stage.

*Table 5:*

| | TDN ('D') | dCP |
|---|---|---|
| 1 month' regrowth | 64% | 90 g |
| 2 months' regrowth | 59% | 50 g |
| 3 months' regrowth | 44% | 20 g |

Note that the energy content and digestibility of Rhodes grass do not drop very much between 1 and 2 months' regrowth and that most of this drop in digestibility is due to the decreased protein content. After two months there is a rapid drop in energy and digestibility as the Rhodes grass matures and sets seed. As a result its fibre content increases. A farmer can expect a higher production from his cows if they graze on not more than 2 months' regrowth. Once the grass stops growing, however, the quality must decline, so in the dry season the farmer cannot expect the same production from his cows as in the wet season, unless the cows are fed other high-quality feeds.

*Soil fertility*

The soil on which grass is grown often has not enough nutrients for proper grass growth. A fertilizer application can do something about this. Fertilizer (usually phosphorus and nitrogen) not only **improves growth** but also the **feeding value.** The response to nitrogen (N) should be in the order of 15-20 kg DM per kg N applied.

The application of (single) superphosphate to grass can improve the nitrogen (protein) content by 30% and the sulphur content by 100%.

*Type of grass*

There are often quite **large differences** in nutritive value between species of grasses, especially between improved species and unimproved (local) grasses.

It is sometimes a good idea to make use of surplus grass growth during the growing season **by making grass hay.** The difference in feeding value between the fresh grass and the early cut hay is less than the difference in feeding value between the fresh grass and 3 months' regrowth of standing hay (see list on page 25):

*Table 6:*

| | TDN | dCP |
|---|---|---|
| Rhodes grass; 2 months' regrowth | 590 | 50 |
| Rhodes grass; 3 months' regrowth | 440 | 20 |
| Rhodes grass hay; early cut | 540 | 23 |
| Rhodes grass hay; late cut | 470 | 0 |

It is only worth making hay if it is fed in the latter half of the dry season.

The cost of making the hay should be compared with the cost of providing alternative feeds.

Hay is usually made at the end of the rains. As there is quite a big difference in feeding value between early and late-cut hay, it requires quite a high standard of management to make good grass hay.

Grass **silage** is often of higher quality than hay. This is because it is normally made from grass at an earlier stage of growth. It can be made before the rains have finished because it is left in the field for a much shorter period of time than hay with less risk of spoilage from rain.

One cut of hay usually gives a higher yield than one cut of silage, but two or more cuts of silage can be made over the growing season to give a greater total yield.

Table 4gives some figures for grass silage.

*Table 7:*

| | TDN | dCP |
|---|---|---|
| Rhodes grass, mature | 460 | 16 |
| Rhodes grass, early flowering | 580 | 63 |

Mature Rhodes grass makes rather poor silage compared with the good-quality product obtained from early flowering Rhodes grass.

## 4.2 Green fodder (legumes)

Legumes in the ration of cattle make a substantial contribution to the overall feeding value, especially the **protein content.** They are particularly valuable to grazing cattle in the dry season, when the protein content of grass is low. They are also valuable in supplementing high energy/low protein forages such as maize silage, and, through their N-fixing ability, improving the growth of grass.

The protein content of tropical perennial pasture legume is usually in the range of 10-15% dCP with TDN values of 50-60%. Lucerne is in the range of 15-20% dCP.
The protein content and the digestibility of legumes do not drop as quickly as those of maturing grasses.
Calcium, phosphorus and magnesium levels in legumes are all higher than in grasses growing on the same soils.
Legumes need (single) superphosphate fertilizers for best growth and feeding value.

## 4.3 Straw

Straw consists of mature stem plus some leaf, from cereal or legume crops and is that part of the plant which remains after harvesting. Table 4 gives some figures for the feeding value of straws; they have a high CF content:

*Table 8:*

| | TDN | dCP |
|---|---|---|
| Soybean straw | 380 | 17 |
| Cowpea straw | 420 | 22 |
| Maize stover | 500 | 2 |

It can be seen that maize stover is a useful roughage as an energy source, while the legume straws are low in energy but reasonable in protein content.

## 4.4 Maize and sorghum

Maize and sorghum are rather exceptional roughages because of their **high TDN value** when conserved as silage. They have a **low protein content,** however, and are best supplemented with legumes or medium high protein concentrates.

*Table 9:*

| | TDN | dCP |
|---|---|---|
| Maize; good, high DM | 700 | 47 |
| Maize; average | 640 | 42 |
| Maize; poor | 550 | 26 |
| Sorghum | 560 | 40 |

**Judging the quality of roughage**

Judging the quality of locally produced roughages is an indispensable practical in dairy farming training.

Elements:

- origin of the roughage, growth stage, when harvested
- colour, smell, palatability
- estimation of DM content, energy value and crude protein content
- overall quality of the product as compared with the average product
- price

# 5 Feed requirements of dairy cows

## 5.1 TDN and dCP requirements

An adult cow which is not producing milk still needs nutrients.
These nutrients are needed for respiration, blood circulation, movement, etc. The nutrients needed for these purposes make up the **maintenance requirements** of the cow.
The maintenance requirements are related to bodyweight. The following table shows the maintenance requirements of adult cows of different bodyweight, walking an average of 5 km/day, in a subtropical environment (Southern Africa).

*Table 10: Maintenance requirements per day*

| Bodyweight (kg) | Protein (g dCP) | TDN (g) |
|---|---|---|
| 400 | 250 | 3100 |
| 450 | 270 | 3400 |
| 500 | 290 | 3700 |
| 550 | 310 | 4300 |

When a cow is **producing** (giving milk), **extra** nutrients are needed above the maintenance level. These extra nutrients needed for production make up the **production requirements** of the cow. In the next table the amount of digestible crude protein and TDN is shown, which a cow needs to produce one (1) kg of milk. The production requirements are related to the fat content of the milk.

*Table 11: Production requirements per kg milk*

| % Fat in the milk | Protein (g dCP) | TDN (g) |
|---|---|---|
| 3.0 | 48 | 355 |
| 3.5 | 51 | 415 |
| 4.0 | 56 | 470 |
| 4.5 | 63 | 530 |

### Example

A cow weighs 500 kg and produces 10 kg milk/day. The milk contains 4% fat. What are the total TDN and dCP requirements of this cow?

| | | | | |
|---|---|---|---|---|
| For maintenance the cow needs (see first table) | | | 290 g | dCP |
| | | | 3700 g | TDN |
| For production the cow needs (second table) | 10 × 56 | = | 560 g | dCP |
| | 10 × 470 | = | 4700 g | TDN |
| The cow's total requirements are | 290 + 560 | = | 850 g | dCP |
| | 3700 + 4700 | = | 8400 g | TDN |

### Restrictive note

Elsewhere in this guide we will make similar calculations. In these calculations the figures for the feeding value of the feedstuffs and the feed requirements of the cows **determine the outcome.** The user anywhere should consider our data for feeding values and feed requirements **with a critical eye** and use **different figures** of preferably local origin , if necessary and if possible.

## 5.2 Milk production from grass pasture

It is possible to calculate the milk yield expected from pasture if we know:
- the daily DM intake of the cows
- the feeding value of the pasture
- the feed requirements of the cows

Cows weighing 500 kg and producing 5-10 kg milk per day should consume around 12 kg DM per day of a good-quality ration.
Cows producing 15 kg milk per day or more should consume around 14 kg DM per day or more. In the following examples an intake of 12 kg DM per day is assumed.

For the calculation the data for Rhodes grass and Star grass are used (list on pages 25 and 26).
Rhodes grass has the reputation of being a relatively nutritious tropical grass.

*Table 12:*

| | **g TDN/kg DM** | **g dCP/kg DM** |
|---|---|---|
| Rhodes grass, 1 month' regrowth | 640 | 90 |
| Rhodes grass, 2 months' regrowth | 590 | 50 |
| Star grass, 2½ months' regrowth | 520 | 45 |

Requirements of the cows (500 kg weight, 4% milk fat):

*Table 13:*

| | **g TDN** | **g dCP** |
|---|---|---|
| for maintenance | 3700 | 290 |
| for production, per kg milk | 470 | 56 |

Using the above figures, the total consumption of energy and protein per cow per day at 12 kg DM intake is:

*Table 14:*

| | **g TDN** | **g dCP** |
|---|---|---|
| Rhodes grass, 1 month' regrowth (12 × 640 =) | 7680 (12 × 90 =) | 1080 |
| Rhodes grass, 2 months' regrowth (12 × 590 =) | 7080 etc. | 600 |
| Star grass, 2½ months' regrowth (12 × 520 =) | 6240 etc. | 540 |

Now we should deduct the maintenance requirements, to give the nutrients remaining for **production:**

*Table 15:*

| | **g TDN** | **g dCP** |
|---|---|---|
| Rhodes grass, 1 month' regrowth, 7680 – 3700 = | 3980 | 790 (1080 – 290) |
| Rhodes grass, 2 months' regrowth, 7080 – 3700 = | 3380 | 310 etc. |
| Star grass, 2½ months' regrowth, 6240 – 3700 = | 2540 | 250 etc. |

The nutrients remaining for production should now be divided by the requirements per kg of milk, to give the milk yield that can be expected:

*Table 16:*

| | **on TDN** | **on dCP** |
|---|---|---|
| Rhodes grass, 1 month' regrowth | 3980 ÷ 470 ≈ 8½ litres | 790 ÷ 56 ≈ 14 litres |
| Rhodes grass, 2 months' regrowth | 3380 ÷ 470 ≈ 7 litres | 310 ÷ 56 ≈ 5½ litres |
| Star grass, 2½ months' regrowth | 2540 ÷ 470 ≈ 5½ litres | 250 ÷ 56 ≈ 4½ litres |

**Conclusion**

Cows grazing young Rhodes grass should produce at least 8½ litres of milk per day (assuming that they have the potential to do so).
It is the energy content of the grass that limits milk production as there is enough protein for 14 litres of milk.

In practice, some cows on young Rhodes grass can produce 10-12 kg milk, due to higher DM intakes and selection of young leaves (selective grazing).
Cows grazing on 2 months' regrowth of Rhodes grass should produce 5½ litres of milk. In this case protein is limiting milk yields.
Cows grazing 2½ months' regrowth of Star grass should produce 4½ litres of milk.

## 5.3 Milk production from grass-legume pasture

Similar calculations can be made to estimate how much milk we can expect from pastures made up of a **mixture** of grass and legumes.
The nutritive value of such pastures, especially the protein content, depends to a great extent on the percentage of the dry matter production made up of the legume component. In practice this usually varies between 10 and 25%.

As example we take silver-leaf Desmodium, which has a TDN value of about 60% and a dCP of about 10%.
Our Star grass/Desmodium pasture has not been grazed for 2½ months because it is required for mid-dry season grazing.
The percentage of legume in the pasture is 25%, and it is expected that the cows will eat 12 kg DM per day.

**solution**

The nutritive value of this pasture will be:

**TDN:** $\left(\frac{75}{100}\times\frac{520}{1}\right)+\left(\frac{25}{100}\times\frac{630}{1}\right)\approx 550$

**dCP:** $\left(\frac{75}{100}\times\frac{45}{1}\right)+\left(\frac{25}{100}\times\frac{108}{1}\right)\approx 60$

The total nutritive value of 12 kg DM intake of this pasture will be:

12 × 550 g = 6600 g TDN
12 × 60 g = 720 g dCP

The cows' maintenance requirements should now be deducted in order to give the nutrients remaining for production:

6600 – 3700 g = 2900 g TDN
720 – 290 g = 430 g dCP

Expected milk yields:

on TDN $\frac{2900}{470}$ = about 6 litres

on dCP $\frac{430}{56}$ = about 7.5 litres

**Conclusion**

Cows grazing 2½ months' regrowth of Star grass and Desmodium should produce at least 6 litres of milk.

This is a worthwhile increase in milk yield over a straight Star grass pasture, which in the previous example gave 4½ litres.

It is important to remember that these production figures are for well-fertilized pasture and assume that the cows' DM intake is 12 kg/day. If the pasture is not fertilized or the legume content less than 25%, the quality of the pasture will be less than that given in the examples and production will be lower.

Similarly, if the cows are unable to eat 12 kg DM/day, perhaps because there is not enough grass remaining in the paddock to graze, or the digestibility of the grass is low, then production will be lower.

For example, if DM intake in the case of the 2-2½ months' regrowth pasture is only 10 kg, milk production will only be 4 litres (Rhodes grass), 3 litres (Star grass) and 5 litres (Star grass/Desmodium).

# 6 Concentrate feeds for dairy cows

Concentrates are feedstuffs which have **more TDN** per kg DM than roughage and a **lower crude** fibre (CF) content.

**Examples of concentrate feedstuffs are:**
- grains and their processing by-products
- oilseeds and their processing by-products (meals, cakes)
- products of animal origin (meat and bone meal, blood meal, fish meal)
- other processing by-products (brewers' grains, molasses, citrus pulp, to mention a few)

Concentrate mixtures manufactured by stockfeed millers (e.g. dairy meal, calf meal) contain a number of feedstuffs belonging to the above-mentioned categories, **plus** extra minerals and vitamins.

**Something to remember**
**grains:**
- low protein content (e.g. 5% dCP)
- high energy content (e.g. 90% TDN in the maize grain)

by-products of the **vegetable oil** industry:
- normally a high protein content of 20-35% dCP

products of **animal** origin:
- even higher protein contents

By-products of the vegetable oil industry are the main protein source in concentrate mixtures for dairy cows.
With the (temporary?) ban on meat and bone meal in the EU (year 2001), the use of non-animal protein in dairy cattle feeding is likely to increase (with a corresponding rise in prices?)

Concentrate mixtures in combination with suitable roughages are balanced in composition, to meet the requirements of the type of animal they are designed for.
They are often sold in the form of a meal; such meals should not contain more than about 13% of water otherwise they cannot be stored for a long period.

## 6.1 Types of concentrates

The concentrate mix which is best for dairy cattle provides the nutrients lacking in the roughage part of the diet so that production is as high as economically possible.
If the roughage is high in TDN content but low in protein (e.g. maize silage), a concentrate may be used which has a medium TDN value and a high protein content.
If the roughage has only a medium TDN value but is high in protein (e.g. young grass/legume pasture), then a high TDN/low protein concentrate may be used.

Concentrates may be bought from milling companies or made on the farm, from mainly farm-grown ingredients.
On-farm mixing is often cheaper, but it may not be advisable if the farmer does not have all the ingredients or the knowledge of how to mix them.

In practice, three kinds of concentrates are fed to dairy cattle:
- low protein content mixtures = 50-110 g dCP/kg DM
- medium protein content mixtures = 110-150 g dCP/kg DM

➢ high protein content mixtures = 150-200 g dCP/kg DM

**Low protein** content mixtures may be fed to cows producing 10-15 litres of milk and grazing good-quality pastures i.e. 1 month' regrowth or less. Such pastures are usually high in protein but relatively low in energy content.
A very good response in milk yield can then be obtained by feeding high energy/low protein concentrates such as maize grain (coarsely cracked or milled), corn and cob meal, or molasses. The various brans (maize, wheat or rice) can also be fed, although their energy content is lower.
The quantities fed depend on the cows' production, but cows producing 10-15 litres of milk per day would normally be fed 2-4 kg per day of the concentrate.

**Medium protein** content mixtures are suitable for cows producing 5-20 litres of milk per day, grazing average to good-quality pastures or fed good-quality conserved roughages such as grass hay or silage or maize silage.
Depending on milk yield and roughage quality, these cows could be fed 2-10 kg concentrate per day.
Cows on poor-quality grazing or overgrazed pasture would not produce more than 10-15 litres of milk even if 10 kg concentrate per day were fed.
Cows receiving maize silage and lucerne, which in combination provide a high energy/high protein ration, will produce more than 20 litres of milk per day when fed 10 kg or more of such concentrates.

**High protein** content mixtures are fed to high-producing cows (20 litres and above) which receive a high-quality roughage such as green maize. The concentrate may be mixed with the roughage and fed as a complete feed, which gives good results because the diet of the cows remains constant, with the high concentrate intake distributed throughout the day.

**NOTE**
Whether concentrates are available on the market or not, the **basis for profitable milk production** is normally the **availability of good-quality roughage** on the farm itself. In other words, the production of good-quality roughage should always be a primary concern for the farmer.

## 6.2 Formulation of concentrate mixtures on the farm

### Example No. 1

Suppose that a concentrate is wanted with a medium protein content of 130 g dCP/kg DM and at least 700 g TDN/kg DM. The ingredients available are:

*Table 17:*

| | TDN | dCP |
|---|---|---|
| wheat bran | 650 g | 110 g |
| sunflower heads | 650 g | 59 g (see list page 23) |
| cottonseed (whole) | 900 g | 177 g |

First the difference between the desired dCP content and the content of each ingredient is calculated:
wheat bran 110 – 130 = – 20
sunflower heads 59 – 130 = – 71
cottonseed (whole) 177 – 130 = + 47

Two of the ingredients contain less dCP than desired and one contains more.
These differences must be combined in such a way that they add up to about zero. Then the overall mixture will have the desired dCP content:

*Table 18:*

| | difference | multiplication | balance |
|---|---|---|---|
| wheat bran | – 20 | × 5 | – 100 |
| sunflower | – 71 | × 2 | – 142 |
| cottonseed (whole) | + 47 | × 5 | + 235 |
| | | 12 | – 7 |

The multiplication factors indicate which portion (or part) each ingredient contributes to the desired concentrate. The desired concentrate consists of $^5/_{12}$ wheat bran, $^2/_{12}$ sunflower heads and $^5/_{12}$ whole cottonseed.

It is possible to check whether the above answer is correct. This is done as follows:

If 12 kg DM of the desired concentrate is made, then 12 × 130 = 1560 g dCP and 12 × 700 g TDN must be present.

*Table 19:*

| | g TDN | g dCP |
|---|---|---|
| wheat bran contributes | 5 × 650 = 3250 | 5 × 110 = 550 |
| sunflower heads contribute | 2 × 650 = 1300 | 2 × 59 = 118 |
| cottonseed contributes | 5 × 900 = 4500 | 5 × 177 = 885 |
| | 9050 | 1553 |

Thus per kg mixture there is 9050 ÷ 12 = 745 g TDN and 1553 ÷ 12 = 129 g dCP.

This meets the requirement of at least 700 g TDN/kg DM and 130 g dCP/kg DM.

If 100 kg DM of the mixture is required, then:

| | | |
|---|---|---|
| wheat bran contributes | $^5/_{12}$ × 100 = 41.7 | kg DM |
| sunflower heads contribute | $^2/_{12}$ × 100 = 16.7 | |
| whole cottonseed contributes | $^5/_{12}$ × 100 = 41.7 | |
| | ———————— | + |
| | 100.1 | kg DM |

When preparing such a mixture, the quantities given should be converted from DM to ‘as fed’ i.e. the water content of the feeds should be taken into account. However, most dry ingredients of concentrate feeds have about the same DM content of 90%. The proportions of ingredients calculated on a DM basis will therefore remain the same as for ‘as fed’ basis.

Note that the above mixture contains a high proportion of whole cottonseed, which has a high fat content. Cows should therefore not be fed more than 6-7 kg/day of this mixture. Higher intakes could upset the working of the rumen.
The fibre content of this mixture is rather high, but the cost will probably be low.

**Example No. 2**
In some places small-scale dairy farmers grow maize and sunflower. They then mix milled corn and cob with the whole sunflower heads. Can this make a suitable concentrate for dairy cows containing 130 g dCP/kg DM?

See the list earlier in this guide. Corn and cob meal has a dCP content of 46 g dCP and sunflower heads a dCP content of 59 g dCP/kg DM. Both are less than 130 g dCP, so it is not possible to make a suitable mixture from these two ingredients.

However, if a third ingredient is used with a dCP content higher than 130 g/kg DM, it is possible to make a suitable mix. Soybean has a dCP content of 310 g dCP/kg DM, so it is suitable (velvet bean could also be used).
The ingredients are

*Table 20:*

| | TDN | dCP |
|---|---|---|
| corn and cob meal | 860 g | 46 g |
| sunflower heads | 650 g | 59 g |
| soybean seed (whole) | 960 g | 310 g |

First calculate the difference between the desired dCP content and the content of each ingredient:

| | |
|---|---|
| corn and cob meal | 46 – 130 = – 84 |
| sunflower heads | 59 – 130 = – 71 |
| soybean seed (whole) | 310 – 130 = + 180 |

The following combination of these ingredients can now be made:

*Table 21:*

| | difference | multiplication | balance |
|---|---|---|---|
| corn and cob meal | – 84 | × 8 | – 672 |
| sunflower heads | – 71 | × 3 | – 213 |
| soybean seed (whole) | + 180 | × 5 | + 900 |
| | | 16 | – 15 |

To obtain the desired concentrate, mix 8 parts corn and cob meal, 3 parts sunflower heads and 5 parts whole soybean.
If 100 kg DM of the mixture is required:

| | | |
|---|---|---|
| corn and cob meal contributes | $^{8}/_{16} \times 100 = 50$ | kg DM |
| sunflower heads contributes | $^{3}/_{16} \times 100 = 18.8$ | kg DM |
| soybean contributes | $^{5}/_{16} \times 100 = 31.2$ | kg DM |
| | | + |
| | 100 | kg DM |

**Example No.3**
Because the cost of protein in the concentrate mixture can be quite high, and a farmer may not have enough of the protein source (e.g. oil seeds) on the farm, it may be interesting to replace some of the vegetable protein with **non-protein nitrogen** in the form of **urea.**
Urea has a very high dCP value. Already a small amount of urea can therefore make quite a big difference to the dCP content of a mixture.
However, **urea is poisonous to cattle** when eaten in too great a quantity. And it can only be used by ruminants, so it should not be included in a ration for calves as their rumen is not yet developed.
As a general rule $1\frac{1}{2}$% urea in the dry matter of the concentrate should be the maximum. Cows eating more than 3 kg concentrate per day should only have 1% included.
Fertilizer-grade urea **should be finely ground** using a mortar and pestle (or similar) and mixed **thoroughly** with the other ingredients of the mixture. If this is not done, a cow may consume a quantity large enough to kill her.
There should always be enough easily-digested carbohydrate (e.g. maize) in a diet containing urea.

For example, a mixture may be made of corn and cob meal, whole cottonseed and urea.
Soybeans should not be included in a mixture containing urea as there will be a toxic effect.

In practice, equal parts of cottonseed and corn and cob are mixed together and urea is added at 1% of the total weight of the mixture.
Urea should first be mixed with a few kg of maize bran (or similar) before it is mixed **thoroughly** with the other ingredients.

### Example No.4

Always make maximum use of **milling and oilseed industry residues** for feeding dairy cattle if such residues are being sold at a reasonable price.
Wheatings, maize bran, rice bran and cottonseed cake are often available and may be used on their own or in mixtures according to the requirements of the cows.

For example, a useful concentrate of 130 g dCP/kg DM, with a good TDN content, suitable for feeding to cows on medium to poor-quality grazing, can be made from maize bran and cottonseed cake.

The following combination of the ingredients can be made (on a dCP basis):

*Table 22:*

| | difference | multiplication | balance |
|---|---|---|---|
| maize bran | 44 – 130 = – 86 | × 2 | – 172 |
| cottonseed cake | 300 – 130 = + 170 | × 1 | + 170 |
| | | 3 | – 2 |

The mixture is therefore made up of 1 part cottonseed cake to 2 parts maize bran.
50 kg cottonseed cake is mixed with 100 kg maize bran.

### Example No.5

**Molasses** is a useful supplement for dairy cattle, because its energy content is quite high (72% TDN) and it is usually cheap.
With the inclusion of 2% urea it has a dCP value of approximately 4%.
Normally cows will only consume 2-3 kg/day of molasses when given free choice. Higher intakes cause digestive problems, so molasses has only a limited role in rations for high-producing cows but is valuable for low- to medium producers which are meeting most of their protein requirements from other sources.

### Other possibilities

There are several other possible ingredients which can be used in concentrate rations for dairy cows.

**Poultry manure,** if available, is useful for low-producing cows but not for high producers due to its high NPN content. See our guides on **chicken farming.**
Poultry manure has a variable analysis, depending on the diet of the chickens, whether litter is used, and what kind of litter.
Manure from battery layers has a dCP value of around 15% while a common analysis for broiler manure is around 12% dCP.
The energy content of battery manure is only about 40%, but if maize bran is used as a litter, the energy content will be much higher.

It is also possible to use the **pods of various indigenous fodder trees** in concentrate rations. They have a dCP value of around 12%.

**N.B.:**
The examples and calculations in this chapter show how to make use of ingredients to obtain balanced concentrate rations for dairy cows.

To teachers and trainers we would suggest to make a survey of what is **locally** available.
Try to establish correct feeding values and then let the students learn to work with these.
Do not forget to include physical aspects as well: let the students see, smell, etc. what is available and consult research people, advisory personnel and the local feed milling industry. And visit dairy farms to see what is happening 'in the field'.
The feeding of dairy cows: its importance can hardly be over-emphasized!

# 7 Minerals: requirements and supply

Dairy cows require minerals in their feed (see page 13).
The minerals required in greatest quantities are:
- calcium (Ca)
- phosphorus (P)
- sodium (Na)
- sulphur (S)

Other minerals required, such as magnesium, iodine and copper are usually present in the feeds in sufficient amounts although shortages may occur here and there.

The **daily requirements** of a dairy cow of 500 kg are in the order of:

*Table 23:*

| | Ca | P | Na |
|---|---|---|---|
| for maintenance | 37 g | 25 g | 8 g |
| extra per litre of milk | 2 | 1½ | ½ |
| extra for pregnancy, 7-9 months' period | 15 | 10 | |

The best ratio of calcium to phosphorus in the diet is around 1½ : 1.

**Minerals in the roughage**
The minerals required by dairy cows are found in all roughages, but in varying quantities, depending on the type of roughage and the fertility status of the soil on which the roughage is grown.
We take a few examples.

*No.1*
Well fertilized Rhodes grass, 1 month' regrowth, has a Ca content of 0.51% in the DM and 0.32% P. A cow eats 12 kg DM of this young Rhodes grass:

the intake of calcium will be $12 \times 5.1 = 61$ g (approx.)
the intake of phosphorus will be $12 \times 3.2 = 38$ g (approx.)

Conclusion: this well-fertilized Rhodes grass contains enough calcium and phosphorus for cows producing about 8 kg milk/day.

*No.2*
A cow eats 10 kg DM/day of natural pasture hay, with 0.27% Ca and 0.15% P in the DM:

intake of calcium $10 \times 2.7 = 27$ g
intake of phosphorus $10 \times 1.5 = 15$ g

Conclusion: there is **not** enough calcium or phosphorus in this hay, not even for maintenance.

*No.3*
A cow eats 10 kg DM/day of average maize silage (0.34% Ca and 0.23% P) and 2 kg lucerne (1.6% Ca and 0.25% P):

intake of calcium $(14 \times 3.4) + (2 \times 16) = 66$ g
intake of phosphorus $(10 \times 2.3) + (2 \times 2.5) = 28$ g

Conclusion: here Ca : P = $2\frac{1}{2}$ : 1, so there is a big imbalance which will have to be corrected by a mineral lick for instance.

In general it can be said that when dairy cows are fed on plenty of good-quality roughage grown on well-fertilized soils, there is no shortage of minerals.
But the concentrate given to high-producing cows should always contain a mineral mixture.
Cows only grazing on grass may be given additional salt (NaCl) since pastures in general contain very little sodium.

Another important point: remember that in general **grain products are from a practical point of view poor in calcium (and sodium) and rich in phosphorus.**
So, when cows are fed with grain products one must always be aware of a possible shortage of Ca and Na. The addition of coarse salt (NaCl) and limestone ($CaCO_3$) is then a very sensible thing to do.

### Minerals in the concentrate

The concentrate feeds that are available on the market normally contain a 2% mineral mixture, added purposely by the miller.
These minerals, together with the minerals provided by the roughage, will normally meet the cows' requirements.

If ready-made concentrates are not available (or too expensive), one can buy a ready-made mineral mixture and add this to a self-made concentrate.
However, ready-made mineral mixtures may not be available either. In that case one has to resort to single ingredients, such as coarse salt (40% Na) and dicalciumphosphate (21% Ca, 18% P). These ingredients are then mixed as follows:

| | | |
|---|---|---|
| 1 kg | coarse salt (NaCl) | = 400 g Na |
| 9 kg | dicalciumphosphate | = 1890 g Ca + 1620 g P |
| —— | | —————————— + |
| 10 kg | mixture | = 400 g Na +1890 g Ca + 1620 g P |

One kg of this mixture contains (approx.) 190 g Ca + 160 g P + 40 g Na.
Two kg of this mixture must be added to 98 kg of the self-made concentrate, in order to obtain a concentrate with 2% mineral mixture. This concentrate then contains per kg
3.8 g Ca + 3.2 g P + 0.8 g Na.

### Mineral licks

Cows and heifers on pasture without concentrates being fed, may not get sufficient minerals. They should be supplied with a lick made up of dicalciumphosphate and salt. Usually a 50:50 ratio is suitable.
Alternatively, the mineral requirements can be met by a small daily concentrate ration, e.g. maize bran or molasses enriched with minerals. This may be cheaper and easier to control.

### A problem to end with:

A farmer feeds 20 kg/day average quality maize silage (33% DM) to the cows. What is the DM intake of this maize silage?
The same farmer also feeds the cows 3 kg of wheat bran and 2 kg of whole cottonseed. What is the DM intake of these two feedstuffs?
Calculate the expected milk yield.

# 8 Full lactation feeding of dairy cows

## 8.1 Milk production patterns and lactation curves

Dairy cows which are healthy, well-fed and well-managed should have a lactation curve of the shape shown in the diagram:

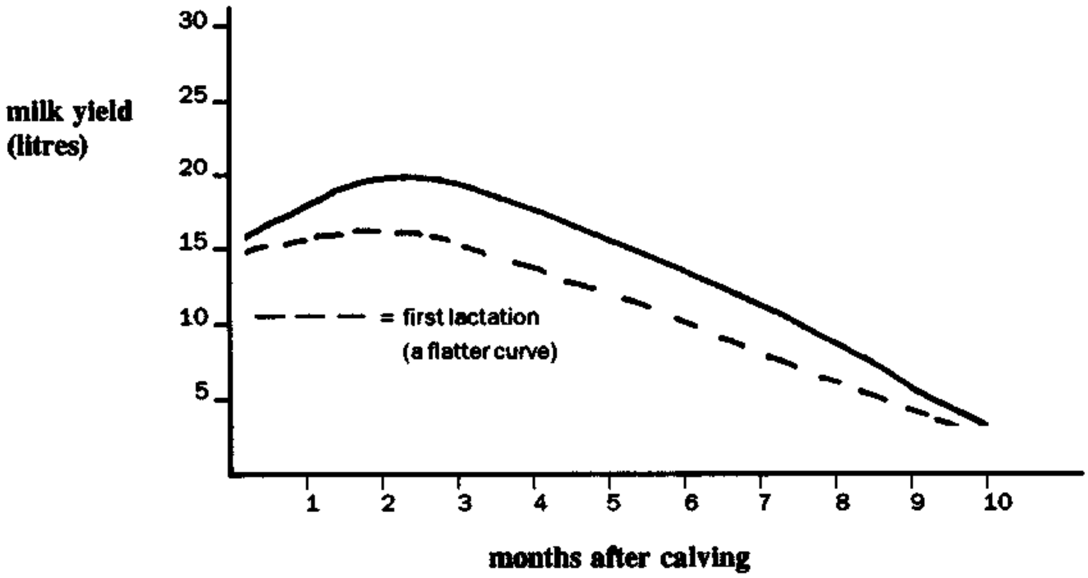



*Figure 4:*

The total yield in a lactation is determined by:
1 starting yield
2 peak yield
3 length of lactation period

*starting yield*
This is the average daily amount of milk produced during the first month of lactation.
The total amount for the whole lactation period can be estimated from the starting yield. For a cow which is well-fed over the whole lactation, the starting yield multiplied by 200 will give the approximate lactation yield. For instance, if the starting yield of a cow is 15 litres, the total yield should be around 3000 litres.

Good starting yields are **only** possible if:
- the cow is in good condition after calving;
- the feed available after calving has enough energy and protein, and
- the milk is efficiently removed from the udder.

*peak yield*
Provided that a cow is in good condition at calving and is given good-quality feed, she will increase production from her starting yield to a **peak.** This peak yield is usually reached 40-50 days after calving. This peak may **not** be her (maximum) potential yield i.e. genetically she may be capable to produce more, but she may not get enough feed to reach her potential yield.

To reach her highest yield the cow must draw on body fat reserves, so the peak yield depends on the cow being in good condition at calving and this body fat being used to produce milk. Extra protein in the diet may be needed to utilize the body fat.

If body condition at calving and/or feeding after calving are inadequate, the peak yield may be the same as the starting yield (the cow 'does not peak').

*length of lactation*
The normal lactation length of dairy cows is 270-320 days.
Cross-bred cows and poorly-fed cows will often be dried off earlier as milk yield and/or body condition drop too much.
A gradual decline of 10% per month is considered normal after the peak yield has been reached.
In mid- to late lactation, cows should start to gain weight in preparation for the next lactation. In order that cows start their next lactation in good condition and renew the milk-producing cells in the udder, a 6-8 weeks **dry period** is usual.
Calving at not more than 12 months' intervals set the lactation length to around 300 days. This gives more **lifetime** production per cow than longer lactations.

### Seasonal production patterns
Cows calving at different times of the year are often fed different rations, so their milk production patterns are different.
These differences are greater for farms without irrigation and greater still for farms without enough good-quality conserved roughage (hay or silage).
Usually cows calving in the early part of the wet season on good-quality grass/legume pasture will have a fairly normal lactation curve, especially if concentrates are fed throughout the lactation.

The curves in the following diagram show changes from the normal lactation curve.
Curves 1 and 2 show likely patterns if protein were inadequate for a long time. The peak yield is poorly defined, if at all, and bodyweight often does not change.

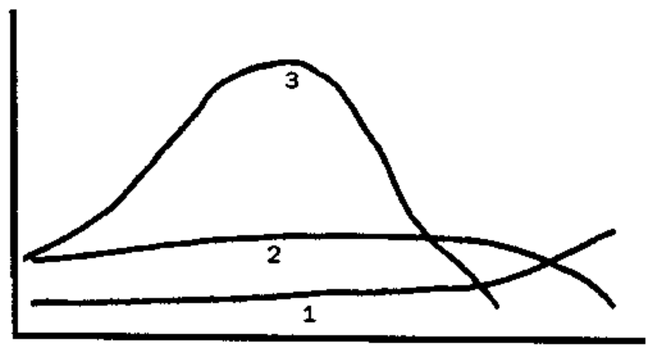



*Figure 5:*

Curve 3 shows the production pattern where energy is severely restricted. The cow was in good condition at calving and has peaked well. The collapse in production occurred when the cow lost too much body condition.

The only way to **increase lactation yields** (assuming a normal lactation curve) is for the whole curve to move **upwards,** i.e. the starting yield and the peak yield must be higher. As the rate of decline of milk production stays constant at around 10%, the extra area under the curve corresponds with the total yield increase. This assumes that there is **no interruption** in the feeding or the good health of the cow which would cause yields to drop.

Increasing lactation yields, once correct feeding for a normal lactation curve is achieved, requires the **breeding of cows with an improved genetic potential.**

### The influence of breeding on milk production
Dairy cows have different genetic potentials for milk production.

Some of the best Friesian milking cows in the (sub)tropics have lactation yields of 6000-8000 litres, with an average well-fed cow giving 4000 litres. A good Friesian cross-bred cow can give 2500 litres but most will only give 2000 litres or less.

It is important that the cows' potential milk production is taken into account when feeding. There is no point in feeding a cow with a peak milk yield potential of 15 litres the same amount of concentrate in early calving as one with a potential of 25 litres. This would be very unprofitable.
Similarly, it is inefficient and unprofitable to keep cows capable of high levels of milk production when feeding is poor.
On farms without a year-round supply of quality feed, good crossbred cattle may give the most economic results.

### Concentrate feeding

The use of concentrates will be necessary if more production is expected than is considered possible on the basis of the available roughage and the body reserves of the cows.

It is generally accepted that a balanced (i.e. enough TDN and dCP) concentrate for dairy cows provides enough nutrients to make a cow produce two units of milk for every unit of concentrate fed.
In other words, 1 kg concentrate provides enough nutrients to make a cow produce 2 kg of milk (which is 2 litres).
This means that for every 2 kg of milk produced above the level expected from roughage alone, 1 kg of concentrate must be fed.

When single feedstuffs are used instead of balanced concentrate mixture, the response in terms of milk production is normally lower.
However, if certain feedstuffs are (much) cheaper than balanced concentrates, it can be profitable to use them.

If concentrate feeds are available on the market, it depends on their price whether it is profitable to use them and if so, to what extent. Especially the difference in price between concentrate and milk is important.
If one kg of concentrate is as expensive or more expensive than the money obtained for two kg of milk, the use of concentrates is not advised. This is because more money would be spent on additional feed than would be gained from the increased milk production.

In general, it can be said that the closer the price of feed and milk are together, the more restricted the use of concentrate has to be. If the use of concentrate has to be restricted, it is best to use the limited amount for the newly-calved cows. Cows that have recently calved are most responsive to additional feeding in terms of milk production.

Whether concentrates are available on the market or not, the **basis for profitable milk production is normally the availability of good-quality roughage** on the farm itself. In other words, the production of good-quality roughage must always be a primary concern for the farmer.

Remember that feeding concentrate may reduce the intake of grass or other roughage which is much cheaper than concentrate. It is not good practice to replace too much quality roughage with concentrate; also the rumen needs at least 30% roughage for proper functioning.

In general, cows on good-quality grazing will show a good response to concentrate feeding when fed 3 kg cereal grain or milling by-products per day throughout the lactation, or 3 kg in early lactation, 2 kg in mid-lactation and 1 kg in late lactation (i.e. 600-900 kg over the whole lactation).

More than 3 kg concentrate/day can profitably be fed to medium to high-producing cows on good-quality conserved roughages, on the basis of 1 kg concentrate per 2-3 kg milk produced i.e. a cow receiving maize silage and producing 15 litres milk/day might get 5-7 kg/day of a 130 dCP/kg DM concentrate, or perhaps 2 kg molasses and 3-5 kg concentrate.

**Dry cows** which are in reasonably good condition at drying-off, with access to good-quality grazing, hay or silage, will **not** need concentrate. However, to put on condition or maintain condition on poor pasture, concentrates may be fed at 1-3 kg/cow/day.

Cows should **not** be fed large quantities of concentrate before calving ('steaming-up'). These concentrates are used more efficiently **after** calving.
Dry cows which are not fed a concentrate containing a sufficient amount of minerals, should be supplied with a salt/dicalciumphosphate lick.

### Concentrate for high-producing dairy cows

After calving, especially high-producing cows experience a strong natural urge to produce milk.
In order to realize this potentially high milk yield, such cows should be very well fed, particularly as far as protein is concerned. Temporarily the cow may draw on stored energy (she will lose weight!) but normally there are no protein reserves and that is the reason why protein needs particular attention.

In the (sub)tropics one often sees potentially high-producing dairy cows reaching their maximum milk production already after 2-3 weeks (or even earlier) after which milk production starts to decline. A disappointing lactation is the result. Usually the cause is improper feeding:

- not enough energy and protein in the ration
- a poor quality concentrate (not enough TDN and dCP per kg concentrate)

*practical advice*

1 Provide **roughage** of the very best quality available, as much as the cow will eat. Dry matter content should not be low due to wetness.
2 Provide **concentrate** of the very best quality available, up to 8-10 kg per day depending on the bodyweight of the cow (maximum 2 kg/100 kg live weight). When a large amount of concentrate is fed, do not give it to the cow all at once.
3 Concentrate feeding must be built up gradually; e.g. the first day 4 kg, the second day 5 kg, the third day 6 kg, etc., till the maximum amount has been reached. Digestive troubles must be avoided.

Proper feeding of freshly-calved high-producing dairy cows is difficult and requires insight, skill and experience.
Once the maximum milk production has been reached (in the second month after calving), the cow should be fed according to what she produces (roughage provides so and so many kg milk; on top of this 1 kg concentrate for 2 kg milk).
From now onward milk production will gradually decrease and the feeding of concentrate should be done accordingly.

Remember that a **temporary shortage** of concentrate results in a **sharp drop** in milk production. It is very difficult to **restore** milk production to its original level once the concentrate is again available. **Continuity** in feed supplies is very important.
Needless to say that the price of concentrate is an important factor.

## 8.2 The rearing of replacement heifers

The rearing of heifers can be divided into 3 periods:
1 weaning to six months
2 six months to mating
3 mating to calving

*weaning to six months*
Calves need good-quality pasture or roughage.
Also concentrate should be supplied, at the rate of 1-1½ kg/head/day.
The concentrate should contain 120-130 g dCP/kg DM, and more if the roughage is of low quality.

If possible, every 7-10 days calves should be moved to fresh paddocks rested from grazing for at least 3 weeks. This is often not possible, and as a matter of routine calves should then be drenched against worms every 6 weeks to 6 months of age (starting at 6-8 weeks age), then every 2 months to 10-12 months of age, or as locally recommended.
Calves may also be treated against flukes as required.

*six months to mating*
Concentrate supplements of 1-1½ kg/day should be supplied.
If the pasture is of good quality, maize, corn and cob or milling by-products can be fed, but if not, a 120-130 g dCP/kg concentrate should be supplied. Molasses or 2% urea/molasses may also be fed at 1½-2 kg/day.
Concentrates may be reduced at 9-10 months of age or omitted if the heifers are growing well on good-quality pasture.

*mating to calving*
Well-fed Friesian heifers should reach 250-270 kg at 15 months of age, i.e. they should grow at 0.5-0.6 kg/day (= 500-600 g) from birth.
They can be mated at this weight as long as this rate of gain can be maintained until calving, feeding concentrate supplement as required.

Where this rate of gain cannot be maintained, heifers should not be mated until they are 320-350 kg (Friesian heifers).
However, heifers older than 3 years are more difficult to get in calf.

For Friesian heifers the aim is to reach 450 kg at calving. The bigger the heifer at calving is, the more milk it will produce in its first, second and third lactation.

**Always remember: to-day's calf is to-morrow's cow!!**

## 8.3 More calculations (problems)

Problem solving makes the students 'digest' the information contained in the previous pages. Try to adapt the following problems to **local** conditions and circumstances.

In our problems it is assumed that a dairy cow weighs 500 kg (live weight) and that the production of 1 kg milk requires 470 g TDN and 56 g dCP. The DM intake is assumed to be 10 kg.

The maintenance requirements are 3700 g TDN and 290 g dCP. The nutritive value of the feedstuffs is taken from the list figuring earlier in this guide.
Again, it is emphasized that the above data must not be taken as rigid values.

The teacher who works with these problems is advised to use data which are locally applicable. Even then, the results of the calculations have an indicative value only; there is **no guarantee** that a cow will actually produce what has been calculated.

A cow does not solve problems like we do, but will use her proper (highly complicated) production capacity in response to what she is being fed.
On the other hand, **milk production is not sheer 'magic';** it definitely has something to do with what the cow is being fed.The students should be made aware of this and solving problems on this subject will help in this respect.

**Problem № 1**
Ten kg of medium Nandi Setaria grass is available (10 kg per cow per day), as DM. What milk production can be expected?

*answer*
This is the equivalent of 40 kg fresh product.
In 1 kg product there is 250 g DM (130 g TDN and 250 g dCP).
In 1 kg DM there is 520 g TDN and 80 g dCP.

| | |
|---|---|
| So, 10 kg DM | = 5200 g TDN + 800 g dCP |
| maintenance requirements are | = 3700 g TDN + 290 g dCP |
| | – |
| left over for production | 1500 g TDN + 510 g dCP |

on TDN: 1500 ÷ 470 ≈ 3 kg milk;
on dCP: 510 ÷ 56 ≈ 9 kg milk

Conclusion??

**Problem № 2**
Available 10 kg DM maize silage (milk stage, 22% DM). What milk production can be expected?

*answer*
This is the equivalent of 10,000 ÷ 220 = 45 kg fresh product.
In 1 kg product there is 220 g DM (120 g TDN and 10 g dCP).
In 1 kg DM there is 545 g TDN and 45 g dCP.

| | |
|---|---|
| So, 10 kg DM | = 5450 g TDN + 450 g dCP |
| maintenance requirements are | = 3700 g TDN + 290 g dCP |
| | – |
| for production | 1750 g TDN + 160 g dCP |

on TDN: 1750 ÷ 470 ≈ 4 kg milk;
on dCP: 160 ÷ 56 ≈ 3 kg milk

Conclusion??

**Problem № 3**
Available 5 kg DM maize silage and 5 kg DM medium Nandi Setaria. What milk production can be expected?

*answer*

| | |
|---|---|
| 5 kg DM maize silage | = 2725 g TDN + 225 g dCP |

| | |
|---|---|
| 5 kg DM Nandi Setaria | = 2600 g TDN + 400 g dCP |
| | ———————— + |
| | 5325 g TDN + 625 g dCP |
| maintenance requirements are | 3700 g TDN + 290 g dCP |
| | ———————— – |
| for production | 1625 g TDN + 335 g dCP |

on TDN: 1625 ÷ 470 ≈ 3.4 kg milk;
on dCP: 335 ÷ 56 ≈ 6 kg milk

Conclusion??

**Problem № 4**
Available 3 kg DM maize silage and 3 kg DM young lucerne, together with 4 kg DM fully flowering Nandi Setaria. What milk production can be expected?

*answer*

| | |
|---|---|
| 3 kg DM maize silage | = 1635 g TDN + 135 g dCP |
| 3 kg young lucerne | = 1665 g TDN + 585 g dCP |
| 4 kg DM fully flowering Nandi Setaria | = 1860 g TDN + 60 g dCP |
| | ———————— + |
| | 5160 g TDN + 780 g dCP |
| maintenance requirements are | 3700 g TDN + 290 g dCP |
| | ———————— – |
| for production | 1460 g TDN + 490 g dCP |

on TDN: 1460 ÷ 470 ≈ 3 kg milk;
on dCP: 490 ÷ 56 ≈ 8-9 kg milk

Conclusion??

**Problem № 5**
Available 3 kg DM Egyptian cotton cake and 3 kg DM lucerne hay, together with 4 kg DM fresh berseem (1st cutting, irrigated). What milk production can be expected?

*answer*

| | |
|---|---|
| 3 kg DM cotton cake | = 1695 g TDN + 615 g dCP |
| 3 kg DM lucerne hay | = 1410 g TDN + 390 g dCP |
| 4 kg DM fresh berseem | = 2560 g TDN + 720 g dCP |
| | ———————— + |
| | 5665 g TDN + 1725 g dCP |
| maintenance requirements | 3700 g TDN + 290 g dCP |
| | ———————— – |
| | 1965 g TDN + 1435 g dCP |

on TDN: 1965 ÷ 470 ≈ 4 kg milk;
on dCP: 1435 ÷ 56 ≈ 25 kg milk

Conclusion??

# Pasture and fodder crops

In the tropics dairy cattle usually obtain most of their feed from grazing.
However, where farms are very small, or where high-yielding cows are kept, the feed needed by the cows is often (partially) provided by the farmer.

The quality of the grazing often varies a lot, hence the production of the cows also varies considerably. During much of the dry season, cows on grazing produce little milk and lose weight as well, unless they get supplementary feed.

The aim of the dairy farmer should be to try and produce as much milk from his cows as possible, at the lowest cost. He may consider the growing of better-quality pasture and fodder crops, and conserving some of it for use when the quality of grazing is low.

The following two chapters explain the factors involved in choosing better-quality pasture species and obtaining their proper establishment. They are followed by a discussion of important aspects of management such as fertilization and grazing practices. Other elements that receive attention:
- calculation of carrying capacity
- fodder production planning
- fodder conservation
- some common fodder crops in the (sub)tropics

It goes without saying that it is difficult to produce a text which is equally valid everywhere in the (sub)tropics. Particularly the humid tropics (where dairy farming is difficult) are not well covered so far.

In addition to the (general) information contained in this guide, we would advise the users of this guide to try and obtain as much information as possible about pasture and fodder crops that is **locally** provided. Recommendations formulated by locally established research stations are important in this respect.
We would suggest to trainers to spend a large part of available teaching time on putting these recommendations into practice with the students. The school farm or farms in the neighbourhood probably offer suitable facilities for doing this. Practice, in combination with a discussion of underlying facts and the relative merits of what is recommended, is probably more useful than classroom teaching. Practical work should include counts, weighing of samples, dry matter estimations, quality judgments, and so on.
And of course students should learn to recognize all grasses and legumes which are of local importance for dairy farming and be made aware of their properties and qualities.

**A constant supply of good-quality forage, in sufficient amounts, is a basic necessity in modern dairy farming** and this should be properly reflected in training programmes. Also very important are **reproduction, milking, milk quality, milk handling and, of course, the socio-economic aspects of dairy farming.** With perhaps a little bit less attention for other aspects of dairy farming such as dairy breed characteristics, breeding programmes and, possibly, health and diseases.

Lastly, the noun ‘pasture’ has more than one meaning; we mention (a) herbage for cattle and (b) piece of land covered with this. We use both meanings in the following text.

As is also mentioned elsewhere in this guide, we have a more ‘academic’ publication entitled Tropical Grasslands (lecture notes).
It should be clear that the underlying text is much more restrictive; it is only about pasture and fodder crops in the (sub)tropics relevant to ‘modern’ dairy farming as defined in chapter 1.

# 9 Natural grassland and improved pasture

Natural grassland is made up of a number of plant species: grasses, legumes, other herbaceous species, shrubs and trees. The balance anywhere is the result of a number of factors including:
- the climate and the soil
- fires
- wildlife
- the influence of man and his livestock

Grasses are the most important plants for grazing cattle. Normally grasses in the tropics make most of their growth early in the wet season and then flower and set seed, after which their growth almost stops. If they are grazed during the growing season, however, they keep growing longer.
Under these conditions the nutritive value of grasses is low; example from Central Africa:

*Table 24:*

| | TDN% | dCP |
|---|---|---|
| early growing season | 63 | 6.2 |
| mid growing season | 49 | 2.9 |
| early dry season | 49 | 0 |

Dry matter production is usually low, often 2000 kg/ha/year or less, depending on soils and rainfall.

The low quality and quantity of natural pasture results in rather poor animal production. Usually natural grassland is suitable only for beef production except for the (early) wet season.

For best results from natural grassland grazing, the stocking rate must be set at a level which allows the cattle to eat to appetite and to select a high proportion of grass leaves rather than stems.
If the land is **overgrazed,** then often the more nutritious and productive plants will be reduced in number and production per animal will drop.

The **stocking rate** on natural grassland can be increased by increasing the amount of grass produced. Methods are:
- ring barking (killing the trees)
- stumping of trees (more effective but it requires more labour)
- burning the grass at certain intervals may kill and control bush regrowth on cleared land

The introduction of certain **pasture legumes** in natural grassland may substantially improve the productivity of cattle. Successful legumes improve grass growth by increasing the nitrogen levels in the soil and making the cattle eat more protein.

## 9.1 Improved pasture

Improved pasture as opposed to ‘natural grassland’ is rare in the (sub)tropics. The reasons are:
- often the grazing is unsuitable for improvement because of low rainfall or poor soils
- the risks involved in investing money in pasture improvement in relation to the returns expected are often considerable and not worthwhile taking
- it may be a question of lack of knowledge of suitable pasture plant species, on the part of the farmer
- the seed or planting material may not be available (there may be good reasons for that)

In general, improved plant species can only be successfully established where
1 rainfall is not less than 600 mm/year

2 the soil is at least reasonably fertile

On top of this anyone considering improving his pasture **should be prepared to apply fertilizer.**

Here and there the price offered for milk makes it worthwhile to invest money in pasture improvement.
For beef production it is normally not profitable.
But there may be other objectives when a pasture is established:

**1 crop production**
After a soil has been used for cropping for some years, its fertility may have dropped considerably. Some years of grazing of properly fertilized and managed pasture will then restore the fertility of the soil to its former level.
Where certain weeds, insects or diseases have reduced crop yields, or threaten to do so in future years, a break in the cropping cycle provided by several years of planted pasture ( a so-called 'ley') can control the problem.
An example of this is the control of eelworm in tobacco soils by planting Rhodes grass (Central Africa).

**2 erosion control**
On sloping land a planted pasture forms a good soil cover, prevents soil erosion and allows rainfall to sink into the soil. This is very important in catchment areas and in contour stripping on sloping land.

## 9.2 Improving the grazing

A condition is the continuous availability of good-quality seed or planting material at a reasonable price.
In the past this has often been a problem but nowadays in many countries specialized government agencies or private firms operate in this field.

The following is important **at farm level:**
- What is purpose of pasture improvement?
  In our case it is to serve dairy farming; therefore grass and legume species must be selected which are particularly adapted to dairy farming.
- The additional (better-quality) forage produced must be turned into animal products (mainly milk in the case of dairy farming), otherwise pasture improvement makes little sense.
  The nutritive value should be watched constantly; in principle this means that the plants which are grown should remain **young.**
  Hence there must be enough animals to eat the additional forage (stocking rate) and if this is the case the plants will remain young in principle.
- And of course there is the benefit-and-cost factor.
  In general it is the weakest link in the production process which requires attention.
  Feeding is often the weakest link but not always.
  A large profit for a relatively small investment is of course what we all like.

## 9.3 Choice of pasture plant species

For good results from pasture improvement it is very important that well-adapted, vigorous plant species with good persistence and nutritive value are chosen. In the following we consider:
- nutritive value
- growth
- persistence
- ease of establishment

*nutritive value*
The nutritive value of pasture depends on the amount of energy the cow can obtain from it and on its protein, mineral and vitamin content.
Toxic substances should be absent.
The amount of pasture the cow eats and the digestibility of the pasture determine the cow's production.

The protein content of (tropical) grasses is not very high and for improved milk yields pasture legumes are required.
The mineral content of pasture in the (sub)tropics is often not high enough for milking cows, which therefore need mineral supplements.
The vitamin content is usually adequate.
Cows grazing on tropical legumes are unlikely to suffer from bloat. In general, toxicity problems are rare.

*growth*
Yields from improved tropical grasses are generally much higher than from grasses grown in temperate climates. Very roughly speaking 30,000 kg DM/ha/year against 15,000.
But of course it is not the total DM yield which finally matters, but whether the product (the assimilate) can be **eaten** and is in fact eaten by the cows and then converted into an animal product!
Generally speaking roots and flowers are **not** eaten.

For an improved grass pasture it is desirable that some DM is produced during the dry season rather than all during the wet season, with a sudden reduction in growth at the end of the rains. The root system has an important influence on this seasonal growth distribution.

The growth of improved pasture species often depends on good fertility which requires the use of fertilizers.
Ideally, pasture legumes growing with grasses fix nitrogen and contribute to soil fertility and grass growth. The more legume plants there are and the more vigorously they are growing, the greater the grass growth (unless they compete too strongly with the grass).

*persistence*
Persistent pasture plants are those which have adapted well to their environment and yield consistently well under grazing, from year to year, even in competition with other plants. They are not troubled by insects or diseases.

Grazing cattle can affect pasture growth considerably. This particularly applies to legumes which have growing points along the stem (i.e. which have a trailing habit). The advantages of legumes have often been much smaller than claimed because legumes tend to disappear from the sward after grazing.
By contrast, grasses which spread by runners or rhizomes have growing points inaccessible to the grazing animal and recover quickly from heavy grazing.

## 9.4 Types of improved grasses and legumes

**Perennial pasture grasses for the humid tropics**
Well-adapted pasture grasses are now available for all regions of the tropics, but there remain difficulties: how to maintain these grasses at a high nutritive level and how to obtain reliable supplies of high-quality seeds.

*Example*
Pennisetum, Cynodon, Digitaria, Melinis, Setaria, Panicum and Brachiaria.

**Selected perennial pasture grasses suitable for the drier tropics are also available**

*Examples*
Cenchrus, Chloris and Panicum.

**Perennial pasture legumes for the tropics**
Plant breeders have in particular tried to develop cultivars with improved persistence under (heavy) grazing and with improved energy values.
Various improved legumes are now available, for quite diverse conditions. Many are trailing and twining, but there are also erect species. But persistence under grazing has remained a problem.
In general, perennial pasture legumes are productive for a longer period than annual legumes; they are also capable of fixing larger amounts of nitrogen. Optimum growth is around 30 °C.
Compared with temperate legumes, tropical legumes are generally better adapted to a wider range of soils and they are less demanding in their mineral needs.

*Examples*
Desmodium, Stylosanthes, Centrosema, Pueraria and Leucaena.

However, in recent years there have been very serious outbreaks of pests and diseases which were very damaging (to the point of 'wiping out') to certain much publicised legumes: Stylo (by anthracnose), Siratro (by Rhizoctonia) and Leucaena (by psyllids).

**Annual fodder crops for the tropics**
The reasons why annual fodder crops are sometimes preferred to perennial pastures:
- higher short-term plant growth
- they fit well in integrated crop and livestock enterprises
- convenient in overcoming seasonal feed shortages
- good fodder conservation properties
- they make a break in crop rotation (control of weeds, insects and diseases).

*Examples*
Pennisetum (also perennial), sorghum and maize.
DM production per ha per day can be spectacular under favourable conditions.
Suitable cultivars have been selected for most types of tropical and subtropical environments.
Legume fodder crops have the additional advantage of improving soil fertility and structure.

**Temperate pasture species for the high-altitude tropics and subtropics**
Their optimum growing temperature is around 25 °C.
In general, with temperate grass species milk production can be maintained at a much higher level than with tropical grasses. This is (partly) due to the fact that tropical grasses are generally taller; they have therefore more structural material (conducting vessels) and this material is not so nutritive.
For this reason dairy farming enterprises try to grow temperate grasses in the (sub)tropics wherever this is possible.
Rye grass (Lolium) has the highest nutritive value of temperate grasses.
Well known temperate legumes are Trifolium repens and Medicago sativa.

# 10 Pasture establishment and fertilization

## 10.1 Pasture establishment

Successful pasture establishment depends on:
1 seed quality and seed treatment
2 seedbed quality
3 moisture conditions
4 soil fertility
5 plant competition
6 pests and diseases

### Seed quality and seed treatment

Once a pasture species or combination of species has been chosen, it is important that high-quality seed or planting material be used, so that under good conditions a high proportion of the seed germinates or starts growing.
Seed should be bought from a reliable company or agency which sells clean, tested seed.
The seller should state the standards of seed purity and viability which applies to that seed.
Poorer-quality seed should be sown at a higher rate per hectare than the above 'certified' seed.

Pasture legume seeds often do not germinate all at the same time after sowing as some seeds have very hard seed coats which water does not penetrate easily.
If a farmer is in an area where drought seldom occurs, and is sowing when the rains have already well started, he may wish to have an evenly germinating stand of legumes. He should then **scarify** the seed which means:
- place required amount of seed in a bag which allows the entry of water
- then soak the seed in a drum with hot (but not boiling) water at about 70 °C, for about 10 minutes
- this will soften the seed coat and germination will take place quickly

**Inoculation** is required for legume seeds such as lucerne or Leucaena when sown into a field or paddock for the first time. This is because the specific Rhizobium bacteria required by the plant for the formation of root nodules are not naturally present in soil.
Procedure:
- obtain inoculum and keep it in a cool, dark place, preferably a refrigerator, until required
- moisten the dry legume seeds slightly with a 5% sugar solution (1 teaspoon per 100 ml of water)
- then sprinkle with enough inoculum to coat the seeds
- the seeds should be dried in the shade (because direct sunshine kills bacteria) and sown within 24 hours

The above is the general picture with regard to scarification and inoculation. Follow particular instructions given by the seed supplier.

Some grass seeds (e.g.Buffel grass) should be kept **in storage** for a year after harvesting so that the **seed dormancy** is broken. If not, germination will be very poor.

### Seedbed quality

This is more important for small pasture seeds than for the large seeds of crops such as maize.
Usually, for improved pastures grown for dairy cattle, most of the trees are removed by stumping and the whole surface area is ploughed and disked ready for sowing early in the wet season.
Before sowing the seedbed should be rolled in one way or another. The sowing should be done after the rains have started.

A **fine seedbed tilth** is important because then the small pasture seeds have a better chance of having good contact with soil particles which hold water for germination. Also, depth of sowing can be better controlled; pasture seeds generally should not be sown deeper than 1 cm.
Some germinating seeds may not emerge from the soil if there is a hard crust on the soil surface. This depends on the soil type.
Often the best germination on a rough seedbed (which is not as it should be) takes place in the furrows made by the tractor wheels, because of better soil/seed contact.

#### Moisture conditions

Pasture seed should be sown into **moist** soil, followed within a day or so by enough rain to wet the surface layers of the soil thoroughly. Good germination, emergence and establishment should result as long as the soil does not subsequently dry out too much due to periods of drought.
Good establishment may not be obtained if seed is sown too late in the rainy season. Legumes, being slow-growing plants, should be sown as early as possible. Grasses may be planted later as they grow faster.

#### Soil fertility

Pastures establish better in soils of higher fertility.
Legumes respond to **higher phosphorus levels** by increasing the growth of root nodules which then fix more nitrogen and make plants grow faster and establish better.
Sulphur also increases growth of legume seedlings and it should be applied with phosphorus at establishment, in the form of single superphosphate (21% $P_2O_5$, 12% S).
Grasses respond well when both phosphorus and nitrogen are present in adequate amounts.

#### Plant competition

A pasture planted into a ploughed virgin soil is unlikely to suffer much from weed competition compared to one planted into old cropping land.
In old cropping land weed competition can be reduced by **the use of herbicides** (although great care must be taken to choose a herbicide that does not affect the growth of the pasture species) **and** by obtaining a high density of rapidly-establishing pasture plants which compete well with weeds.
Sometimes good control of weeds is obtained by soil cultivation and later planting of pasture seed.
Grazing or slashing at a later stage of growth may also help to control weeds.
With a well-established, well-fertilized and managed pasture, weeds are rarely a problem after the first year.

#### Pests and diseases

Pests and diseases are often specific to particular pasture species or particular areas, so if a poor establishment is obtained when conditions are good, perhaps a pest (e.g.seed harvesting ants) or a disease (e.g.'damping-off' fungus) may be responsible. The advice of experts in this field should then be sought.

## 10.2 Methods of pasture improvement

The method of pasture improvement **with the lowest cost per hectare is broadcasting of suitable legume seed** (or even grass seed) into natural grassland which has been heavily grazed or burnt.
Under good soil moisture conditions reasonable results can be obtained.
Another method is to use a **disk** harrow with some of the disks removed, to make narrow (30 cm wide) strips. The legume seed (possibly mixed with single superphosphate; this may be a must in many places) is then broadcast over the disked area.
This can give good results as long as stocking rates are reduced in the first year.

### Cultivated pasture

**Underseeding maize** is a very suitable method to use when a pasture ley is planted or a cropping area converted to a permanent pasture, because the land is out of production for as short a time as possible.
For good establishment of the pasture, the plant population of the maize should be not more than 35,000 plants/ha (e.g. 90 cm rows, with plants 32 cm apart in the rows).
The maize crop is planted in the usual way. If herbicide is used, legume (not grass) seed can be planted at the same time as the maize or soon afterwards.
Legumes and grasses may be planted in alternate rows.
If weed control is by cultivation, the pasture seeds can be sown 4-6 weeks after the maize (i.e. after the first weeding). The seed can be dropped by hand into the disturbed soil immediately after the last cultivation, at the usual recommended seed rate per hectare.
The advantage of this method is that the maize crop will pay for the cost of the pasture established. The maize crop also helps to prevent soil erosion and rapid drying-out of soil, and the shading effect of the maize favours most legumes over grasses.

**Open (direct) seeding** is an expensive way of establishing a pasture because there is no crop to cover establishment costs.
Weeds are also more of a problem and there is a risk of soil erosion.

Weeds must be reduced by pre-seeding cultivation (not too deep otherwise fresh weed seed will be brought to the surface).
Post-seeding cultivation is easier if seed (grass and/or legume) is sown in rows, rather than broadcast.
Legumes should be planted as early as possible in the wet season due to their slower rate of growth; grasses may be planted 4-6 weeks later, if necessary.

### Establishing legumes in existing grass pasture

If grass is of the tufted type (e.g. Rhodes grass), disked strips can be made in the pasture (as above) and the legume seed broadcast into the prepared seedbed and covered.
If grass has rhizomes or stolons (e.g.Star grass), then the grass should be set back as much as possible before sowing the legume seed.
A combination of ploughing in the previous late growing season, disking in mid-season and disking again in the hot late-dry season should reduce the competition with young legume plants.

The combination of a **green fodder and a plantation crop** is another possibility (e.g. legumes under coconuts in the humid tropics).

**Note:**
(Boonman; see appendix III).
'The successful introduction of legumes into pastures is not easily obtained. And farmers cannot be expected to invest in a plant that requires extra inputs - especially P-fertilizer, but also seed, inoculant amd microelements - only for its own upkeep and then to see it disappear when the sward is grazed to the potential of the grass companion as had been the practice before. Farmers will simply not bother to try again.
Scientists tend to think lightly of the efforts and extra inputs required to establish a legume in the field.
Even when legumes can be made to stay in the sward, the benefit accrued is less than often assumed. In a normal, grazed sward it is rare to find a grass patch that is more vigorous because of a legume nearby. Nitrogen is fixed in quantity only when legumes themselves are in a vigorous state, i.e. when allowed to grow relatively mature, together with the grass companion.
Legume's nutritive value should not be overstressed either. Young legumes are no more digestible than their companion grasses. Only past the rational-grazing stage are legumes able to make up for the inevitable decline in nutritive value of the grass'.

# 11 Fertilization of pasture

Pasture is often grown on not so fertile soils which are not well suited for cropping. The natural vegetation growing on these soils is adapted to the level of soil fertility and the dry matter production is usually low.
Improved pastures are capable of much higher production but **only if soil fertility can be improved.** Unless the soils are naturally fertile, the DM production of an improved grass, for example, may not be much higher than that of a good coverage of natural grasses, yet a considerable investment may have been made on the establishment.

Before improving a pasture by introducing new grass species or legumes, it is advisable to take soil samples for analysis to the nearest Agricultural Research Station, so that advice can be obtained on the fertility of the soil and the amount and type of fertilizer required for good pasture growth.

The results of soil analyses may be difficult to interpret. The most important figures are pH (soil acidity) and 'available phosphorus' which is usually measured in parts per million (ppm). **Phosphorus is an essential nutrient for root development.** When there is not enough phosphorus, the root system will not properly develop. Most tropical soils are phosphorus-poor, especially the more marginal soils.
The following table shows the yield response likely from superphosphate application for different levels of 'available phosphorus':

*Table 25:*

| Available P | P-status of the soil | Effect of applying P-fertilizer (other nutrients being adequate) |
|---|---|---|
| less than 3 | very deficient | up to double yield increases |
| 3-7 | deficient | yield increases ⅓ to ⅔ |
| 7-15 | marginal | yield increases small (less than ⅓) |
| 15-25 | adequate | no yield response likely in establishment year but maintenance dressings desirable |

On acid sandy soils (pH of 5 or less and low in calcium) there will often only be a good yield response to P-fertilizer with pasture legumes if **lime** is first applied at 500-1000 kg/ha.

Some legumes need more phosphorus than others and are usually suitable to reasonably fertile soils, whereas others (e.g. Siratro and the Stylos) will usually grow quite well at lower soil P levels.

In general, a soil which has an 'available P' level of 20-25 ppm need not receive any phosphorus fertilizer for grass or grass-legume pasture in the first year. However, after another 1-2 years the pasture will need top-dressing with phosphorus as some of this nutrient is removed from the soil by the plants, eaten by cattle and converted to animal products.

Soils which have low 'available P' need heavy applications of superphosphate for good establishment and growth, especially if legumes like silverleaf Desmodium are planted. Some 400 kg/ha single superphosphate at planting would not be too much.
Every year after planting 200 kg/ha should be applied in addition.
Single superphosphate is usually recommended for pasture because of its sulphur content, which is especially important for legume growth. However, if the sulphur content of the soil is reasonably good, single superphosphate can be replaced by triple superphosphate.

If triple super is used, only half the quantity per hectare is needed; this can be seen from the following figures:
single super 21% P 12% S
triple super 46% P

This can result in big savings in fertilizer costs if the price of the two types of superphosphate is about the same.

Compound fertilizers, especially 1:2:1 NPK are valuable for the establishment of pure grass pasture. Application rates depend on soil fertility; pastures grown on well-fertilized cropping land may only need 200 kg/ha or less while low-fertility soils will benefit from 400 kg/ha or more.

### Nitrogen

Pure grass pasture should be topdressed with nitrogen fertilizer if good yields of pasture DM are to be obtained.
However, the response to this fertilizer will be poor unless the 'available P' level in the soil is adequate.

In the establishment year of a pure grass pasture, at least 50 kg N should be applied in the early/mid growing period, and in subsequent years two applications of at least 50 kg N should be applied, one in the early/mid growing season and the other in the mid/late growing season.

Either ammonium nitrate (34% N) or urea (46% N) may be used, but where the prices per kg product are about the same, urea is the cheapest source of N.

*Example*

$$50 \text{ kg N} = \frac{50 \times 100}{46} = 108 \text{ kg urea or}$$

$$\frac{50 \times 100}{34} = 147 \text{ kg ammonium nitrate}$$

Urea should **not** be applied to bare, dry soil as atmospheric losses may then be 25% or more.

When a mixture of legumes and grass is used, nitrogen fertilizer is not really necessary. If there is a good proportion of vigorously-growing legumes in the pasture, they can release 100 kg N/year or more into the soil, at no cost to the farmer.
Some legumes release more nitrogen than others.

It is assumed that milking cows retain about 10% of the minerals and 25% of the nitrogen which they ingest from the pasture, in case of continuous grazing. The biggest part is returned (faeces, urine).
But, in the case of night-yarding or housing, losses are very considerable unless faeces and urine are carefully returned to the pasture!
An extreme case is 'zero grazing'.

In the field there may be considerable transfer of nutrients from point to point: dung and urine patches in the field and dung and urine in gateways.

### The effect of fertilizer on plant nutrient value

The application of 200 kg/ha single superphosphate to a pasture increases its nutritive value. The nitrogen content of a legume can increase by 30% due to more and bigger nodules fixing more nitrogen for the plant to use. The phosphorus content can also increase by 20%.
With grasses, the increase in nitrogen is around 20% and phosphorus 50%.
For both legumes and grasses the sulphur content is doubled.
Nitrogen fertilizer also increases leafiness and digestibility, so intake is higher and the cows may be able to select more high-protein leaf (up to 16% crude protein).

**The costs and benefits of fertilizer use**

Fertilizer is expensive and many farmers are reluctant to use it on pasture. When only little is available, then it may be best to use it for crops.
It is perhaps more difficult to see the benefit of applying fertilizer to pasture than it is for crops; as cows 'harvest' pasture the benefits must therefore be looked for in increased cow production.

Fertilizers increase pasture growth. On average (if other nutrients in the soil are not lacking) each kilogram of nitrogen fertilizer applied (i.e. 2.16 kg urea or 2.94 kg ammonium nitrate) produces about 20 kg DM.
Therefore, if 100 kg N is applied to one hectare of grass pasture, there will be an extra 2000 kg DM produced above the DM produced from the nutrients already in the soil.
This means that more cows can be kept on this hectare of pasture because there is more grass to eat, or the same number of cows can select a higher-quality diet from the grass that is on offer.

*Example*

A grass growing on a soil with an adequate level of 'available P', but with no nitrogen fertilizer applied, produces 4000 kg DM/ha. This 1 ha pasture is grazed for 200 days.
20% of the DM is uneaten, leaving 80% (3200 kg) eaten by cows. This is enough to meet the roughage requirement of 1 to 1½ cows, for these 200 days.

If 100 kg N-fertilizer is applied during the growing period of the grass, there should be an extra $100 \times 20 = 2000$ kg DM produced. With 20% grazing losses, 1600 kg DM is actually eaten. This is enough (at 12 kg DM/day intake) to feed another 0.7 cows for these 200 days. Therefore 1.7 to 2.2 cows can be carried where only 1 to 1½ cows could be carried before.

It has been found (in Queensland, Australia) that 1 kg N produces 9 kg milk, if stocking rates are increased to use the extra forage produced.

By this method 100 kg N/ha should give 900 litres of milk. If this is produced by an extra 0.7 cows/ha, then each cow at 1.7 to 2.2 cows/ha stocking rate should produce 1300 litres of milk over 200 days from grass.
This is a reasonable figure to expect from improved pastures.

Whether or not the application of nitrogen to pasture is profitable (milk price!) has to be calculated from place to place:

| | |
|---|---|
| ➢ milk 900 litres at M ... /litre | = M ............ |
| ➢ 100 kg N in the form of ammonium nitrate is approx. equal to 300 kg of the product = 6 bags of 50 kg at M .... /bag | = M ............ – |
| Gross Margin | = M ............ |

Usually a farmer will only apply additional N-fertilizer if he has extra cows available to utilize the additional grazing produced.
However, if his pastures were overgrazed at the lower stocking rate to such an extent that his cows were unable to eat to appetite or select a high enough quality diet, the application of additional N with the same stocking rate will also give good results.

Another option is to **conserve** the extra DM produced as hay or silage.
This can be fed during the dry season to maintain or improve production when the quality of grazing is low.

# 12 Pasture management

Once the dairy farmer has chosen well-adapted, vigorous pasture species and has obtained good establishment and growth, his aim should be to get as much as possible animal production from his pasture, without affecting its future productivity.

In general, **grasses can be quite heavily grazed** to a level at a few cm's height; this allows the grass to produce new growth rapidly from the buds in the 'crown' of the plants.
Rhizotomous grasses which have buried buds such as Star grass can be grazed more heavily than those with above-ground buds.
However, once a grass has been heavily defoliated, it should be allowed to regrow for some time, to allow many new leaves to be produced. These new leaves produce plant food which is transported to the roots; this enables the grass to build up its root food reserves for the next grazing.
If this is not done, the grass loses vigour and does not grow so fast after grazing.

Normally the grass should not be allowed to grow for too long after grazing as then the nutritive value of the grass will be lower.

Most **pasture legumes cannot be grazed as heavily as** grasses because they have their buds along the stem. If much of the stem is eaten, there are very few buds left to produce new leaves and regrowth will be very slow.
If legumes are grazed heavily like this too often, the plants may not survive.
Legumes need a longer period of regrowth than grasses (preferably 6-8 weeks) and lighter grazing (i.e. the pasture should not be grazed down to the same height as pure grass pasture).

Grasses and especially legumes often benefit from being allowed to go to seed every 2-3 years. This practice helps to maintain the vigour of the pasture.

## 12.1 Stocking rate

How heavily grasses and legumes are grazed depends on the number of cows, the area of pasture available and the period of grazing involved.
**Stocking rate** is the term to define how heavily an area of pasture is grazed; it is the number of animals carried per unit of pasture, over a period of time e.g. a year.
The **carrying capacity** is the **optimum** stocking rate: the number of animals per unit area of pasture which gives the maximum long-term profit.

The following factors influence the optimum stocking rate:
1 the rate of pasture growth
2 total pasture production per hectare
3 seasonal variations
4 the need for selective grazing

*the rate of pasture growth*
The faster the rate of growth of a pasture, the higher the optimum stocking rate. The rate of pasture growth mainly depends on rainfall, soil fertility and choice of pasture species.

*total pasture production per hectare*
Rate of growth is important in determining total pasture production, but production per hectare also depends on the number of pasture plants per unit area. A pasture which has many weeds and bare areas of soil will have a lower production.

*seasonal variations*
In areas where there is a big variation in annual rainfall, the stocking rate used may be lower than the optimum in the good years so that it is not too high in the poor years.
In years of below average rainfall when grazing is scarce, the cows should still survive at the lower stocking rate, with little if any destocking.

*the need for selective grazing*
If milk yields from pasture are to be high, dairy cows should be able to select quite a high proportion of young leaves.
Beef animals and growing dairy heifers do not need as much energy and protein, and so their optimum stocking rate can be higher than that of dairy cows.

**what should be the optimum stocking rate?**
The answer will vary according to the factors listed above, so the optimum rate for a particular farm can best be discovered from experience.
However, the following is put forward as a guideline. All rates refer to areas with rainfall of 750 mm or more, and reasonably fertile soil, with a 6 months' dry season:

| | |
|---|---|
| natural grassland (good-quality cleared land) | – at least 0.5 cow/ha (= 2 ha/cow) |
| improved grassland (no fertilizer) | – 0.5-0.75 cow/ha (= 1.5-2.0 ha/cow) |
| improved grass, with 200 kg single super + 100 kg N per year | – 2.0-2.5 cows/ha |
| improved grass/legume, with 200 kg single super per year | – 1.0-1.5 cow/ha |

Cows grazed on these stocking rates on improved grass pastures should give average milk yields of 8-10 litres (without concentrates) over the rainy season while yields from improved grass/legume pasture should be at least 10 litres on average.
Actual milk yields per hectare depend on the stocking rate used.

*calculation of actual stocking rate*
The above examples of stocking rates are given in terms of 'cows per hectare'.
However, cows and heifers have different bodyweights, and bodyweight is important in determining the intake of grass.
For this reason it is preferable to use **'livestock units per ha'** as the measure of stocking rate.

One livestock unit (1 LU) is taken to be the equivalent of a cow weighing 500 kg which is a good average for a fully-grown Friesian cow.

The weight of cattle can then be converted to LU's as follows:
- a cow weighing 600 kg has an LU equivalent of 600 ÷ 500 = 1.2
- an in-calf heifer weighing 400 kg has an LU equivalent of 400 ÷ 500 = 0.8

A herd made up of 4 cows weighing 600 kg each and 1 in-calf heifer of 400 kg therefore makes up (4 × 1.2) + 0.8 = 5.6 LU.

If this herd is put in a 2 ha paddock, then the stocking rate is 5.6 ÷ 2 = 2.8 LU/ha.

## 12.2 Stocking method

The most important factor affecting production from pasture is the stocking rate, as this largely determines the animals' intake.

The method by which the pasture is managed is not so important, as long as the composition of the animals' diet does not vary much.

The two **main methods of stocking are:**

1 **Continuous grazing,** where cattle are kept in a single enclosed pasture area (paddock) for the whole grazing season.
The number of cattle in the paddock will often remain the same, in which case the pasture is 'set-stocked'.
If the number of cattle in the paddock changes e.g. according to the pasture available, the paddock is 'variably-stocked'.

2 **Rotational grazing** requires that the pasture area is sub-divided into a number of paddocks with at least one more paddock than the number of separate herds.
Sometimes cattle are rotated through each paddock in succession, or some paddocks may be reserved from grazing for a period of time e.g. grass/legume pasture which is needed for conservation as hay or for grazing as standing hay.

Other modifications of rotational grazing are 'strip grazing' where an electric fence is often used to control cattle access to pasture or fodder crops.
Another is 'leader-follower' grazing where dairy cows have first access to pasture and, after they have moved out, are followed by other stock. The aim of this system is to ensure that the pasture is grazed down more evenly, for uniform growth.

We also mention so-called **zero grazing**, around large towns or, in general, where land is (very) scarce.

### Choice of stocking method

In general, continuous grazing with set- or variable stocking is the most suitable method for tropical pastures and gives equal or better results in terms of animal production compared to rotational grazing.
It has the advantage of lower costs (less fencing and watering materials are required) and simplicity (not so many movements of animals) which makes management easier.
However, under certain circumstances some form of rotational grazing may be desirable. These circumstances are:

1 rotational grazing is necessary in order to maintain pasture composition and vigour
2 fodder conservation
3 better pasture use is desirable
4 there is poor surface drainage (in excessively wet periods)
5 in case of heavy clay soils, peat soils, trampling
6 rotational grazing is necessary in order to better control internal parasites

*re 1: maintenance of pasture composition and vigour*

Usually an improved grass pasture made up of a single species, properly stocked, will maintain its vigour satisfactorily, even under continuous grazing. A reasonable balance will then be obtained between food reserves moving to and from the roots.
However, an overstocked grass pasture may have to be rested for some time if its vigour is to be maintained.
This is even more important for a grass/legume pasture, otherwise the legume component may be lost.
A possible way of handling this situation is to have two paddocks for the milking herd, one an improved grass pasture and the other perhaps an improved grass/legume pasture.
The herd grazes the improved grass pasture in the early wet season except for a period of time sufficient to graze down the grass component of the grass/legume pasture, enough for the legume to compete better for light.
However, later in the wet season the cows move onto the grass/legume pasture and stay there until this mixed pasture has been correctly grazed. The cows then move back to the improved grass pas-

ture, staying there for the rest of the dry season, while the grass/legume pasture is allowed to rest and recover.

The overall stocking rate under this system of 'deferred' grazing will be a little less than if a pure grass pasture was used throughout, but milk production or weight gain will be higher. This increase in production is brought about without affecting long-term pasture composition and vigour.

*re 2: fodder conservation*
If it is desired to make pasture hay or silage, then a paddock must be rested from grazing for a certain period.
Animals must then be moved to another paddock, and plant material removed must be taken into account in setting the stocking rate for the paddock.

*re 3: better pasture use*
Sometimes with continuous grazing, the pasture is not grazed evenly as the cattle return again to graze the fresh regrowth of plants they have grazed already, leaving other less-palatable plants or plant parts uneaten.
Milking cows should be allowed to graze selectively in order to get good yields, but it also means that grass is being wasted.
This can be overcome by moving milking cows out of the paddock and putting-in (many) less-productive animals for a short period to remove uneaten grass.
Then the paddock should be rested for a period before putting milking cows in again.

A better way of using all the pasture growth is by **strip grazing.**

**Zero grazing,** or feeding animals solely with cut forage, usually results in even better pasture use as there are no losses from trampling and little opportunity for cows to select their feed. However, with zero grazing the labour and equipment demand is high and considerable amounts of plant nutrients are removed from the soil. Tethering is another option (the animal does the work!).

*re 6: control of internal parasites*
Newly-weaned calves and young heifers up to one year of age, do not have much resistance to internal parasites (worms).
If they are on a continuous grazing system on improved pasture, they should be de-wormed every 4-8 weeks, depending on their age and the moisture conditions in the pasture.
If they are rotationally grazed, so that a paddock is rested for at least four weeks before being grazed again, they will not have to be dosed so often.

Internal parasite control in older heifers and cows is rarely such a problem because they have built up a certain level of resistance. For them the stocking method is less important in this respect.

Resting a pasture for **tick control** is generally not effective because ticks can survive long periods on pasture without hosts.

ALWAYS REMEMBER THAT SUCCESSFUL DAIRY FARMING REQUIRES HIGH-QUALITY GRAZING ALL THE TIME, PARTICULARLY WHEN SHORTAGES CANNOT BE OVERCOME BY CONCENTRATE FEEDING.
THE MILK FLOW OF THE COWS IS **VERY SENSITIVE** TO PASTURE QUALITY!

## 12.3 Summary of possible feed resources on a dairy farm

1 Natural grassland
2 Improved natural pasture
   - a first step is tree cover reduction
   - followed by broadcasting of (legume) seed ('overseeding')
   - fertilizer application
3 Sown legumes
4 Crop residues in mixed farming
5 Sown pastures
   - grass/legume mixture or
   - grass plus fertilizer application
6 Rainfed foddercrops
7 Irrigated pasture and crops
8 Pasture hay or silage
9 Home-produced stored grains
10 Concentrates and roughages bought from elsewhere

**Summary of ways to maintain an even feed supply on a dairy farm: five basic approaches**

1 Conserve roughage.
2 Buy feed from elsewhere. Dairy farmers are traditionally buyers of concentrates. Even buying roughages may be cheaper than producing the whole year round.
3 Increase feed production on the farm. For example, through irrigation and fertilizer application. Add forage species which produce the whole year round.
4 Adapt animal requirements to the available feed supply. For example, by varying mating time.
5 Buy and sell animals.

**No modern dairy farm can do without planning** as far as feed availability is concerned.

## 12.4 Farm planning

A dairy farmer should **plan** the size and the number of his paddocks so that the overall farm stocking rate is maintained at the desired level and each herd has enough grazing in the paddocks allocated to it. Once he has decided on the optimum stocking rate of his pasture, the farmer should check that the number of livestock units in his grazing herd is not higher than the carrying capacity multiplied by the area of pasture that is available.
This applies to farms which only depend on grazing for their cattle. Where forage crops are grown, the production of these will also have to be taken into account.

The overall carrying capacity of the farm will be the sum of the individual carrying capacities of the different paddocks plus the feed produced on the cropping area.

*Example*

*Table 26: A farm has a total area of 100 ha, divided up as follows:*

| land | area (ha) | estimated carrying capacity |
|---|---|---|
| house and yard | 5 | 0 ha/LU |
| stony hill | 5 | 0 ha/LU |
| poorly drained area | 10 | 2 ha/LU |
| cropping land (maize, soybean, a.o.) | 20 | 2 ha/LU * |
| cleared natural grassland | 40 | 2½ ha/LU |
| improved grass pasture | 20 | 1½ LU/ha |

* the carrying capacity of the cropping land will depend on the type of crops planted and their yields; here we have assumed 2 ha/LU

The total number of LU which can be carried on this farm is therefore:

| | | |
|---|---|---|
| poorly drained area | 10 ÷ 2 | = 5 |
| cropping land | 20 ÷ 2 | = 10 |
| cleared natural grassland | 40 ÷ 2½ | = 16 |
| improved grass pasture | 20 × 1.5 | = 30 |
| | | — + |
| | | 61 LU |

The farm may have a cattle herd made up of the following categories of animals which are grazing on the farm.
By calculating the LU equivalent of his herd the farmer can check and see whether he is overstocked or not:

*Table 27:*

| **category** | **number** | **LU equivalent** | **LU** |
|---|---|---|---|
| **dairy herd:** | | | |
| cows | 20 × | 1.0 | 20.0 |
| bulling heifers | 6 | 0.8 | 4.8 |
| in-calf heifers | 8 | 0.6 | 4.8 |
| yearling heifers | 7 | 0.2 | 1.4 |
| | | | 31.0 |
| **beef herd:** | | | |
| cows | 10 | 1.0 | 10.0 |
| bulls | 1 | 1.5 | 1.5 |
| 2-years'old heifers | 3 | 0.6 | 1.8 |
| yearling heifers | 3 | 0.4 | 1.2 |
| yearling steers | 2 | 0.5 | 1.0 |
| 2-years'old steers | 2 | 0.6 | 1.2 |
| oxen | 4 | 1.2 | 4.8 |
| | | | 21.5 |

**The total LU on the farm is therefore 31 + 21.5 = 52.5**
This farm is understocked and the herds can be allowed to increase further in size until the carrying capacity is reached.
Subsequently, the carrying capacity can be increased by, for example, increasing the area of improved fertilized grass pasture.

# 13 Fodder production planning

The idea of **planning** fodder production is further elaborated in this chapter, mainly by means of examples and 'problems' which have to be solved by making calculations.

*Example*
Given a mixed small holding in an area with a dry season.
The size of the farm is 2.4 hectare; one-half is pasture, the other half cropping land.
The farm's stock is expressed in livestock units, in which

| | |
|---|---|
| 1 adult cow | = 1 LU |
| other cattle over 2 years of age | = 0.7 LU |
| cattle 1-2 years | = 0.5 LU |
| cattle under 1 year | = 0.3 LU |

In our farm we have

| | | |
|---|---|---|
| 3 dairy cows | × 1 | = 3 LU |
| 1 in-calf heifer | × 0.7 | = 0.7 LU |
| 1 heifer, 12-18 months old | × 0.3 | = 0.3 LU |
| | | + |
| | total | 4.5 LU |

The dry season is expected to last about 130 days.
One LU is assumed to need 10 kg DM/day.
We assume that there is no grazing during the dry season; this means that

4.5 (LU) × 10 kg DM × 130 (days) = 5850 kg DM has to be obtained from conserved forage.

(a)
If the yield of 1 ha maize for silage is 10,000 kg DM, the farmer must plant
5850 ÷ 10,000 ≈ 0.6 ha
(b)
If the yield of 1 ha Napier grass (one cut) is 4000 kg, the farmer must plant
5850 ÷ 4000 ≈ 1.5 ha
Napier grass, however, can be used twice.
During the rainy season it can be ensiled, while during the dry season it can be fed green. So, in the case of napier grass the area needed is 1.5 ÷ 2 = 0.75 ha
(c)
But if there is any grazing during the dry season, this must be taken into account.
If, for example, the farmer estimates 4 kg DM the amount of DM the cattle get from grazing, the cattle will need only 6 kg DM from another source.
In our example:
4.5 (LU) × 6 kg DM × 130 (days) = 3150 kg DM.

If the yield of 1 ha sorghum is 4500 kg DM, the farmer must plant 3510 ÷ 4500 ≈ 0.8 ha(one cut).

**Model fodder production plan**

The following is a **model** that can help in planning fodder production:

| | |
|---|---|
| Size of the farm ......... ha | Pasture ............. ha |
| | Cropping land ....... ha |

*Livestock units*

| | | | |
|---|---|---|---|
| .......... dairy cows | × 1 LU | = ....... | LU |
| .......... in-calf heifers | × 0.7 LU | = ....... | LU |
| .......... heifers, 12-18 months | × 0.5 LU | = ....... | LU |
| .......... heifers, 6-12 months | × 0.3 LU | = ....... | LU |
| .......... .................. | × ... LU | = ....... | LU |
| | | | + |
| | total | ....... | LU |

**Dry period** ....... days

**Available from grazing:** ........ (LU) × ..... kg DM × ......... (days) = ........ kg DM

**Required:**
green fodder ..... (LU) × ...... kg DM × ..... (days) = ..... kg DM
silage ........... (LU) × ...... kg DM × ...... (days) = ..... kg DM

The farmer likes to grow .......................
The yield per hectare of this crop is ... kg DM (one cut). The number of cuts per year is ......
Therefore the farmer has to grow ...... ha of this crop.

**Average yields (indicative only):**

| | | |
|---|---|---|
| pasture grass | 2000 kg | DM/cut/ha |
| Napier grass | 4000 | ,, |
| sweet potato vines | 2500 | ,, |
| maize | 10,000 | ,, |
| sorghum | 4500 | ,, |
| legumes | 2500 | ,, |

It goes without saying that from place to place conditions and possibilities are different, but modern dairy farming anywhere cannot do without **planning** which means **relating number of cows kept to available feeds, for optimum economic results.**

**Problems**

In the following problems feed supplies are related to maintenance and production requirements of dairy cows.
We make the following assumptions:

- dairy cows of 500 kg live weight
- DM intake is 10 kg/DM/day
- maintenance requirements per day are 3700 g TDN + 290 g dCP
- for milk production 470 g TDN + 56 g dCP per litre of milk

The feeding value data are taken from the list on pages 23 to 26.
It should be realized that **we work from assumptions** which nevertheless determine the results of the calculations. We would suggest that users of this guide make similar calculations based on **local**

(dairy farming) situations and conditions. We suggest to use data considered to be the most reliable under the prevailing conditions.
Students should 'recognize' the problems; they should have the feeling that the problems are realistic and applicable to what they themselves have experienced or will experience.
By the way, we would very much like to receive 'field' problems from users of this guide, to replace the present ones or to add them to the collection which is presented here.

*Problem № 1*
Medium-quality Star grass is available on a farm, for grazing to appetite.

*Questions:*
1 How many kg Star grass will the average cow eat per day?
2 What milk production can be expected from this grazing?
3 Which type of concentrate could be recommended if milk production is to be increased?

*Answers:*
1 10,000 ÷ 300 = 33 kg Star grass

| | | |
|---|---|---|
| 2 | 10 kg DM Star grass | = 4300 g TDN + 650 g dCP |
| | maintenance requirements | = 3700 g TDN + 290 g dCP |
| | | – |
| | remaining for milk production | 600 g TDN + 360 g dCP |

on TDN: 600 ÷ 470 ≈ 1 kg milk;
on dCP: 360 ÷ 56 ≈ 6.5 kg milk

Conclusion: ..........................................

*Problem № 2*
On a farm is available per cow per day:
- 4 kg DM pasture hay (average quality)
- 2 kg brewer's grain, dry
- 4 kg DM maize silage, milk stage

and maize grain, soyabean seed and Egyptian cottonseed cake.

*Questions:*
1 What is the roughage ration?
2 What milk production can be expected from this ration?
3 Given the concentrate ingredients available on the farm, what would be a suitable concentrate in this case?
Make an 'expected milk yield' calculation with this concentrate.

*Answers:*

| | | |
|---|---|---|
| 1 | pasture hay, 4 kg DM | = 1200 g TDN + 220 g dCP |
| | brewer's grain, 2 kg DM | = 740 g TDN + 320 g dCP |
| | maize silage, 4 kg DM | = 2180 g TDN + 180 g dCP |
| | | + |
| | | 4120 g TDN + 720 g dCP |
| | maintenance requirements | 3700 g TDN + 290 g dCP |
| | | – |
| | remaining for milk production | 420 g TDN + 430 g dCP |

2 On TDN: 420 ÷ 470 ≈ 1 kg milk;

on dCP: 430 ÷ 56 ≈ 7 kg milk

3 ............................................................

*Problem № 3*

Given a dairy farm at a time just before the start of the dry season.
The dry season is assumed to last 150 days. There will be no sale of stock nor buying of stock and the average stocking during the dry season is predicted to be:

- 30 dairy cows
- 6 in-calf heifers
- 2 heifers 12-18 months old
- 5 heifers 6-12 months old
- 1 bull
- 2 oxen

The feedstuffs which are available on the farm:
maize silage: a pit 10 × 4 × 3 m filled with silage, at 180 kg DM/$m^3$
hay from grass: 1030 bales at 22 kg/bale, at 80% DM

It is estimated that on top of this there will be 0.6 kg DM/LUD(ay) of grazing (fully flowering Rhodes grass).

*Questions:*

1 Is there enough feed to carry this stock through the dry season?
2 What milk production can be expected from the feed that is available?

*Answers:*

1 First of all, the farm's stock is expressed in livestock units, as follows:

| | | |
|---|---|---|
| 30 dairy cows | × 1 | = 30 LU |
| 6 in-calf heifers | × 0.7 | = 4.2 LU |
| 2 heifers 12-18 months | × 0.5 | = 1 LU |
| 5 heifers 6-12 months | × 0.3 | = 1.5 LU |
| 1 bull | × 1 | = 1 LU |
| 2 oxen | × 1 | = 2 LU |
| | | + |
| total about | | 40 LU |

The DM which is available for the dry season:

| | | |
|---|---|---|
| grass | 150 (days) × 3 kg DM ×H 40 (LU) | = 18,000 kg DM |
| maize silage | 120 ($m^3$) × 180 (kg DM/$m^3$) | = 21,600 kg DM |
| hay | 1030 (bales) × 22 at 80% DM | = 18,128 kg DM |
| | | + |
| | | 57,728 kg DM |

available per day: 57,728 ÷ 150 = 385 kg DM
available per LUD: 385 ÷ 40 = about 9.5 kg DM

This is just about the right quantity.
So, the available feed will carry the stock through the dry season and, as far as feeding is concerned, there is no reason either to buy or to sell stock (or to sell or to buy roughage).

2

| | | |
|---|---|---|
| fully flowering Rhodes grass, 3 kg DM | = 1200 g TDN + 90 g dCP | |
| maize silage (milk stage) 21,600 ÷ (150 × 40) = about 3.5 kg DM | = 1900 g TDN + 160 g dCP | |
| hay (average) 18,128 ÷ (150 × 40) = 3 kg DM | = 900 g TDN + 165 g dCP | |
| | | + |
| | 4000 g TDN + 415 g dCP | |
| maintenance requirements | 3700 g TDN + 290 g dCP | |
| | | – |
| remaining for production | 300 g TDN + 125 g dCP | |

Conclusion ..........................................................................................

*Problem № 4*

On a dairy farm, the average stock during the dry seasonn will be:

| | | |
|---|---|---|
| 20 dairy cows | × 1 = | 20 LU |
| 4 in-calf heifers | × 0.7 = | 2.8 LU |
| 2 heifers 12-18 months | × 0.5 = | 1 LU |
| 1 heifer 6-12 months | × 0.3 = | 0,3 LU |
| 15 sheep | × 0.2 = | 3 LU |
| | | + |
| total about | | 27 LU |

The dry season is expected to last 120 days.
Available: maize silage 72 $m^3$ at 180 kg $DM/m^3$ and 600 bales of hay at 17 kg DM/bale.
The farm has the possibility to grow lucerne during the dry season and this will be fed fresh.
The hay will be fed at equal amounts throughout the dry season.
During part of the dry season, only hay + silage will be fed; for the other period only hay + fresh lucerne.

*Questions:*

1 How many kg hay/LUD should be fed?
2 In how many days will the hay + silage ration be finished?
3 How many kg fresh lucerne is needed per day for the other period?

*Answers:*

1 600 × 17 = 10,200 kg DM hay
per LUD 10,200 ÷ (120 × 27) = 3.1 kg DM which is about (1000 ÷ 850) × 3.1 = 4 kg product

2 In addition to this 6 kg DM/LUD silage must be fed. In total there is 72 × 180 = 12,960 kg DM silage.
Requirements per day 6 × 27 = 162 kg DM; therefore the hay + silage ration will last 12,690 ÷ 162 = about 80 days.

3 6 kg DM × 27 (LU) = about 160 kg DM of fresh lucerne is needed per day, for a period of 40 days. This is the equivalent of (1000 ÷ 200) × 160 = 800 kg product.

Note: as a matter of principle the best ration must be fed when the average cow has its highest production.

*Problem № 5*
Given a farm of 250 ha.
It is planned to:

- have dairy cows on 84 ha grass
- have 10 ha under irrigation, for the production of lucerne
- produce maize silage; 30 ha
- produce concentrate on the farm, namely 1000 kg DM/ha sunflower, 1500 kg DM/ha soyabeans and 3000 kg DM/ha maize grain

*Question:*
What will be the carrying capacity of this farm?

*Answer:*
Yearly DM yield:

| | |
|---|---|
| 84 ha grass at 4000 kg DM/ha | = 336,000 kg DM |
| 10 ha lucerne; 8 cuts at 3000 kg DM/ha | = 240,000 kg DM |
| 30 ha maize for silage at 10,000 kg DM/ha | = 300,000 kg DM |
| —— + | —————— + |
| 124 ha | 876,000 kg DM |

Carrying capacity $\frac{876}{10\ (\text{kg DM/LUD}) \times 365\ (\text{days})} = 240$ LU

The stock will be made up as follows:

| | | |
|---|---|---|
| 190 dairy cows | × 1.0 = | 190 LU |
| 50 heifers 1-2 year | × 0.5 = | 25 LU |
| 60 heifers 0-1 year | × 0.3 = | 18 LU |
| 2 bulls | × 1.0 = | 2 LU |
| 5 oxen | × 1.0 = | 5 LU |
| | | —————— + |
| | | 240 LU |

The aim is to produce 3500 kg milk per lactation per cow.
It is estimated that the roughage takes care of the maintenance requirements plus 1500 kg milk. Hence the concentrate must provide 2000 kg milk (per cow).

*Question:* How much land is required to produce the ingredients for the farm-made concentrate?

*Answer:*
2000 kg milk from concentrate means that 2000 ÷ 2 = 1000 kg concentrate must be available for 1 LU for one year.
In all 240 (LU) × 1000 (kg) = 240,000 kg concentrate.

| | | |
|---|---|---|
| (1/5th) sunflower seed | 124 – 130 = – 6 × 1 | = – 6 |
| (1/5th) soyabean seed | 290 – 130 = + 160 × 1 | = + 160 |
| (3/5th) maize grain | 80 – 130 = – 50 × 3 | = – 150 |
| | | —————— + |
| | | + 4 |

240,000 ÷ 5 = 48,000 kg

| | | |
|---|---|---|
| sunflower | 48,000 ÷ 1000 = | 48 ha |
| soyabeans | 48,000 ÷ 1500 = | 32 ha |
| maize | 144,000 ÷ 3000 = | 48 ha + |
| | | 128 ha |

*Problem № 6*
Given a dairy farm of 200 ha.
It has been decided to produce maize silage on the farm; this will cost 2000 M/ha.
The milk can be sold for M 0.60 per kg.
There are three possibilities as far as concentrate feed is concerned.:

Plan A
90 ha grass and 40 ha maize for silage. The farm makes its own concentrate:
produce soyabeans - yield 1500 kg DM/ha - cost M 1000/ha
produce maize grain - yield 3000 kg/ha - cost M 125/ha
buy wheat bran for M $^{20}/_{100}$ kg.

Plan B
110 ha grass and 45 ha maize silage
buy brewer's grain for M $^{200}/_{1000}$ kg
produce maize grain - yield 3000 kg DM/ha - cost M 1250/ha

Plan C
140 ha grass and 60 ha maize silage
buy concentrate (dairy meal) for M $^{40}/_{100}$ kg

*Question:* Which plan will lead to the highest financial return?

**Plan A**

| | |
|---|---|
| 90 ha grass at 4000 kg DM/ha | = 360,000 kg DM |
| 40 ha maize for silage at 10,000 kg DM/ha | = 400,000 kg DM + |
| | 760,000 kg DM |

Carrying capacity 760,000 ÷ (10 × 365) = 208LU

| | | |
|---|---|---|
| 170 dairy cows | × 1 = | 170 LU |
| 44 heifers 1-2 years | × 0.5 = | 22 LU |
| 50 heifers 0-1 year | × 0.3 = | 15 LU |
| 1 bull | × 1 = | 1 LU + |
| | | 208 LU |

The aim is to produce 3000 kg milk per lactation. It is estimated that the roughage takes care of the maintenance requirements plus 750 kg milk. The concentrate must then produce 2250 kg milk, which means 2250 ÷ 2 = 1125 kg concentrate/LU/year. In all 1125 × 208 = 234,000 kg concentrate.

| | |
|---|---|
| soyabean seed | 200 – 130 = + 160 × 1 |
| maize grain | 80 – 130 = – 50 × 2 |
| wheat bran | 90 – 130 = – 40 × 1.5 |

234,000 ÷ 4,5 = 52,000 kg

| | | |
|---|---|---|
| soyabeans | 52,000 (kg) ÷ 1500 (kg DM/ha) | = 35 ha |
| maize | 104,000 ÷ 3000 | = 35 ha |
| wheat bran | 52,000 × 1.5 | = 78,000 kg |

**milk yield minus feedcosts:**

| | | | |
|---|---|---|---|
| milk yield 170 × 3000 kg = 510,000 kg at M 0.60/kg | | | = M 306,000 |
| maize silage 40 (ha) | × M 2000 | = M 80,000 | |
| soyabeans 35 (ha) | × M 1000 | = M 35,000 | |
| maize grain 35 (ha) | × M 1250 | = M 42,750 | |
| wheat bran 78,000 (kg) | × M 20 per 100 kg | = M 15,600 | |
| | | + | |
| | | | = M 174,350 |
| | | | + |
| **Gross Margin** | | | M 131,650 |

**Plan B**

| | |
|---|---|
| 110 ha grass at 4000 kg DM/ha | = 440,000 kg DM |
| 45 ha maize silage at 10,000 kg DM/ha | = 450,000 kg DM |
| | + |
| | 890,000 kg DM |

Carrying capacity 890,000 ÷ (10 × 365) = 244 LU

| | | |
|---|---|---|
| 195 dairy cows | × 1 | = 195 LU |
| 50 heifers 1-2 years | × 0.5 | = 25 LU |
| 70 heifers 0-1 year | × 0.3 | = 21 LU |
| 3 bulls | × 1 | = 3 LU |
| | | + |
| | | 244 LU |

The aim is to produce 3000 kg milk per lactation. It is estimated that the roughage takes care of the maintenance requirements plus 750 kg milk. The concentrate will be made up of 3 kg brewer's grain plus 1 kg maize grain. One kg of the mixture will produce 1 kg milk in this case.
In all 2250 (kg milk) × 244 (LU) = 549,000 kg concentrate is required.
This means 549,000 ÷ 4 = 137,250 kg maize grain. 137,250 ÷ 3000 = 45 ha is needed to produce the maize.
Of the brewer's grain 549,000 – 137,250 = 412,000 kg is needed.

**milk yield minus feedcost**

| | | | |
|---|---|---|---|
| milk yield | 195 × 3000 kg = 585,000 kg at M 0.60 | | = M 351,000 |
| maize silage | 45 (ha) × M 2000 | = M 90,000 | |
| maize grain | 45 (ha) × M 1250 | = M 56,250 | |
| brewer's grain | 412,000 × M $^{200}/_{1000}$ kg | = M 82,400 | |
| | | + | |
| | | | = M 228,650 |
| | | | – |
| **Gross margin** | | | M 122,350 |

**Plan C**

| | |
|---|---|
| 140 ha grass at 4000 kg DM/ha | = 560,000 kg DM |
| 60 ha maize silage at 10,000 kg DM/ha | = 600,000 kg DM |
| | + |
| | 1,160,000 kg DM |

Carrying capacity 1,160,000 ÷ (10 × 365) = 318 LU

| | | | |
|---|---|---|---|
| 255 dairy cows | × 1 | = | 255 LU |
| 70 heifers 1-2 years | × 0.5 | = | 35 LU |
| 80 heifers 0-1 year | × 0.3 | = | 24 LU |
| 4 bulls | × 1 | = | 4 LU + |
| | | | 318 LU |

Again, the aim is to produce 3000 kg milk per lactation. The roughage will take care of the maintenance requirements plus 750 kg milk. The concentrate (dairy meal) will produce 2250 kg milk.
This means 2250 ÷ 2 = 1125 kg concentrate/LU/year.
In all 318(LU) × 1125(kg) = 357,750 kg dairy meal is required.

**Milk yield minus feed costs**

| | | | |
|---|---|---|---|
| milk yield | 255 × 3000 kg = 765,000 kg at M 0.60 | | = M 459,000 |
| maize silage | 60 (ha) × M 2000/ha | = M 120,000 | |
| dairy meal | 357,750 kg × M $^{40}/_{100}$ kg | = M 143,000 + | |
| | | | = M 263,000 − |
| **Gross Margin** | | | M 196,000 |

# 14 Fodder conservation

Under most climatic conditions there are periods in the year with very rapid growth of pasture and fodder crops and periods with little growth or no growth at all.
This may result in a surplus of roughage followed by a shortage. In principle a surplus has to be saved for the season with a shortage and thus **fodder conservation** comes into the picture.

Fodder conservation is a normal practice in temperate climates and is on the increase in Mediterranean countries.
In the tropics fodder conservation is rarely practised.

There are several ways to conserve crop products with a high water content. For roughages which are bulky and relatively cheap products, the only practical methods of conservation are

## 14.1 Hay making

The principle of hay making is that grass (DM 25%) is dried so much that it becomes hay (DM 80% or more). The best time to cut the grass for hay is when it **starts** to flower. This stage gives a good compromise between quality and quantity.

There are two simple methods of making hay from grasses.
**Making field hay** is the most simple method. After cutting, the grass should be turned over at least once a day. One can use a fork or machine. The hay should be cocked when rain is expected. The next day, under favourable weather conditions, the hay should be spread again. Hay is dry when it starts to rustle.

**Making rack hay** is more complicated. There are three types of racks, namely tripod, tetrapod and hut racks. Whichever rack is going to be used, the method is the same.
After cutting, the grass should be dried till the DM content is about 40% (1-3 days). Then the product can be put on the racks. The method is labour-intensive but weather risks are minimized. The time of keeping the product on the racks depends on the type of product and on weather conditions. In general, 3-6 weeks. Rack hay is superior in quality to field hay.

When making hay from **legumes**, after cutting there should be as little turning over as possible, because leaves of legumes break off easily (losses). A suggestion is to turn over the material during the evening or early morning on the second day, to promote even drying. Legumes can be put on racks soon after cutting.

**The hay can be stored** under a roof or in a hay stack. The stack must be made in such a way that the top is round; in that case rain does not penetrate into the hay.

**Unfavourable weather conditions** during hay making can cause heavy losses:
- heat development if hay is stacked when it is still wet;
- mould development when the weather is humid; the hay becomes less palatable and the nutritive value declines rapidly.

The advantages of hay making are:
1 that it is a very suitable method for small farms;
2 that every small amount of excess fodder can be turned into hay.

Some reasons why hay making is rarely practised in the tropics (and why hay making is in fact not such a good proposition for the tropics) are the following:

1 Tropical pasture species often have thick stems which dry much more slowly than the leaves. This results in uneven drying; leaves become too dry and stems not dry enough.
2 Good hay making weather in the (very) humid tropics usually occurs at the end of the rainy season. By this time the digestibility of the pasture is already low (low nitrogen and high fibre content). Generally speaking it is then hardly worthwhile to go into the trouble of hay making.
This points into the direction of silage making, early during the rainy season. However, in the not so wet tropics there are dry days early in the wet season proper for hay making.
3 Lack of proper equipment (for instance, for grass cutting; not to speak of baling).

## 14.2 Silage making

### The silage making process

Silage making is a method of conservation by which **bacteria** produce a certain amount of organic acids resulting in such a low pH that a stable situation is achieved and no further deterioration of the product occurs. It is also possible **to add all or a part of the acids** required (i.e. artificial silage making).

**Air exclusion** is a basic principle of silage making. When there is no air (no oxygen), the **respiration** in the plant cell stops and there is no more heat development.
On the contrary, air still present in - or entering into - the ensiled materials results in heavy losses of DM and nutritive value due to continuing respiration. Part of the carbohydrates (sugars) also gets lost due to respiration; these sugars are the main 'feed' for the (lactic acid) bacteria. Usually these carbohydrates are already in short supply and losses are most unwelcome here.

Respiration also means 'heat production'. The increased temperatures in the silage heap will favour the growth of undesirable micro organisms. High temperatures will also decrease the digestibility of the DM and particularly that of the proteins. Therefore heating-up must be avoided at all cost!

When there is no air in the heap, plant cells will die and collapse.
Cell content will thus become available for the micro organisms which are already present in forage.
Several types of bacteria will start **fermenting** the carbohydrates released by the plant cells.
Some of them produce mainly **lactic acid.**
These fermentation processes result in a decrease of the pH (the product becomes 'acid').
A **rapid** decrease of pH is desirable.

**Rapid** acidification is stimulated by:
- a high amount of available sugars (forage maize!)
- a relatively large number of lactic acid bacteria
- a temperature of between 20 and 30 degrees Celsius.

In an ideal situation a pH of about 4 is reached within a few days. The product is now **stable** (provided that airtightness is maintained): all microbiological activities cease; even the lactic acid bacteria are stopped by the acid they have produced themselves.

Unfavourable circumstances are:
- the presence of air (oxygen)
- a relatively low sugar content of the product; in this case bacteria other than lactic acid bacteria are favoured and this mainly results in the production of acids which are weaker than lactic acid bacteria
- a high protein content also slows down the acidification process (this is the case with legumes); a high sugar-protein ratio is very desirable in this respect (this is the case with forage maize).

If a low pH is not obtained in the silage within a few days, all kinds of undesirable processes will continue and lead to a more or less decomposed product without value as a feed.
So, the making of good-quality silage depends largely on the **rapid fermentation** of soluble carbohydrates (sugars) by anaerobic bacteria, to produce an acid (acetic acid in the case of grasses, lactic acid for maize and sorghum). When the acid concentration becomes high enough, all fermentation activities stop and the high acid level preserves the silage material.
Well-made silage can be kept for years without deterioration.

**Tropical grasses** generally have a low content of soluble carbohydrates. This means that fermentation takes place more slowly and when it stops, the pH is higher. This makes spoilage more likely as bacteria and enzymes may still be able to act and decompose the silage.
Another difficulty with tropical grasses is their bulky and low-density nature.
They are difficult to compress (compact); so the removal of the air 'entrapped' in this material is not easy to say the least, and in the tropics as elsewhere, air in the silage leads to certain failure.

Most tropical grasses have a relatively low feeding value and changes during ensiling may reduce feeding value even further. The question is then: is it worthwhile to go into the trouble and expense (!) of silage-making?

However, **the picture is different in the case of forage maize and sorghum.** These are quite ideal crops for silage making **everywhere,** particularly **forage maize.**

In general, to reduce the chance of spoilage, several procedures may be followed:

1. Chopping the plant material into small pieces.
   If the grass or legume is cut into short (2 cm or less) lengths, with the use of a forage harvester for example, better-quality silage results (better compaction, faster fermentation). Also with forage maize and sorghum, chopping is a must.
2. Wilting the material to 30-50% DM before ensiling.
   This improves the preservation of the silage.
   In good weather wilting needs to be carried out for a few hours only; if left too long in wet conditions the cut forage can become mouldy.
3. Adding molasses.
   This improves fermentation as more sugars are available for the bacteria.
   Molasses should be added as the silage material is being heaped in the pit, at about 6-8% of the fresh material. An even distribution of the molasses is very important.
   Adding molasses is especially important for long-cut, unwilted material and legumes in particular; but the practice is recommended for all grass silage.
4. Effective compacting and sealing of the silo.
   Silage material is added to a silo and progressively compacted. The silo should be filled as quickly as possible and once it is full, it should be covered in such a way that air is prevented from entering the heap.
   Plastic sheeting covered by earth or used rubber tyres is the best way of doing this.
   But if this is not available, banana leaves or other materials which will not contaminate the silage, may do (i.e. replace the plastic sheeting).
   Covering with earth alone will result in some spoilage of the top layer of the silage.

### Silos for small farms

A **silage pit** (or trench silo) is often suitable. The pit should be dug in a place where the groundwater level is not so high that water will collect in the bottom. Ideally the place chosen should be sloping a little to all sides so that water drains away quickly, but it may still be necessary to make surface drainage.

The pit should be made rather long and narrow, and not deeper than 1 metre. This makes it easier to compact the silage. Plant material should be added to the heap until, after compaction, the silage surface is above the surface of the surrounding ground. The silage can be used from about 8 weeks afterwards.

A better type of silo (often called a silage **clamp**) is made above the ground. A number of poles are laid on top of each other to form both sides of the silo and the silage is heaped in between and compacted in the usual way. There is less of a drainage problem with this type; silage is easier to compact and feed out, and the structure should last longer.
A simple heap may also be constructed at ground level without any supporting structure.

### Calculation of the size of a silo

The size of the silo required depends on the amount of silage the farmer has calculated he needs for his herd.
Every cubic metre of silage in small silos can be expected to contain about 150 kg DM.
If a farmer wants to feed 5 kg Dm silage per day to 10 cows for 200 days, he needs 5 × 10 × 200= 10,000 kg DM silage. It follows that he needs a silo with a capacity of at least 10,000)150 ≈ 67 cubic metres.
If he then makes a silo of dimensions 25 m long, 3 m wide and 1 m deep, i.e. 75 cubic metres, and fills it, he will have 75 × 150 = 11.25 tonnes DM. This will allow for a loss of 1.25 tonnes due to spoilage, transport and feeding-out.

## 14.3 Comparison of hay and silage

Good-quality hay can have TDN and dCP values not much lower than the green grass from which it was made. However, this requires **rapid drying** of the hay, on a rack or tripod, and proper storage.
Hay which is dried on the ground for several days, especially if rain falls on it, suffers a big drop in digestibility.
Cows' intake of such hay is then much less than the grass it was made from.

The best time to make hay is at early-flowering stage, because then the nutrient content of the grass is still relatively high, and the yield of hay will be close to maximum.

Often, however, hay is made at the late-flowering stage to reduce the chance of rain damage. Such hay is then of poor quality and again the cows' intake is reduced.

Like hay, **good-quality silage** is almost as high in feeding value as the fresh grass. Often grass silage is of a better quality than that because it is made at an earlier stage of growth. This is easier because once cut, grass needs only to be wilted for a few hours before ensiling. Silage making can be carried out before the rains have ended.

If silage is made before flowering when quality is high, dry matter yields will be lower. To get the same yield as for hay, two cuts of silage may have to be made.

Poor-quality grass silage is often made from grass at later growth stages when fibre content is high. To put it bluntly : rubbish in = rubbish out. Poor methods of ensiling also result in lower quality. Cows' intake of such silage is lower.

In most cases tropical grass hay and silage provide no more than a **maintenance ration** for dairy cows.

Great care is needed to make good-quality hay and silage and to reduce losses of plant material in cutting, transport, storage and feeding-out.

## 14.4 Further reading

**A relatively recent FAO publication, namely FAO Plant Production and Protection Paper # 161 contains a wealth of information on silage making in the tropics, with particular emphasis on smallholders (published in the year 2000).**

Some quotations from the above source:
(1)
Any method of ensiling, if it is to be suitable for smallholders in the tropics, it must:
- have low investment costs
- be reliable and repeatable
- use uncomplicated technology
- use locally sourced equipment and consumables
- be safe and
- give rapid and significant returns on investments

(2)
Fodder with low sugar content is more likely to rot than ferment, and this has led to a bad reputation for silage in the tropics.
Problem fodders include mature C4 pasture grasses harvested in the rains, legumes in general and possibly tree fodders.
Wet grass must be partially dried before ensiling, under shelter if it is still raining, and legumes should also be wilted.
(3)
Making 'little bag silage' is an interesting proposition, for farmers with one or two dairy cows. It allows conservation of available fodder in small quantities over a long period of time. Suitable plastic bags must be readily available. Airtightness is crucial. Mice and rats may cause big problems if they like the
product which is inside the bags.
(4)
The silage production process can be divided into four stages: (1) forage harvesting; (2) transport to the silo; (3) compaction and (4) sealing = airtightness.
The first management decision to take when planning to make silage is on the amount of silage required, which depends on the following factors:
- number and type of livestock to receive silage;
- length of the feeding period;
- percentage silage in the full ration;
- material resources available (equipment,labour,finances,technical assistance, a.o.)

This is illustrated by the following example:

An adult cow, consuming 50% of the ration of 10 kg DM per day as silage would receive 5 kg of silage DM. For a feeding period of 180 days, 900 kg of silage DM/cow would be reuired, equivalent to 3.6 t of fresh forage containing 25% DM. Assuming 15% silage loss, a total of 4.14 t/head of forage DM to be ensiled is required. This is equivalent to 2.3 $m^3$ of silage capacity per animal.

Irrespective of the amount of silage to be made, the following principles for good silage apply:
- the material to be conserved must have a high nutritive value
- the forage must not be contaminated with soil
- the forage should be chopped into pieces no longer tahn 2 cm to facilitate good compaction and reduce air retention
- it is necessary to expel the maximum amount of air within the forage before closing the silo preventing air and water penetration
- the accumulation of the forage and sealing should be done in the shortest possible time

- during the feeding of the silage, the area exposed to air should be as small as possible and the time between opening and finishing the silo as short as possible

(5)
Silo type. There are many different types of silo: permanent or temporary and structures that may be vertical or horizontal. Further, all kinds of receptacles can be used as well; including barrels made of metal or plastic, concrete water pipes and thick plastic packing bags such as those used for fertilizers.
(6)
Anything that has feeding value can be ensiled. What actually is ensiled depends on availability and quality, but only good quality material should be ensiled, to ensure that costs will be reimbursed. Materials mentioned in the ensiling literature include grasses, legumes (both herbaceous and edible material of woody species), fodder crops, crop residues, oil palm fronds (Malaysia!), tomato pomace and citrus pulp, and (not to forget) poultry litter.
Although a large range of additives is available, there is little evidence of their use on small farms in the tropics. If anything, molasses is used with materials having low sugar levels.

**The editor of the above FAO publication concludes:**
Silage making is generally known by scientists in the tropics, but actual small-scale silage making activity is low, except in Malaysia and China. The main reasons for non-adoption of silage technology are:

- lack of know-how, also by extension workers
- lack of finance
- silage making is considered cumbersome and labour intensive; benefits are not commensurate with effort and time
- cows have a low genetic potential for production
- lack of available feedstuffs of good quality

# 15 Irrigated pasture and fodder crops in central africa

**Central Africa is climatically characterized by a hot rainy season and a relatively cool dry season turning hot toward the end.**

In this region a commercial dairy farmer who has sufficient area of **irrigated land** is in a very good position to obtain consistently high milk yields year-round, as he can always produce high-quality forage. However, **irrigation is expensive** and the farmer should try to obtain the highest profitable profit per hectare from his irrigated land.
Grasses such as Star grass and Rhodes grass can be irrigated, but growth is not good in the cold season. Better cold-season growth can be obtained from temperate climate grasses such as rye grass or forage oats.
Rye grass is recommended for irrigation together with lucerne which gives better growth during the hot season.
Leucaena and Napier grass may also be irrigated with good results.

## 15.1 Lucerne (alfalfa)

Lucerne is the best fodder crop to grow under irrigation, on a dairy farm where high yields of protein DM/ha are required.

A well-established crop of lucerne (with a dense plant population) should give yields at early flowering of at least 2 tonnes DM per hectare per cut, with a dCP content of 18% on average.
Lucerne is also high in minerals (except phosphorus) and vitamins. It is, however, relatively **low in energy** and should be fed as supplement to a high-energy feed such as maize silage.

Lucerne will not survive in standing water (periods of heavy rainfall; improper irrigation) and should therefore be grown in well-drained soils properly irrigated, with a pH higher than 5. Soil preparation should result in a fine tilth, with the seed sown at 15-25 kg/ha, no more than 2 cm deep and rolled afterwards if possible.
The seeds should first be inoculated with specific lucerne Rhizobium and either drilled or broadcast. If drilled, rows should not be more than 30 cm apart.

NPK fertilizer should be applied before sowing, at around 800 kg/ha, with an annual topdressing of around 300 kg.
Lucerne has a high boron requirement and this should be met with the application of a special boron fertilizer where necessary.

Weed control can be a problem with lucerne. Ideally it should be sown into land which has not been cropped previously. If not, herbicides may be the best way of controlling certain weeds.

### Management

During the rains lucerne should not be cut more often than every 8 weeks, otherwise vigour during the dry season may be less.
After the rains the lucerne may be cut every 4-6 weeks, depending on the time taken to reach flowering. Flowering takes place more quickly in the hot months.
Well-managed lucerne should persist for 3-4 years before replanting becomes necessary.

Lucerne needs a regular supply of water for good results, even though it has a deep root system.

### Utilization

Lucerne is best fed as 'green chop'.

It can be cut with a scythe, sickle or forage harvester and fed direct to cows. There is a risk of bloat (tympany) if large quantities are eaten in a short period of time; in this case cows should not be watered for two hours after feeding. Normally, cows fed on small quantities of lucerne together with other roughages will not be affected by bloat.

## 15.2 Leucaena

Leucaena is a leguminous shrub or small tree that produces a high-protein fodder (15-20% dCP) in the leaves, including thin stems).
The vitamin A content is higher than that of lucerne.

Leucaena is very deep-rooting and drought-resistant. It will retain green leaves throughout the year.
Rapid growth occurs during the rains and early dry season, with slower growth during the cold season.
Rapid growth will also take place during the hot dry season if irrigation is available or if there is enough soil moisture in the root zone.

### Establishment

Leucaena is best grown as a pure stand for cutting or grazing.
A seedbed should be prepared which is as free from weeds as possible. The seed is easily harvested from mature plants.
Before sowing, the seed should be scarified in 80 °C water for 2 minutes and then inoculated.

The seed should be sown at a depth of 2 cm as soon as the rains have become established. Spacing of plants for hand-cutting should be 1 metre between rows and 15-30 cm within the row.
Seeds can be sown at a spacing of 2-3 cm in the row and plants thinned later if required. For grazing, rows should be 2 m apart.
The area of Leucaena should be divided so that areas of Leucaena, once grazed, can be allowed to regrow while the cows move to another area.
Before planting, 400 kg/ha single superphosphate fertilizer should be applied. 200 kg/ha NPK or single super should be applied every year afterwards.

It is very important **to control weeds among the young Leucaena plants,** as Leucaena plants grow very slowly for the first 3 months or so. Herbicides can be very effective, otherwise regular mechanical cultivation is needed.
Sometimes termites may need to be controlled.

### Management

When Leucaena first flowers the stem can be cut to a height of 30 cm. After that, the regrowth can be cut when the branches reach 1 m in length.
Branches can be fed green immediately after cutting or stacked and allowed to dry for 3-4 days.
Dried leaves can be easily stripped off branches and stored in bags for later use. The dried leaves can provide the protein part of a concentrate ration as the dCP content is about 20%.

Leucaena contains **a toxic substance** called **mimosine** and not more than 2 kg DM should be fed to cattle per day. There is usually no problem with poisoning if cows are fed by hand or graze Leucaena for a short period every day. It should be fed to dairy cows at, or shortly after, milking otherwise milk taint may occur.

Leucaena can give good DM yields. In a two-months' regrowth period during the rain, yields of 2-4 tonnes DM/ha can be obtained from a closely-spaced, well established crop.
With irrigation, double that yield over the whole year can be expected.

## 15.3 Maize and sorghum

Maize is an excellent crop for ensiling. This is because:

1 High yields per hectare can be obtained (18-30 tonnes fresh material or 6-10 tonnes DM/ha are quite normal).
2 The technology of growing maize is well-known.
3 The energy content of maize silage is high (TDN 60-65%) although the protein content is rather low (around 4% dCP).
4 A good quality product with little chance of spoilage can easily be obtained, due to the high sugar content of the maize plants (see previous chapter).

The disadvantages of maize silage are:

1 Drought can severely reduce yields. In drought-prone areas short-season maize varieties or sorghum can be grown; however, sorghum has a lower energy content then maize (TDN around 55%).
2 Maize is usually regarded as human food and therefore it may not be acceptable to some people to feed it to cattle.

Maize for silage is grown in the normal way.
When the maize grain has reached the ‘dough’ stage, a forage harvester cuts and chops the maize plant into small pieces (not bigger than 2 cm) for ensiling. Harvesting at the dough stage gives the highest yield of DM energy per hectare.
The DM content of maize when ensiled should be at least 30%. This gives the best quality lactic acid-type silage which is most palatable to cattle (see previous chapter).

It is very difficult for small-scale farmers to make good maize silage as there is no suitable equipment available which is capable of chopping the maize plant into small enough pieces.
Proper compaction of the silage is also very difficult without a tractor.
Maize silage should be well-compacted for best results. Molasses is not required.
The silage is ready for feeding-out after about 8 weeks.

## 15.4 Napier grass (Elephant grass)

Napier grass is a tall, deep-rooted grass which looks like sugar cane.
It is very high-yielding and does well under irrigation.
It is generally cut for silage or green-fed, but can be grazed as well.
It is drought-resistant and moderately frost-resistant.

### Establishment

Napier grass is established vegetatively from young stem material or root splits.
Stem cuttings should contain 3-4 nodes and be placed at an angle in the ground so that at least 2 nodes are buried (i.e. cuttings are placed ‘the right way up’). Cuttings should be planted in rows 1 metre apart and ½ m in the row.
In lower rainfall areas, or where legumes are planted between the rows, a spacing of 1.5-2.0 m between rows should be used.

Before planting, the soil should be ploughed and harrowed, or planting holes may be dug into burnt or heavily-grazed pasture.
Planting is best done in the early wet season.

500 kg/ha NPK fertilizer disked into the soil is needed for good growth from establishment, with an annual maintenance dressing of 200-300 kg NPK and 100 kg urea/ha after each harvest.

**Management**
Napier grass should be cut down to a height of 20 cm when it has reached 60-100 cm height.
During the rains this should take about 4 weeks.
The feeding value of the material cut at this stage is relatively high (about 60% TDN, 7-10% dCP).
Dry season growth is improved by allowing Napier grass to flower before the last wet-season cut.

Napier grass maintains its feeding value longer than most grasses; even 7 months' regrowth has a TDN of around 50% and a dCP of around 2%.

Napier grass makes good-quality silage without the addition of molasses if young stem and leaf is chopped into short lengths (2 cm) and wilted before ensiling.

Napier grass usually needs replanting after 3-4 years.

**Note:**
In the 'high agricultural potential' areas in Kenya smallholder zero-grazing milk production systems are common. Napier grass is among the major feed resources and the average milk yield is 5-7 kg on Napier (late nineties). This milk yield is below the potential ('genetic') milk yield which is about 10 kg.
The available concentrates are too expensive for smallholder farmers. Fodder trees and legumes are not often used because of poor establishment and persistency.
Instead of the above supplements, many farmers are feeding home-made concentrates using poultry litter as a cheap source of protein.
See the chapter on waste management in our guide '**Lecture notes on chicken farming in warm climate zones**'.

# 16 Fodder crops in north africa

North Africa is climatically characterized by **mild winters** with rainy days (the further away from the coast, the less rain) and **hot, dry summers** with occasional showers.

The information about fodder crops has been collected from texts prepared by the Sidi Thabet Dairy Training Centre in Tunisia, and is probably valid for much of North Africa as well as for parts of the Middle East.

The Tunisian texts underline the importance of harvesting fodder **without (flowering) weeds** which unfortunately often make up 20-30% of the crop. Dairy cows need fodder of high quality; therefore weeds must be strictly controlled, either mechanically or by means of herbicides.

All crops mentioned below need a rainfall higher than 400 mm/year. In areas with a rainfall between 300 and 400 mm, the cultivation of barley (vetch) is recommended. However, dairy farming is risky under these conditions.

Below 300 mm, dairy farming without irrigation is not possible. In almost all cases the crops should be fertilized (phosphate, nitrogen).

**Rye grass** (Lolium perenne)
- relatively highly nutritive grass compared with other grasses; as far as DM production is concerned rye grass can even compete with oats and barleys
- together with berseem (seed rate 15 kg berseem and 30 kg rye grass) it provides excellent fodder for dairy cows
- rainfall higher than 500 mm, but it can be cultivated anywhere when irrigated
- seed rate 20-40 kg/ha; sowing date end September/beginning October when rainfed; somewhat earlier when irrigated
- height 15 cm when used for grazing; 25 cm when cut (green fodder, silage, hay)

**Berseem** (Trifolium alexandrinum)
- together with rye grass, berseem is excellent fodder for dairy cows; also with barley (seed rate 20 kg barley and 30 kg berseem) which protects the berseem in harsh winters
- rainfall higher than 500 mm; anywhere when irrigated
- seed rate 25-40 kg/ha; sowing date as rye grass
- height between 20-40 cm when cut

**Horse beans** (Vicia faba var.equina)
- rainfall higher than 450 mm
- seed rate 100-150 kg/ha, distance between the rows 40 cm
- harvesting for silage in the milky stage

**Sulla** (Hedysarum coronaria)
- rainfall higher than 400 mm
- a watery plant, hence not suitable for silage
- seed rate 40-50 kg/ha, grains 15-20 kg; inoculation desirable, sowing date from mid September to end October
- 1st year grazing from 20 cm height or cutting from 40 cm; 2nd year cutting or grazing from January to April followed by seed collection

**Alfalfa-Lucerne** (Medicago sativa)
- irrigated

- seed rate 25-30 kg/ha; sowing date second half of September or in March
- normally used as green fodder, height 25-30 cm; may be conserved in the form of hay but one must be particularly aware of the possible loss of leaves!
- it is not so easy to master the right cutting stage; therefore avoid large surfaces

**Sorghum** as fodder crop
- irrigated
- seed rate 25-50 kg/ha, distance between the rows 30-40 cm; sowing date March-April
- cutting at a height of 45 cm, for green fodder, silage or hay; a large surface is difficult to master for green fodder

**Meadow fescue** (Festuca)
- a plant typically suitable for low-lying areas because it tolerates inundation; it can last for many years if correctly maintained
- seed rate 15-20 kg/ha; sowing date between mid September and end October
- for grazing from 10-15 cm height and for cutting (hay or silage) to 20-30 cm

# 17 List of important tropical grasses and legumes

*Table 28: Grasses (indicative only)*

| Botanical name | Common name | Remarks |
|---|---|---|
| Pennisetum purpureum | Elephant grass<br>Napier grass<br>Merker grass | tall, perennial grass; very productive, originally from Africa |
| Pennisetum clandestinum | Kikuyu grass | valuable grass at high altitudes |
| Cynodon dactylon | Bermuda grass<br>Common Star grass | found all over the tropics; persistent under grazing |
| Cynodon plectostachyum | Naivasha Star grass<br>Giant Star grass | Africa |
| Chloris gayana | Rhodes grass | relatively nutritious; suitable for hay-making |
| Hyparrhenia rufa | Jaragua grass | drought-resistant |
| Digitaria decumbens | Pangola grass | for lowland with high rainfall; relatively nutritious |
| Brachiaria decumbens | Sheep grass | strong grass; persistent under grazing |
| Brachiaria mutica | Para grass | suitable under wet soil conditions |
| Brachiaria brizantha | Signal grass | good-yielding, palatable, moderately nutritive |
| Trypsacum laxum | Guatemala grass | suitable for poor soils |
| Melinis minutiflora | Molasses grass | suitable for light soils |
| Panicum maximum | Guinea grass | coarser than Pennisetum |
| Setaria sp. | Setaria | poor growth during dry season; high oxalic acid content |
| Axonopus compressus | Carpet grass | valuable in South and Central America |
| Stenotaphrum secundatum | St.Augustin grass | important in the Caribbean |
| Cenchrus ciliaris | Buffel grass | semi drought-resistant |
| Andropogon gayanus | Gamba grass | valuable under semi-arid conditions |
| Themada triandra | Red oat grass | valuable in ranching (Africa) |
| Sorghum sudanense | Sudan grass | sometimes cross-bred with Elephant grass |

*Table 29: Legumes (indicative only)*

| Botanical name | Common name | Remarks |
|---|---|---|
| Trifolium alexandrinum | Berseem<br>Egyptian clover | very important winter crop in the Mediterranean (fodder) |
| Medicago sativa | Alfalfa<br>Lucerne | very important perennial fodder crop in climates without a cold spell; often irrigated |
| Trifolium resupinatum | Persian clover | of importance in the Middle East |
| Vigna | Cowpea | all over the tropics |
| Pueraria phaseoloides or<br>Desmodium sp. | Tropical kudzu<br>Tick clover | in the humid tropics; often combined with citrus coconuts |
| Stylosanthes gracillis | Stylo | promising legume with some drought-resistance |
| Stylosanthes humilis | Townsville clover | an annual, particularly successful in Queensland |
| Cyamopsis psoralioides | Guar | of importance in India and Pakistan |
| Cayanus cajan | Pigeon pea | sometimes used as cattle feed |
| Dolichos lablab | Hyacinth bean | fodder crop in the Sudan |
| Stizolobium sp. | Velvet bean | fodder in rotational crop production |
| Arachis hypogaea | Groundnut, peanut | hay used as fodder for cattle |
| Glycine sp. | Soya bean | hay used as fodder for cattle |
| Centrosema sp. | Centro | cover crop, sometimes used as fodder |
| Phaseolus sp. | Siratro | sometimes sucessfully used in pasture improvement |
| Leucaena sp. | Leucaena | leaves and thin stems have high protein content |

# Appendices

# Appendix I: Some general notes on dairy farm management and planning

Dairy farm management is about how to run the farm:
- day-to-day organisation of labour and machinery
- husbandry
- supplies and marketing
- financial matters; recording and accounting
- income calculations; planning for the future

### Steps in decision-making

In farm management six steps can be distinguished in the decision-making process:
- a problem is recognized and makes people think
- observations are made and facts collected; advice is sought
- observations are analyzed and possible solutions tested
- the decision is made and implemented
- continuity is assured

*For example*

A dairy farm manager becomes aware of the fact that fertility and milk production in his herd are poor.
He sees that the cows eat tree leaves, bushes, paper, fence posts and possibly other things, and realizes that this suggests mineral deficiency in the feeding.
Now the farm manager starts collecting facts about mineral requirements of dairy cows and how they are met in the area. He visits dairy farmers who purposely supply minerals to their cows and asks how they do this (type of minerals, amounts, how they are administered) and what results may be expected.

After a try-out has been made and milk yield, number of cows coming on heat and number of successful services have gone up and turn out to be economically profitable, the decision is made to administer minerals. Concrete action is now required. For instance, seeking the owner's permission, instructing the farm personnel, finding funds for the installation of mineral boxes or the like and the purchase of the minerals. Finally, the daily routine of ad lib access to minerals requires checking and supervision: there should always be minerals in stock and in the boxes for the cows.

### The human factor in dairy farming

Quite often there are large differences in farm income between dairy farms, even in situations where material inputs are the same. It is true that **the human factor is very important in dairy farming.**
Certain things in dairy farming very much depend on human action and care. It is very important to have dedicated and knowledgeable farm labour and staff, in the case of commercial dairy farms.
Whether or not the work is done properly and timely very much affects:
- milking
- feeding (quality, water supply, walking distances)
- disease incidence (mastitis, ticks, vaccination, deworming)
- fodder conservation and pasture fertilization (timing and speed, hay-and silage making, nitrogen gifts)
- reproductive performance (heat observation, timing of service, single or double services)
- calf rearing

### Risks in dairy farming

In feasibility studies the predicted price levels, production per cow, calving rate, calving interval and mortality greatly affect the economic performance. Often optimistic performances are projected but

seldom obtained. One reason may be that average weather conditions are assumed to be more favourable than the actual weather from year to year appears to be, resulting in outcomes that are considerably lower than planned.
Disease incidence, lack of training, experience and dedication and possibly other drawbacks, often lead to lower productions than projected.

**Risks** in dairy farming are of great importance.

Subsistence farmers may not be interested in improvements because of their fear to loose their property in case they have to sell their farm when they do not meet their loan repayments.

Technical improvements like mineral feeding, nitrogen fertilization, a.s.o. may be difficult to implement due to lack of cash for such inputs.

Expansion of the dairy cattle herd to make investments worthwhile, may create liquidity problems.
It may become impossible to pay recurrent costs and even to repay a loan on time.
Especially large improvements such as high-quality cows, mechanisation, fodder conservation, expensive buildings and farm structures **imply big risks** (diseases, breakdowns, lack of spare parts, lack of knowledge and experience). Such risks should be considered beforehand, to avoid great losses of funds.

Reading the following section (pages 109-111) will enhance the sense of precaution which is necessary in this matter of going into dairy farming or enlarging present dairy farming enterprises.

### Some examples of dairy farming planning

*1 Profitability of herd expansion*
A dairy farmer considers the profitability of expanding his herd from 10 to 12 milking cows (including young stock).
The existing farm outfit (buildings, labour, equipment) enables him to do so (no other changes required). He can raise his feed production by applying an extra 500 kg of nitrogen fertilizer without further effect on other costs.

The following calculation can be made in this case:

**Revenues per cow**

| | | | |
|---|---|---|---|
| Milk 2500 kg (at M 0.80 per kg) | M 2,000 | | |
| cattle credits (young stock) | 500 | | |
| | ——— + | | |
| Total Gross Revenues | | | M 2,500 |

**Variable costs per cow**

| | | | |
|---|---|---|---|
| a Feed | | | |
| concentrate 600 kg (at M 0.70 per kg) | M 420 | | |
| milk for calves 300 kg (at M 0.80 per kg) | 240 | | |
| other feed | 40 | | |
| | ——— + | | |
| | | 700 | |
| b Other variable costs | | | |
| interest cows M 3000 (10%) | 300 | | |
| A.I., minerals, vaccines, vet.costs | 200 | | |

| | | | |
|---|---|---|---|
| | ——— + | | |
| | | 500 | |
| | | ——— + | |
| Total Gross Variable Costs | | | M 1,200 |
| | | | ——— – |
| Gross Margin per Cow (for expansion) | | | M 1,300 |
| Increase of Gross Margin for 2 cows + young stock | | | 2,600 |
| Extra costs of nitrogen 500 kg (at M 1.80 per kg) | | | 900 |
| | | | ——— – |
| **Net Benefit of Plan** | | | **M 1,700** |

*2 Another simple planning situation*
A dairy farmer has a herd of 22 cows, 4 in-calf heifers, 6 heifers, 7 heifer calves, 7 bull calves, 9 steers and one bull.
He considers keeping more cows and has been advised to do away all his bull calves after birth (no value), in order to make room for extra dairy cows by not keeping bull calves and steers. Let us assume that he can keep one extra cow for every three steers.

The present 9 steers and 7 bull calves will be sold at M 7,100 (this is the value of the steers; the bull calves have no value).
The farmer will use the money to buy 3 cows at M 3,000 each.

| | | |
|---|---|---|
| **Investment** | | |
| Purchase cows minus sale of steers | M 1,900 | |
| **Costs** | | |
| interest of cattle purchase (10%) | 190 | |
| feed costs at 500 kg concentrate per cow (at M 0.60 per kg) | 900 | |
| veterinary costs, A.I., etc. (M 100 per cow) | 300 | |
| lost annual sale of steers (4 at M 850) | 3,400 | |
| | ——— + | |
| | | M 4,790 |
| **Revenues** | | |
| 3 cows, 2500 litres milk per cow, at M 0.70 per kg | 5,250 | |
| sale of bull calves at birth | - | |
| sale of 1 extra culled cow | 1,500 | |
| saving on rearing costs of bull cales, per year<br>(300 kg milk and 200 kg concentrate per calf) | 2,310 | |
| | ——— + | |
| | | M 9,060 |

**Increased Farm Income** (M 9,060 – 4,790) per year = M 4,270

The text of this appendix has been derived from lecture notes used in the IAC International Course on Dairy Cattle Husbandry, Wageningen, NL.

# Appendix II: Optimizing and modernizing extensive cattle farming

Two veterinarians trained in Western Europe, namely Katrien van 't Hooft and Vivienne Lewis have worked in Nicaragua for some years. In the following they describe how in their opinion cattle farming in Nicaragua could be improved and how this should be approached.
Their text reads as follows:

Many people see the use of purebred dairy cows, artificial insemination and, most of all, producing irrigated fodder crops for feeding in the dry season as intrinsic to modern dairy farming. In the following we adhere to these principles, but also recognize that in many situations extensive cattle farming may be the most common practice.

**How can extensive cattle farming be characterized?**
In extensive cattle farming the cattle graze all the year round on low quality pastures, are hand-milked with the calves allowed to suckle before and after milking. The bulls usually run permanently with the female cattle. Production is low due to severe feeding constraints in the dry season, combined with the adverse effects of infectious and parasitic diseases.
The cattle are mainly dual-purpose, producing milk and beef, as well as herd replacements and draft animals. Usually tropical cattle breeds are utilised, as they survive long periods of food shortages better than non-tropical breeds, and have a greater resistance to common diseases. Often tropical breeds are crossbred with european dairy cattle breeds, giving good results as long as the resultant cattle do not have too much pure dairy blood.

Extensive cattle rearing is often seen as synonymous with 'backwardness' and underdevelopment, because of the perceived low productivity of the cattle. However, for many farmers in tropical regions it is often more important to produce milk and meat at minimal costs rather than concentrating on the total amount produced. Thus, extensive cattle rearing is often the most economic way to keep cattle.

**More intensive dairy farming**
In areas near towns and cities the situation is different for dairy farmers. Milk prices may be higher whilst transport costs are reduced. This should give the producer the incentive to improve milk yields per cow, changing from an extensive to a more intensive dairy farming enterprise.

**Technical strategy to optimize or intensify extensive cattle rearing**
The following strategy can be applied to all levels of cattle management, adapting it to the specific reality of each farm. It is based on improving essential cattle management factors that are possible and economically feasible for the farmers involved. It is derived from the present-day cattle management systems used by farmers in Nicaragua, Central America, and should be adapted to local circumstances when used in other countries.
The strategy recommends step-wise modifications and is divided into three phases:
- Phase 1 - Basic phase for all cattle farmers
- Phase 2 - Extra attention given to cattle feeding
- Phase 3 - Phase of long-term, larger investments

Farmers who rear their cattle in extensive systems will be able to optimise their enterprises by applying phase 1. They may also be able to apply parts of phase 2 depending on their circumstances. Farmers who intend to intensify extensive cattle enterprises, will need to apply all 3 phases.

Improving cattle management and productivity is a long-term process, which requires not only extensive technical knowledge and experience but also organizational and problem-solving skills.

*Phase 1: Basic phase for all cattle farmers*

The purpose of this first phase is by using very low-cost interventions, cattle mortality can be reduced and production can be slightly increased, encouraging greater farmer-interest. This is achieved by **guaranteeing 8 minimum requirements,** as well as some basic management and organizational factors. Cattle improvement will be noticed within a few months, especially decreased mortality and better physical condition, motivating the farmer to carry on with his/her endeavour.

The small investment necessary to provide this basic phase can be obtained by selling one or two poor quality animals.

**A.** The **8 minimum requirements** for extensive cattle rearing are as follows; the relative importance of each requirement depends on the individual characteristics of each farm, the type of cattle and production goals of the farmer:

1 Sufficient clean drinking water (twice a day at least).
2 Strategic supplementary feeding during the last 3 months of the dry season for cows-in-milk, small and recently weaned calves and sick or weak animals. This feeding aimed as survival, can be based on traditional feeds like cattle sorghum, or on crop residues, hay and other cheap and easy to obtain products such as fruits and seeds of mainly leguminous trees.
3 Give sufficient common salt.
4 Adequate grassland management; rotational use of fields and the prevention of overgrazing and weed infestation.
5 Vaccinate twice a year against Anthrax and Blackleg.
6 Worming of young cattle, plus preventive measures to reduce high worm burdens.
7 Regular bathing (ticks).
8 Good general care of all stock, especially cows at calving time, new-born calves and weak or sick animals.

**B.** **Essential cattle management factors** (e.g. for co-operative farms):

1 Castrate all male cattle over 1 year old that run with the female cattle, with the exception of the bulls used for reproduction.
2 Sell/exchange bulls used for reproduction that have been working on the farm for 4 years or more.
3 Separate young heifers from the bulls (if possible).
4 Sell animals in case of overgrazing.
5 Revise and possibly reduce the time the milking cows stay in the corral with their calves after milking.
6 Improve hygiene and milking techniques.
7 Start a small veterinary kit, including the most essential medicines in case of an emergency.
8 Enumerate all female animals, preferably indicating year of birth.
9 Start keeping records: costs and income from cattle enterprises, recording of births, deaths, sales and bought-in animals, and total number by category.

*Phase 2: Extra attention given to cattle feeding*

Maintain the standards that have been set during phase 1. This may not be so easy as it seems and requires continual analysis and evaluation!

Some of the increased farm income due to decreased mortality and increased production can now be invested in improving supplementary feed for the dry season. This could include:

- The construction of simple feed troughs.
- Supplying minerals salts or bone meal in combination with common salt (kitchen salt).
- Supplementary feeding during 5 months of the dry season instead of 3 months.
- Sowing legumes.
- Growing forage crops e.g. sugar cane or elephant grass.
- Buying and installing a simple chopping machine.
- Adding molasses or urea to the forage.
- Preparing (mixing) home-made concentrates.

- Making silage

Which of these interventions to introduce and how to introduce them, depends on local conditions and circumstances, the preferences of the farmer and the prices of meat, milk and other dairy products as well as input prices.
Other important points at this stage are:

Genetic improvement of the cattle; e.g. the acquisition of a superior quality bull, or better selection of female cattle, which is now possible due to the lower mortality rates.
Further grassland improvements; this may take several years.
Control of vampire bats.
Brucellosis control.
Extend record keeping.

*Phase 3: Phase of long-term, larger investments*
Depending on the cattle enterprise, the goals and interest of the farmer and the current government agricultural policy (input/output prices, subsidies, markets, etc.), it may be rational to make some larger investments that give long-term results. However, it must be stressed that making large-scale investments without routinely maintaining the improvements realized in phases 1 and 2, will **not** increase cattle production or profitability.

Long-term investments that could be considered are:
1 More field divisions, to facilitate improved grassland and cattle management.
2 Construct water tanks and reservoirs in farms where water supply is a problem in the dry season.
3 Buy-in more cattle in cases of low stocking rates and general under-productivity.
Ensuring appropriate stocking rates should be part of the grassland improvement programme.
4 Further selection and genetic improvement, by establishing a rational breeding programme. However, it is not recommended to breed cattle with more than 75% of pure dairy blood.
5 Supplementary feeding of the in-calf cows and heifers during the dry season. These animals do not usually receive any extra feeding but as part of a more intensive cattle management programme it should be possible to offer supplementary feeding to all cattle on the farm.

However, many farmers practising small-scale extensive cattle farming, will not find it profitable to make these large-scale investments.

End of article written by
Katrien van ‘t Hooft and Vivienne Lewis.

# Appendix III: The economics in traditional livestock keeping

**Editor:** In our series of educational materials on agriculture and animal production in warm climate zones, we have the titles ‘the farm as commercial enterprise’ and ‘farm accounting’. Both titles are about ‘commercial farming’ of a certain size, with proper account keeping and operating in a free market economy. The contents are hardly applicable to ‘nomadic’ livestock farming, with cattle, sheep and goats all producing milk for family consumption; or to zero-grazing with one or two dairy cows producing for the local town community.

The following is an analysis of the economics in the above ‘non-commercial’ livestock keeping systems which may be useful to policy makers and extensionists and believed to take into account the viewpoint of the livestock keepers in question. The text is from an article by H.A.J.Moll et al. (2001, Dept.of Social Sciences, Wageningen UR, the Netherlands).

### (I) Quantification of resources used and physical production obtained

**Resources which are used (input)**

The resources are split into *purchased recurrent inputs,* such as medicines and drugs, feed supplements and fodders, hand tools and veterinary services, and the *household production factors,* such as family labour, land, and capital invested in animals and stables.

**Livestock production (output)**

The output is separated into *recurrent production* and *embodied production.* Recurrent production is physical production such as milk, wool, manure, and draught power. It becomes available according to livestock types, sex, age and season. Embodied production is production that is not consumed, but which is directly invested in animals, such as changes in body weights and change in number of animals.

### (II) Valuation

**Valuation of recurrent (physical) production**

Valuation is not a straightforward process, as markets for resources and products are imperfect or even absent and thus do not necessarily provide prices. Therefore a distinction is made between marketed and non-marketed recurrent production. The marketed recurrent production is valued at market prices, and the non-marketed recurrent production is valued at estimated prices (both at farm gate level). This leads to two indicators for the recurrent production:

**(a)**

*The net recurrent cash income,* defined as the value of the marketed recurrent production *minus* the purchased recurrent inputs. This income is a partial indicator, but a major one for livestock keepers, as they usually strive for cash income to pay for school fees, medical treatment, and the purchase of consumer goods.

**(b)**

*The recurrent income in kind.* The non-marketed recurrent production is consumed, exchanged or invested and is as such directly observable by livestock keepers.

The value of the **embodied production** is reflected in the third indicator:

**(c)**

**The sale price.** This becomes available when animals are sold, and it reflects the value of the total embodied production over the lifetime of the animal. Markets for slaughter animals are usually present and thus result in prices, but markets for animals in their productive period may be thin, and in such cases prices must be estimated.

The first two indicators refer to the income derived from **keeping** an animal, and they usually refer to a period of one year. The third indicator gives the income obtained when **selling** an animal, thereby terminating the stream of income derived from keeping the animal.

**(III) Estimation of other benefits**

Other benefits are in the functions in insurance, financing and status display, functions which are significant in communities where it is difficult or impossible to fulfil these through other means.
The *insurance function* results from the potential of being able to sell the animals in case of emergencies. In this way, having animals is a substitute for paying insurance premiums.
The *function of livestock in financing* is noticeable in three things: the purchase of animals when income exceeds current consumption requirements; the implicit investment of embodied production in animals; and, the sale of animals for immediate consumption or investment requirements. The benefit of financing through animals results from the avoidance of cost involved either in storing money or goods, or in borrowing and is related to the sale price.
The *function of livestock in providing status* to their owners is related to the presence or absence of other means to display wealth, such as durable consumer goods and building materials. The benefit from providing status is, as in insurance, a proportion of the average value of an animal (or animals) over a period of one year.
The acknowledgement and estimation of the benefits in insurance, financing and status display widens the perspective on the roles of animals for households in developing countries.

**Schematic appraisal of the livestock system:**

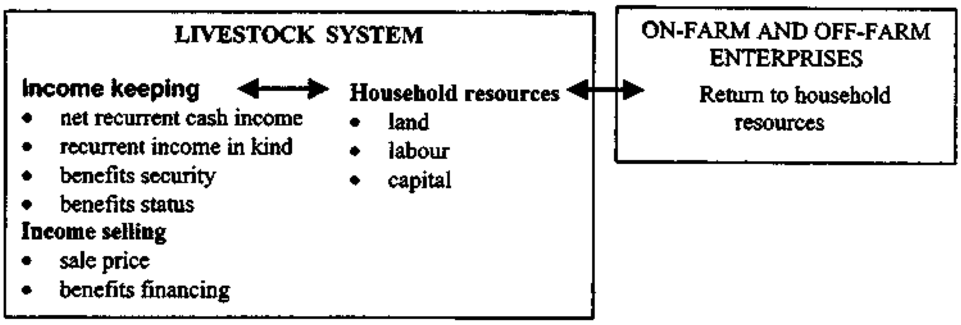



*Figure 6:*

Keeping an animal provides net recurrent cash income, recurrent income in kind, and intangible benefits in insurance and status; selling an animal results in the sale price plus intangible benefits in financing. All income components are directly observable by livestock keepers, although they will not express them all in monetary values.
The incomes of keeping an animal, and eventually selling the animal result from the utilisation of the household's production factors, land, labour and capital. These production factors can generally also be used in other on-farm and off-farm enterprises and this means that in the appraisal of the livestock system by the livestock keeper the total benefits are compared with the returns to the household's production factors in other enterprises.
The outcome of the appraisal may differ per household according to their individual objectives, resource endowment, access to institutions, and options for using their resources in other on-farm and off-farm enterprises.

Editor: the article continues; the described method is applied to three dairy systems in widely different situations, namely:

- cattle grazed on natural pasture in the Western Province of Zambia
- smallholder dairy production in the Coconut Triangle and the wet Lowlands zone, in Sri Lanka
- smallholder dairy production near Nakuru, Rift Valley, in Kenya.

# Appendix IV: Crop-pasture rotations in mixed farming in East Africa

This appendix carries quotations from the publication:
**'Farmer's success with tropical grasses: crop pasture rotations in mixed farming in East Africa' by the late Joseph G.Boonman;**

## 1 On husbandry in agriculture and animal production

**'Good husbandry is always sustainable'**
'In the past the 'early-sowing' recommendation was well received by farmers and did much to improve standards of maize husbandry in the region. It is, however, rarely referred to in present-day circles promoting low-input farming.
This may be just as well since any tendency to hijack an achievement under one, often so vague and ambiguous, slogan - be it low-input farming, agro-forestry or leyfarming - carries the risk of over-simplification. Sooner or later some negative reaction follows and the weak points which are always there draw excessive condemnation so that the whole idea may be lost in the end.
What is now fashionably referred to as sustainable farming may be better understood by the more comprehensive term 'good husbandry'. A good farmer is not guided by profit alone but in his stewardship and good husbandry he will watch over crops and livestock as well as over their principal resource, the soil itself. Inputs are chosen on the basis of their effectiveness towards such husbandry, not of doctrines. As for the latter, it wouldn't be the first time that western theories were doomed to fail when applied to tropical agriculture.'

'Now we have the privilege to be able to choose between fertilizers or no-fertilizers. In the 1930s, also a time when environmental conservation was a hot issue, fertilizer was either not available or too expensive. A lot of high-level research went into inputs adopted from the West: animal manure and legumes for green manuring, but both proved hopelessly inadequate. Only when attention turned to native husbandry, i.e. conventional shifting cultivation, it was discovered that cropping could best be sustained if alternated with grasses'.

'In the recent pleas for more emphasis on low external-input farming the impression is created that improved farming had, thus far, been a matter of high-finance inputs only. Ironically, other high-input issues are given less or no such concern. The high-labour and -environment inputs of some alternative recommendations do not seem to detract from this viewpoint, but perhaps they were not recognized as true costs'.

'In good husbandry first things come first and options are judged for their merits as well as for their costs, either human, financial or environmental. The smaller the costs, the less spectacular the various options often are and the less publicity they receive, because no eyebrows are raised and no one can be expected to have any particular reason to oppose them.
Early sowing and early weeding are the obvious examples of inputs in the non-spectacular category, as already mentioned. The principles apply equally to maize, other arable crops as well as to grasses. Incidentally, 'early' is not necessarily 'easy'.
The 'early' effect has been one of the most exciting challenges to farmers and agronomists, because it greatly enhances the effectiveness of some of the more costly inputs as well as of input combinations. Weeding at the earliest possible date may double the effect of weeding carried out late. Without early sowing and early weeding, hybrids cannot show their superiority convincingly. The same applies to N-fertilizer. When applied to grass at the first possible date in the rainy season, rates can often be reduced by half'.
(End of quotation.)

In the AGROMISA series of educational materials is a title ‘Physiology of crop growth & practicals on plants and soil’, with practical lessons on early sowing and early weeding.
More quotations:

## 2 On animal manure

‘Farmyard manure is a western concept typical of an agriculture with winter-stabled livestock. That, also in the tropics, dung and urine have an effect on grass- and subsequent crop growth is most evident in night paddocks. Dung and urine are concentrated and utilised when they are dropped. This is probably the most effective way, provided that such enclosures are shifted regularly and made part of the crop rotation.
The quantities of dung and urine needed before a ‘night paddock’ effect becomes evident are enormous. Data suggest that 150-200 ton/ha/year of dung alone may be involved.
That there is almost no use made in ordinary farming of manure, other than as fuel or as cement substitute, has its good reasons. There was, of course, no farmyard manure in the true sense, because animals were out in the open. Dung pats are more conveniently collected when they have dried up, but coprophagous insects (i.e.feeding on dung) have by then been at them and contamination with soil is inevitable. Urine has already been lost by volatilisation’.

‘To start with, manure is poor when the feeding is poor. Poor storage can further lower quality to little higher than the levels in the very soil it is supposed to improve. Manure is explicitly low in N and the N-efficiency is low, yet this is the most wanted nutrient. The effective contribution of one ton manure is often not higher than of one kg pure N, applied as fertiliser. This may explain why so little use has been made of manure on cereal food crops. It is relatively rich in K (potassium), which explains why it used to be applied, if at all, to banana and sweet potato on some, rather rare, K-poor acid soils. K-fertiliser itself is little used.
Reports of beneficial effects of manure on physical soil properties are equally rare except perhaps where enormous quantities, which are simply not available, are involved ..........

Apart from manure’s low quality, there is never enough of it around unless feeds are brought in from outside. Surpluses brought about by stall-feeding must by necessity be disposed of, hence the renewed interest. Within an average mixed-farm, however, manure cannot be generated in sufficient quantity to go round to maintain the productivity of the land under cropping. Under continuous cropping, at least 10 ton/ha/year of manure are needed to maintain yields at subsistence level. Some 3 ha of good grassland are needed to feed livestock producing enough manure to maintain the yield of 1 ha of crops of similar potential. West African data speak of even 40-50 ha. Such acreages are simply not available. Animal manure is, therefore, not sustainable.
Manure was even less effective than mulching. In a trial some 3 ha of grass were needed to mulch 1 ha of coffee effectively and also these were not found available. The same applies, for similar reasons, to compost’.

## 3 On the disappearing tropical rain forest

‘While so many rightly bemoan the continuing destruction of forest, it should be comforting to learn of the rapidly growing body of evidence that tropical grasslands turn as much if not more atmospheric $CO_2$ into carbohydrates and that grasses send their roots deeper down the soil profile than trees do. Grasses differ from trees in that much of the OM they synthesise is translocated deep into the soil as root system. What is more, few will doubt that pasture takes considerably shorter to recover or to establish than rain forest’.

## 4 On mixed farming

'The highest degree of integration is reached when crops are rotated frequently with grazed pasture. This requires a grass that is easy to establish and to eradicate. Rhodes grass is grown on an appreciable scale in tobacco and cotton rotations, but the most common of all, in most countries, are maize rotations.

Maize-grass rotations are the most popular, irrespective of soil type and farm size. Maize is responsive to being rotated with grazed pasture and this is reflected in lower weed-control and fertiliser requirements. Maize stover and reject grain are welcome by-products. Conversely, grasses tolerate being undersown to maize. A valuable mixture of young grass and maize stover presents itself at the start of the dry season'.

## 5 What grasses do to the soil in a crop rotation

'In most soils in the tropics the evils of continuous cropping without remedial measures are widely recognized. Under improper land use, abundant sunshine and rainfall become a liability rather than an asset and aggravate soil erosion, leaching and mineral depletion.

The improvement brought about by grass becomes visibly clear when adjacent fields are ploughed, one from under grass, another from a field that has been under crops for the same number of years. For convenience sake we assume that the new crop that is sown is again maize, but the principle can be extended to other crops such as cotton, to which a lot of research on this topic was directed in Uganda and Tanzania. The visible effects are:

- the soil tilth after grass is more robust with visibly reduced erosion
- fewer weeds appear and then only after a long delay
- crops do not show the pale colour of nutrient deficiency
- the response to fertiliser is higher
- crops mature earlier so that the land can be ploughed and prepared well in time before the next cropping season

The start of the new crop is better were it only because more rainfall is trapped and weeds are suppressed. This is perhaps the most striking effect of a grass phase, but as we will see there are also soil nutrient effects.

The improvement in soil structure, as visible with the naked eye, may vanish early but crop yield responses continue to remain significantly higher for a longer period'.

### Roots

'Soils under grass have some of the most dense, intensive and deep rooting systems anywhere in the plant kingdom. Depth of rooting of Rhodes grass and others has been recorded down to 6 metres, within one year after sowing. Their rooting intensity is relevant to indicate the enormous mass of fresh organic matter that builds up in the soil, holding not only water that would otherwise be lost but also nutrients it has captured. At the root depth of 6 m, soil may hold 50 cm of available water.

Roots have also a more direct role. Important in many soils is the presence of channels, down which water can be drained. In pasture soils dead roots produce such channels when they have been decomposed. Grass roots grow into soil crumbs, holding them like beads on a string, also when the root is dead. The longer it lasts until it is decomposed, the more noticeable the effect'.

### Fresh organic matter

'Soil under forest or grassland has a higher OM-content than the same soil when cultivated. It has a higher rate of addition of OM, while less of it is broken down by cultivation. OM provides the main nutrients for soil organisms; in doing so, part of the N is released as ammonium and can be used by plants directly or when converted to nitrate. The size of this active fraction determines the amount of N available. In no-fertiliser agriculture, OM supplies most of the N and half the P of the crop and provides most of the cation exchange capacity'.

### Nutrients

'After grass, crops have lower fertiliser requirements, especially of N.

Deep-rooting grasses pump up N, P and K from subsoil resources to be deposited ultimately in the upper soil. N-accumulation under grass, unlike under legumes, is accompanied by an increase in pH due to the upward transfer of subsoil cations and nitrate. By contrast, continuous cropping decreases pH. Under grass, nutrients accumulate and are immobilised in plant parts and in associated organisms. Soil-N builds up rapidly. Older grassland soils may contain 5000 kg/ha N in the top 15 cm.

From where does all this N come? In part from the subsoil, recycled, but originally mostly from the atmosphere. N is coming down in thunderstorms and rain. In addition, there is increasing evidence that tropical $C_4$ grasses 'fix' nitrogen in a process not too unlike that of legumes, through free-living microbes active in the root- and leave sphere.

How much N is available to benefit plant growth is difficult to measure. The microflora competes with plants for any ammonium present and converts it into microbial protein which is immobilised and, thus, unavailable to plants. Under grass, immobilisation is almost equal to mineralisation. Under grass, leaching is almost non-existent because of the little free N that is present; even less is available as nitrate N is released in quantity only when mineralisation exceeds immobilisation. The balance tips in favour of mineralisation, of N-release, when the decomposition of OM is hastened. In nature this occurs for instance after a drought, when growth is slowed down if not killed. With new rain, dead roots decompose and N is released. This is made visible by the fresh green aspect of grass after a drought. The longer the drought and the higher the temperature, the more N is released. Ploughing stimulates N-release even if it is not carried out primarily for that purpose.

In a cropping period, N and C inevitably decline. The build-up during the grass phase is followed by a breakdown during the cropping phase.

Grass benefits little from the amounts of N building up underneath. Once it has used up the N available, productivity declines. Grass on soils high in organic N can become N-deficient with time. Ironically, in order to benefit from the soil-N it has helped to build up, grass itself must be ploughed out and be sown again either directly or after a temporary cropping phase. The soil-N built up over consecutive grass phases is recycled most effectively by frequent ploughing and subsequent resowing. The crop:pasture duration ratio to be chosen is a matter of balancing costs against benefits. An equal 3 years of pasture and 3 years of cropping used to be standard recommendation.

The true art of husbandry in mixed farming is to manipulate the N-resources available both through and for grasses. Soil-N is a resource largely brought about as well as maintained by grasses in the first place. Only a fraction of it needs to be sacrificed to make it operate at a higher resource level in each consecutive cycle of rotation. When the soil is opened up for cultivation, soil-N is released not only to a young crop but also to freshly sown young grass. Young grass is the best N-source available for livestock while, in its turn, the grazing of young grass accelerates the N-cycle in the soil'.

### The importance of direct grazing

'The full benefit grasses exercise on a soil is realised by grazing. Night paddocks are visible evidence, albeit extreme. The rapid recycling of nutrients through dung and urine is typical of grazing. By contrast zero-grazing leads to depletion of nutrients and since the grass is rapidly weakened this practice is not conducive to soil structure either. Subsequent crop yields may be even lower than under continuous cropping'.

### Double yields

'First year's grass is the most productive and can easily yield more than three times as much as in the 3rd or 4th year. Crop yields, especially of maize, after grazed grass are often more than twice as high compared with continuous cropping and in the 3rd or 4th year the yield advantage may still be 50%. Thus, the same yield objectives of both pasture and crops may be achieved in half the time or on half the land, provided grasses and crops are rotated every 2-3 years.

Such 'two farms in one' may show their greatest advantage in low-input farming and on poorer soils but all soils respond when replenished with fresh organic matter, and there is no easier way to do this than by including a grass phase within the rotation. Immediate yield benefits are understandably more convincing to the farmer than principles related to OM, pH or soil structure, however basic these factors may be. What is more, yield benefits remain by the time the visible signs of improvement of the topsoil structure seem to have vanished'.

### Crop hygiene

'Crop rotation generally reduces the incidence of pests, diseases and weeds. Specific effects have been known for a long time also. In Zambia and Zimbabwe, Rhodes grass has been grown for decades in rotation with tobacco, to control root-knot nematodes.
The weed-suppressing effects of Rhodes grass but also of Setaria pasture are most evident in the arable crops that follow. By contrast, Napier grass and leguminous crops leave the soil contaminated with weeds, especially with Couch grass and sedges'.

## 6 On the choice of (grass) species for cultivation

'East Africa is the home of the world's most famous cultivated tropical grasses: Rhodes-, Napier- (Elephant-), Sudan grass etc. The region thanks this to the unique co-development of its flora and herbivorous fauna, combined with a varied topography and climate.
Yet, in spite of some 1000 grass species recorded from East Africa alone, the species in actual cultivation are very few, and can be traced back to the early days of grassland pioneering and were pioneered by farmers themselves. Like almost anywhere else in the world, also with grasses, the best species were simply too superior not to be noticed by earlier generations of farmers, long before official research even started. Farmers grew and developed them further'.

'Species which have been tested off and on for over half a century but which are still not accepted by farmers and of which, therefore, no seed is available on the market cannot be labelled as promising, let alone as new. For instance, Leucaena was introduced into Uganda in 1915 as a shade and hedge tree for which it proved useful. Farmers were familiar with Leucaena but they never took to planting it for fodder. Leucaena is an example to show that the absence of a highly publicised species from farming is no proof of them having been ignored or not having been tested in the past. To the contrary, those in cultivation today are those that have survived repeated challenges from potential competitors but which proved to be the best the farmer could find to suit his needs'.

Advice to researchers: 'Improve the species already in cultivation by breeding'.

'(In East Africa) Rhodes grass is the most popular because of its ease of sowing and management, wide adaptation and plasticity, high yield and nutritive value. It is both easy to establish and to plough out which makes it the ideal grass for crop-grass rotations. Molasses used to be sown for this purpose in the early days. Lesser-used species are Setaria, Guinea and Brachiaria which have only limited, often special application.
The other main species in cultivation is Napier grass. It is grown for dry-season fodder banks or for stall-feeding. It has to be established vegetatively. Lesser-used for this purpose are Giant Setaria and Guatemala grass.
Oats and (Grass) Sorghum deserve a special place on mixed farms to provide a cover for freshly ploughed pasture and to provide end-of-season forage. At very high altitudes (3000 m) oats are the only feasible forage available where temperate grasses such as rye grass, Cocksfoot or Tall Fescue are not satisfactory.
Lucerne is the only legume that can be recommended universally. An exception could perhaps be made for Desmodium when grown together with Napier grass'.

### Herbage yield and quality

'Rhodes- and Napier grass are both among the most productive grasses that exist. The ultimate value of a cultivated herbage plant must be considered in terms of output of milk, beef or fibre, quite apart from its effect on the performance of subsequent crops in the rotation.

Yield is not constant over seasons and years. Grasses are highly seasonal, delivering most of their potential in the first few months of the growing season. In the tropics, the second part of the rainy season is less efficient, not to speak of the dry season. Also the quality of the newly produced grass is higher at the start of the rains. Grasses utilise this early boost to recover from the onslaught of the dry season and to produce a conservable surplus.
Yield is not constant over the years either. Yields of Rhodes grass are at their best in the first 12-18 months and then drop due to N becoming locked up in the soil biomass. Grasses such as Setaria establish very slowly in the first year and are at their best only when the weeds are gone after the first dry season.
Yields of 15 ton/ha dry matter (DM) in the year of sowing or planting are not unusual, without N-fertiliser. Unless topped-up with N, however, yields drop to one third or less in the 3rd year, especially under cutting systems.
For dairying purposes the aim is usually to have a crude protein of 10-12% and a digestibility (D-vitro) of 55-60. After the first year this is, again, rarely possible without N-fertiliser but the effort is worthwhile. The greening-up of a grass cover and an increase in% crude protein can be noticed in a matter of days.
N is and remains the crucial growth factor, even more so than water. Grasses are so responsive to N, that N-fertiliser is the logical tool to employ when grass needs encouragement, not in the least because it is an input that can be timed and dosed at will'.

'The more often a grass is defoliated (grazed or cut), the lower the yield but the higher the quality. Moreover, the rate of utilisation under frequent grazing is higher since less stem is rejected. For high-yielding dairy cows only the best grass is good enough and a green leafy sward is what is needed'.

'Herbage quality is one of the most researched topics of all, but our understanding of the processes grass-animal-milk etc. is still far from complete. In particular we miss a simple laboratory method whereby quality can be measured in a meaningful way to explain differences in animal responses. 'Crude protein' and 'digestibility' give some indication but this is often not enough, especially in species comparisons. Although legumes are higher in protein than grasses, their digestibility is lower and no advantage may emerge at all. This has been one of the most disappointing properties observed in tropical legumes, compared with their temperate counterparts such as clover and lucerne. Desmodium and many of the legume shrubs or trees have an even lower digestibility and palatability because they are rich in condensed tannins. Tannins make protein insoluble and are extracted on a commercial basis from leguminous trees like Acacia wattle in order to process leather.
Fortunately, nearly all the major grasses are at the top of the list as far as digestibility is concerned.
Aspects which are easily overlooked are sward density and% DM. If the sward is too open animals have great difficulty in collecting their daily portion and become tired before having filled their appetite.
Grasses also differ greatly in% DM. Rhodes grass may have 21% when Napiergrass has only 16%'.

'Tropical grasses have a reputation of being high-yielding but not very nutritious. More to the point is the public image of them being in a stemmy and not in a leafy state. On small farms, however, grasses are under such high pressure of grazing that stems are rarely seen. Stemminess is then not a liability, but rather a luxury. Lack of grass-on-offer or simply yield is, on most farms, the main factor limiting animal production'.

'Husbandry can be adapted to making herbage supply match demand throughout the year. Conservation as hay or silage can shift the surplus from the first months to the last, whereas N-fertiliser can ensure that seasonal shortages are alleviated'.

**Drought tolerance and persistence**

'A grass species should be capable of surviving the dry season without undue damage. Some grasses such as Setaria go completely dormant within 2 weeks of drought. Napier grass, on the other hand, can stay green throughout 3 months of drought in Zone III.

Common Guinea grass can stay beautifully green in dry weather if left alone. In a normal grazed pasture of this grass, however, there is little sign of greenness in the dry season.

On farms with high year-round grazing pressure, the ability of a grass to 'produce' in the dry season should not be overrated. Very few grasses produce more than 10% of their annual yield within a dry season of 3 months, yet the damage due to overgrazing and trampling costs much more than this 10% can justify. Land that could support 1 LU/ha does not even carry 0.1 LU/ha since it is never given a rest. Other means must be sought to save potentially productive pasture, by feeding back hay made from surplus earlier in the same year, by supplementing with Napier grass or by fodder catch- or break crops such as oats and Grass Sorghum'.

'Persistence is not absolute either. Persistence reflects the capacity of a species to maintain a dynamic presence in the sward without giving way to other species. As with drought tolerance, persistence varies with species and husbandry. Rhodes grass is more persistent than Common Guinea but less then Setaria or Brachiaria. Seed fields of Nandi Setaria, well-fertilised with N and cut twice a year, show no decline in persistence.

Brachiaria is an example of a species to show that persistence is not synonymous with productivity because after a productive first year, Brachiaria runs out of N, becomes sod-bound and assumes the aspect rather of a lawn gone pale.

Persistent grasses are difficult to plough out. This makes them not so popular if cropping is to follow but, if one year of cropping is enough, the pasture can be induced to return in style, as if it had re-seeded itself'.

**Ease of management**

'Ease of management is probably the most important property in the eyes of the farmer. A grass should be easy and relatively cheap to establish, to cover the ground quickly and to be maintained weedfree. In addition it should be easy to manage for grazing or for conservation and to eradicate by ploughing. Rhodes grass has all these properties'.

**Mixture of species**

'Legumes are rarely added because the advantages are much smaller than often claimed and because they tend to disappear from the sward after grazing.

Mixtures of grasses are not advocated either. Mixtures are not stable and most of the time one of the components disappears sooner or later. It is also hard to establish a homogeneous sward that is not eaten selectively. Evidence that mixtures are better than the best component on its own is rare'.

**End of quotations**

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Then follows a chapter on 'Sown Grass Species': major grasses (Rhodes grass, Setaria, Napier grass), minor grasses (Coloured Guinea, Molasses grass, Common Guinea, Buffel grass) and other grasses (8 pages). This chapter is followed by:

'Husbandry of Sown Grasses': establishment (direct sowing, undersowing), pasture husbandry (rotational grazing, seasonality in grass productivity, the manipulation of grass availability), conservation (hay, silage), fodder catch-/break crops (oats or Grass Sorghum), N-fertiliser, and farm-saved seed.
(12 pages).

‘Planted Fodder Grasses’: Napier grass (Elephant grass, Pennisetum purpureum; importance as a cultivated plant, varieties, herbage yield and quality, harvest interval and yield, harvest interval and the dry season, stubble height), husbandry (establishment, plant density, fertiliser, spelling during the rainy season, leaf stripping), Desmodium as a cover crop, zero-grazing, a husbandry package, alternative fodder grasses (18 pages).

‘Legumes’: tropical pasture legumes, lucerne, other legume fodder crops (Leucaena, tree saving); 8 pages.

‘Sorghum and Oats as Fodder Catch- or Break crops’ (2 pages).

‘Conclusion’: the foregone concept of new species (new grass species, new legume species), the neglected concept of husbandry (4 pages).

# Appendix V: Dairy development and the environment

The text of this appendix has been adapted from an article by Cees de Haan of the World bank in Washington (2001). As follows.

Dairy development can have a negative effect on the environment. In the USA, dairy production is estimated to cause about one third of agricultural pollution of open surface water (situation 1994).
In the developing world, pollution and land degradation because of dairy development has already been noted and is increasing. For example:

- open access to grazing areas for smallholder dairy producers in India (leading to land degradation)
- uncontrolled waste management of dairy producers around (large) towns in Africa and South Asia
- water pollution by small processors in Central American watersheds

But we should also bear in mind that dairy development can be an important instrument for poverty reduction for rural people. The income dairy development generates can enable investments which lead to more sustainable production systems.

Farm size and type of production system largely determine the environmental effects of dairy production.
For example, nutrient loading and water pollution are low with small farms (but can be significant in areas around (large) towns). They are generally high with large production units.
Pressure on animal genetic resources is generally low with small farms, and high with large production units (exotic breeds crowding out indigenous breeds).

**Improving the environmental sustainability of dairy development**
World Bank thinking.
*Enhancing the environmental sustainability* of dairy production systems will require measures which
(a)
acknowledge the close interaction between the policy and institutional frameworks and the technology which is being used, and the need to focus on the underlying causes of certain environmental effects, rather than on their mitigation;
(b)
to the extent possible, aim for win-win situations, whereby the proposed intervention(s) accrues both socio-economic and environmental benefits, although accepting that in many situations there are winners and losers and policy decisions on the trade-offs are required;
(c)
aim for market pricing of environmental costs and benefits, under the principle 'the polluter pays and the provider gets';
(d)
but clearly accept the political economy of the country, as developing countries may have different valuations of the environment than the developed world.

The *three main policy instruments* which affect livestock and environmental interactions are:

*Financial or pricing instruments* have wide ranging effects. Subsidies on the prices of input and the product (milk) have generally a negative effect on the environment. For example:
- ➢ Subsidies on inorganic fertilizer discourage the proper use of manure and careful nutrient management (urea displacing manure, in China);

- Subsidies on artificial insemination (AI) tend to promote the use of 'improved' breeds and the extinction of indigenous breeds, also in those situations where indigenous breeds would be more suitable for the local conditions;
- Subsidies on feed grain promote intensive, 'modern' dairy production systems, which are often unsustainable.

On the other hand, payment for the introduction of environmentally friendly technologies can have positive effects (e.g. intensification of dairy production with silvo-pastoral means)

*Property right instruments* will affect how people allocate resources to conservation of natural resources. Allocating access rights to grazing areas to groups or individuals will generally improve the environmental sustainability of those areas.

*Regulatory and zoning instruments,* either by regulating the stocking rate of an area, or by restricting access to environmental sensitive areas, such as river banks, is an effective way of reducing environmental degradation in those areas, where there is a strong administrative structure to control the implementation of the regulations.