Tropical dairy farming : feeding management for small holder dairy farmers in the humid tropics
By John Moran, 312 pp., Landlinks Press, 2005

8

Growing quality forages

This chapter:

Explains the milk production benefits from growing quality forages to reduce the level of concentrate fed to milking cows. The management of forages should aim to optimise both yield and quality.

The main points in this chapter:

- home grown quality forages usually provide the cheapest source of energy for milking cows
- milk responses to improving forage quality can be very large, up to 4 L/cow/day
- the four basic principles of growing good quality forages are:
  1. select the most appropriate forage species for the region
  2. prepare the forage production area for sowing
  3. manage the crop with adequate fertiliser to optimise growth and quality
  4. harvest the crop at the best stage of maturity for nutritive value.

Although this manual is specifically about feeding dairy stock, chapters have been included about growing and conserving quality forages. The key to profitable small holder dairying is to utilise sown forages first and then supplement milking cows with concentrates and other forages to overcome shortfalls in nutrients to achieve target milk yields.

Economic pressures decree that small holder dairy farmers zero graze or 'cut and carry' the forages to their stock. Usually, when cut forage is given, the nutritive value of forage is inferior to that grazed by stock, when they can select a better quality diet of leaves and less mature stems. Therefore, grazing cows have better milk production and reproductive performance than stall-fed cows. Aminah and Chen (1991) concluded that in the tropics, grazing systems can yield 15% more milk (9,700 versus 8,400 L milk/ha per year), which may partly explain the low milk yield of small holder dairy farmers.

The basis of economic dairy farming is producing and utilising quality forages. To maintain milk composition, milking cows require diets comprising 30% to 40% forages (on a dry matter basis) and forages are generally cheaper than concentrates. Milking cows have very high nutrient requirements and poor quality forages will just not supply them because of the physical limitations of rumen capacity. Furthermore, the physical demands of hand harvesting and carrying forages to stalled cows also reduces the likelihood of cows being supplied with sufficient quantities of forages. As most forages are harvested by hand, tall erect forage species are preferable to prostrate species. Forage quality can be ensured by selecting improved varieties of forages with optimum agronomic practices, such as described in this chapter.

8.1 Production benefits from good quality forages

It is very difficult for small holder dairy farmers to provide a year-round supply of good quality forages to their milking cows. Ideally, each milking cow should be provided with 50 kg/d of fresh forage containing at least 10 MJ/kg DM of Metabolisable Energy (ME) and 16% protein. During the wet season, forages grow so quickly that they are often too mature and have reduced feeding quality by the time they are harvested. In the dry season, there is generally a shortage of green forage, so many farmers feed forage by-products such as rice straw, banana leaves and sugar cane tops. In areas growing sweet corn, maize stover may be available for much of the year (either as fresh stover or maize stover silage), but it is generally not sufficiently high in energy content and is also very low in protein content.

Cultivated forage crops have many benefits to small holder dairy farmers. They:

- improve forage supplies and diet quality
- provide nutrients to the soil such as nitrogen from legumes and organic matter from grasses
- reduce soil erosion and shade soil from direct sunlight and desiccation
- suppress weeds and reduce pests and diseases in food crop rotations
- provide bulk feed.

Cultivated forages can be perennial (eg Napier grass) or annual (eg forage maize). Throughout this manual, the name 'maize' rather than 'corn' will be used. Forages can be grown in pure stands or as mixed swards.

8.1.1 Overcoming the high cost of concentrates

Compensating for low supplies of forage by feeding more concentrates is generally less profitable because on an energy basis, concentrates cost more. It is important to compare feeds on an energy basis, rather than their cost per kilogram fresh or per kilogram of dry matter. Data for two countries with differing energy systems and currencies are presented in Tables 8.1 and 8.2.

Thailand and Vietnam have been selected because of the difference in magnitude of their currency units (see Appendix 3 for currency conversion of other South-East Asian currencies) and the different energy systems routinely used. Thai dairy specialists use Total Digestible Nutrients (TDN) while Vietnamese dairy specialists use Metabolisable Energy (ME). Full descriptions of these units of energy are presented in Chapter 4.

Table 8.1 presents the typical costs for forages and concentrates in Thailand calculated as Thai Baht (Bt)/kg of Total Digestible Nutrients while Table 8.2 presents typical costs in Vietnam, expressed in Vietnam dong (VND)/MJ of Metabolisable Energy.

In both cases the cheaper forage is home grown while the expensive forage is purchased during the dry season. The cheap and expensive concentrates represent the two extreme prices to purchase formulated mixtures during the year.

Table 8.1 Comparing feed energy costs in Thailand (in Bt/kg TDN) for forages (20% DM, 60% TDN) with formulated concentrates (90% DM, 70% TDN)
Thai baht (Bt); Total Digestible Nutrients (TDN).

Feed	Cost for fresh feed (Bt/kg)	Cost for dry feed (Bt/kg)	Cost for TDN (Bt/kg)	Relative energy cost (%)
Forage				
Cheap	0.5	2.5	4.2	100
Expensive	1.0	5.0	8.3	198
Concentrate				
Cheap	5	5.6	8.0	190
Expensive	7	7.8	11.1	264

Table 8.2 Comparing feed energy costs in Vietnam (in VND/MJ of ME) for forages (20% DM, 9 MJ/kg DM of ME) with formulated concentrates (90% DM, 11 MJ/kg DM of ME)
Vietnam dong (VND); Metabolisable Energy (ME).

Feed	Cost for fresh feed (VND/kg)	Cost for dry feed (VND/kg)	Cost for ME (VND/MJ)	Relative energy cost (%)
Forage				
Cheap	100	500	56	100
Expensive	200	1000	111	198
Concentrate				
Cheap	2000	2222	202	361
Expensive	2500	2777	252	450

The last column of each table presents energy costs relative to that of cheap forages. Compared to the energy sourced from home grown forages, formulated concentrates cost two to three times more in Thailand and three to four times more in Vietnam. Similar conclusions are reached when comparing energy costs of such feeds in other countries in South-East Asia.

8.1.2 Milk responses to improving forage quality

Possible improvement in milk yield arising from feeding higher quality forages are presented in Table 8.3. These data are for a 450 kg, non-pregnant cow with zero live weight change fed the same daily quantity of concentrate.

Depending on feeding levels, cows can produce up to an extra 4 L/d of milk through changing forages from say, maize stover or a poorly managed mature stand of grass to a well-fertilised forage such as Napier grass harvested every 4 weeks.

The financial benefits from such milk responses could be utilised either through:

1 feeding the same quantity of concentrates and producing additional milk, or
2 feeding less concentrates for the same milk yield.

Such a decision would depend on the relative cost of concentrates and returns for milk.

Table 8.3 Milk responses through improving forage quality from 50 to 60% TDN (or from 7.4 to 9.2 MJ/kg DM of ME)
Metabolisable Energy (ME); Total Digestible Nutrients (TDN).

Forage intake		TDN intake from forage (kg/d)			Marginal milk response per day (L/hd)
Fresh (kg/d)	DM (kg/d)	Forage quality in TDN (%) or *ME (MJ/kg DM)*			
		50% (*7.4*)	55% (*8.3*)	60% (*9.2*)	
30	6.0	3.0	3.3	3.6	2.1
40	8.0	4.0	4.4	4.8	3.1
50	10.0	5.0	5.5	6.0	3.7
60	12.0	6.0	6.6	7.2	4.2

8.2 The four basic principles of growing quality forages

The four basic principles of growing quality forages are:

1. select the most appropriate forage species for the region
2. prepare the forage production area for sowing
3. manage the crop, particularly with adequate fertiliser to optimise growth and quality
4. harvest the crop at the best stage of maturity for nutritive value.

8.2.1 Selection of forage species

The forage must suit the local conditions. Farmers should ask the following questions when selecting their forage species:

- are there advantages over local varieties?
- have they been tried and found successful in the region?
- do they suit local farming systems and ecological conditions?
- what extra inputs are required, such as seed costs, labour and fertilisers?
- will their extra cost return a profit?
- what are the risks of crop failure?
- do the seeds come from a reliable source of supply?

Species recommended for small holders in South-East Asia

No forages grow well everywhere. Some grow well in acidic soils while others do not. Some grow well in cool areas, while others do not. Forages can survive in areas where they are not adapted but they will not thrive. It is important to choose forages that are adapted to local soils and climate.

Important climatic factors affecting forage adaptation are the length of the growing season, temperatures, soil fertility, soil pH and drainage.

During the late 1990s an Australian-funded project called 'Forages for smallholders project' established trial sites throughout South-East Asia to involve farmers in the selection of the most suitable forages for livestock feeding in upland farming systems. The farmers needed to access forages that:

- were adapted to the climate and soils
- suited their intended use
- fitted into their particular farming system.

Horne and Stur (1999) identified a range of forages on their suitability to various climates, soil fertility levels and farming systems and these are listed in Table 8.4, with further details in Table 8.5.

Table 8.4 An inventory of forages for small holder livestock farmers for different climates, soil fertility and farming systems in South-East Asia

Key to table; **, highly suitable; *, possible, –, not suitable

Climate:1, wet tropics with no or short dry season; 2, wet/dry tropics with long dry season.

Soil fertility: 1, fertile and neutral to moderately acid soils; 2, moderately fertile and neutral to moderately acid soils.

Farm system: 1, cut and carry; 2, grazed plots. (Source: Horne and Stur 1999)

Species	Variety	Climate		Soil		Farm	
		1	2	1	2	1	2
Grasses							
Andopogan gayanus	Gamba	*	**	*	*	**	*
Brachiaria brizantha	Marandu, Karanga, Serengeti	*	**	*	**	**	*
Brachiaria decumbens	Basilisk	*	**	*	**	*	**
Brachiaria humidicola	Tully, Yanero	**	*	*	*	*	**
Brachiaria ruziensis	Ruzi	**	–	**	*	*	**
Panicum maximum	Si Muang	**	*	**	*	**	*
Paspalum attratum	Terenos	**	–	*	**	**	*
Pennisetum purpureum (and hybrids)	Napier, Mott, King	**	–	**	*	**	–
Setaria sphacelata	Lampung, Solander	**	*	**	*	**	*
Legumes							
Arachis pintolai	Itacambira, Amarillo	**	–	**	**	–	*
Calliandra calothyrsus	Besikah	*	–	*	**	**	–
Centrosema pubescens	Barinas	**	*	**	*	*	–
Centrosema macrocarpum	Ucayali	**	*	**	*	*	–
Desmanthus virgatus	Chaland	**	–	**	*	**	–
Desmodium cinera	Las Delicias	*	*	*	*	**	–
Gliricidia sepium	Retalhulen, Belan Rivas	**	**	*	**	**	–
Leuceana leucocephala	K636, K584	**	**	**	*	**	*
Stylosanthes guianensis	Stylo 184	**	*	**	**	**	*

This Chapter will discuss the management of Napier grass, Guinea grass and the annual forage sorghums in more detail.

Napier (or Elephant) grass

Napier grass (*Pennisetum purpureum*) is a common grass cultivated for feeding dairy cows in many countries in South-East Asia. Napier, King and Mott are all varieties of Elephant grass. King grass is taller, leafier and more productive in soils of high fertility, but is less robust and persistent under declining fertility or during dry periods. Mott, often called dwarf Napier grass, has more tillers and is leafier than Napier grass, and is more suited to growing in hedgerows than other varieties of Elephant grass.

Napier grass is one of the most productive grass crops in the world, in one instance yielding 85 t DM/ha per year in the Caribbean, when fertilised over the year with

Table 8.5 Characteristics of forages suitable for small holder farmers in South-East Asia

(Source: Horne and Stur 1999)

Grasses	Characteristics
Andopogan gayanus	Tall grass for cutting, stays green in dry season, grows well in infertile acid soils, becomes stemmy if not cut frequently
Brachiaria brizantha	Tall grass suitable for cutting, grows well in moderately fertile soils, stays green in dry season, should not be fed to goats, sheep or young cattle
Brachiaria decumbens	For grazing and cutting, adapted to wide range of soils, stays green in dry season, should not be fed to goats or sheep
Brachiaria humidicola	Vigorous creeping grass, can tolerate heavy grazing, can grow in very infertile soils, can tolerate waterlogging, lower quality than other Brachiaria species
Brachiaria ruziensis	Established easily from seeds or cuttings, provides high quality forage, needs high soil fertility, poor persistence in poor soils, not adapted to long dry seasons
Panicum maximum	Tall grass for cutting, suited to more fertile soils, produces high quality forages, must be regularly fertilised, becomes stemmy if not cut frequently, not suited to long dry seasons
Paspalum attratum	Tall grass for cutting, grows well on infertile soils, wet tropics with no dry season, can tolerate water logging, very leafy, not suited to long dry seasons
Pennisetum purpureum (& hybrids)	Very tall grasses for cutting, highest yielding species with high soil fertility and irrigation, high quality seed, will not persist without fertilising, not suited to long dry seasons, becomes stemmy if not cut frequently
Setaria sphacelata	Erect grass for cutting, soft and palatable leaves, can survive in poor soils, can tolerate water logging for short periods, grows well in cool areas, needs good moisture and soil fertility or high production, some leaf diseases in humid tropics, should not be fed to horses
Legumes	
Arachis pintolai	Low growing stoloniferous legume, very persistent under hard grazing, good ground cover under trees, high quality livestock feed, needs moderate soil fertility, not suited to long dry seasons
Calliandra calothyrsus	Good tree legume for cooler climates, can grow in acid soils, high leaf yield under cutting, good fire wood, palatable only when fresh, needs to be planted from seeds, slow seedling growth
Centrosema pubescens and Centrosema macrocarpum	Twining legume, good for weed control, grow well with tall grasses for cut and carry, not adapted to long dry seasons, need moderately fertile, well-drained soils, needs to be planted from seed.
Desmanthus virgatus	Shrubby legume for cutting, grows best in fertile clay soils, high quality feed, used for leaf meal production, easy seed production, not suited to acid soils, needs to be planted from seed
Desmodium cinera	Fast growing shrub for cutting, suited to hedgerows, good quality feed, best for wet tropics, short lived (2–3 yr), needs to be planted from seeds
Gliricidia sepium	Easy to plant from stem cuttings, useful as living fence, grows well in moderately acid soils, low palatability for cattle, susceptible to pests
Leuceana leucocephala	Highly productive, tolerant to heavy grazing and cutting, high quality feed supplement, good fire wood, good dry season growth, not for acid infertile soils, not for monogastric animals, susceptible to psyllid insects, needs to be planted from seed
Stylosanthes guianensis	Erect robust legume for cutting, highly productive, good quality feed, many uses including leaf meal production, widely adapted to low fertility and acid soils, leaf stays green into dry season, resistant to the fungal disease anthracnose, short lived (2-3 yr), not tolerant to heavy grazing or frequent cutting

900 kg N/ha. With the best management, Napier grass can produce 50 t DM/ha per year, enough to feed nearly 14 milking cows every day with 50 kg/cow fresh forage. More typical annual yields are 20 to 30 t DM/ha, depending on fertiliser regimes.

Napier grass is best suited to high rainfall areas and will not persist without fertilising. It is not suited to long dry seasons and becomes very stemmy if not cut frequently. Although Napier grass can produce high yields of good quality forage when fertilised by animal manure only, it will produce even higher yields with a fertiliser program of urea, and possibly superphosphate in some situations.

Napier grass is best grown from runners, 1 to 2 cm in diameter with 3 to 4 nodes cut from the middle of a 9 to 12-month-old stem. It should be planted early in the wet season into a ploughed and harrowed field. At sowing, 500 kg/ha of NPK (nitrogen, phosphorus, potassium) fertiliser should be incorporated, with an annual maintenance dressing of 200 to 300 kg/ha of NPK fertiliser. After each harvest, 100 kg/ha of urea should be applied (STOAS 1999).

Napier grass should be harvested down to 20 cm, when it reaches about 100 cm in height. This can take 25 to 30 days in the wet season or 50 to 60 days in the dry season. It should be allowed to flower just prior to the last wet-season harvest. To maintain good quality forage, it must be replanted every three to four years.

Annual forage sorghums and millets

Several of the latest varieties of these annual sorghum and millet forages have been tested recently in Indonesia (J Moran unpublished 2002):

- Jumbo, which is a late flowering sorghum × Sudan grass hybrid. It has a high initial growth rate and a rapid regrowth after cutting.
- Sugargraze, which is a sweet sorghum hybrid suitable for silage making. It is a high yielding crop with high sugar levels and good resistance against leaf diseases.
- Chopper, which is a grain sorghum hybrid bred specifically for silage. It is a tall, late maturing crop with a large, white, grain-filled head. It is ready for harvest between 85 and 95 days, with high yields and good protein and energy levels.
- Nutrifeed, which is a pearl millet hybrid with no prussic acid (cyanide which can kill cows). It has a fast regrowth and prefers well-drained soils.

Results from our evaluations, which included King grass as a control, are presented in Table 8.6. These particular forages were fertilised with a mixture of manure (18.5 t/ha) and 150 kg/ha of fertiliser (27:7:7:1 for NPKS), which provided 37 kg N, 10 kg P, 10 kg K and 1.5 kg S per ha.

The highest yielding forage was Jumbo, closely followed by Sugargraze. King grass produced the best quality forage, while all crops had similar energy and protein levels. These forages were all harvested on the same day, however, and not at their optimum stage of maturity for quality. For example, Jumbo and Sugargraze were harvested above their optimum heights while Chopper was harvested before it had produced any seed heads.

Table 8.6 Dry matter yields and quality of 50-day-old forages in Indonesia (West Java)
dry matter (DM); Neutral Detergent Fibre (NDF); Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: J Moran, unpublished 2002)

Forage	DM yield (t/ha)	DM (%)	Protein (%)	NDF (%)	DM digestibility (%)	ME (MJ/kg DM)	TDN (%)
Jumbo	26.6	14.1	14.5	74.3	51.3	7.2	49
Sugargraze	23.4	12.2	11.9	74.8	52.7	7.4	50
Chopper	7.7	11.6	12.9	75.2	54.9	7.8	52
Nutrifeed	7.4	12.4	13.6	74.4	53.2	7.5	51
King grass	7.7	12.9	16.0	69.8	55.7	7.9	53

Comparing King and Guinea grass

Although Napier grass has traditionally been considered one of the most suitable grasses for intensive animal production, its reliance on high soil fertility and regular rainfall limits its applicability. There is a renewed interest in Guinea grass (*Panicum maximum*) as an alternative pasture crop.

Like Napier, Guinea grass is an erect perennial grass but does not grow as tall as Napier grass (1–1.5 m compared to up to 7 m in height). Guinea grass is adapted to both the tropics and subtropics and is even tolerant to shading, and hence has a role in agroforestry plantations. In certain situations its yield can be equivalent to Napier grass.

For example in Queensland, with fertiliser regimes of 250 kg N/ha at establishment and 200 kg N/ha over the following five months and harvested every four weeks, Napier grass yielded 10.1 t DM/ha over 12 weeks compared to 9.8 t DM/ha with Guinea grass (Lisson, pers. comm. 2004). Increasing harvest intervals to eight weeks increased total DM yields over two harvests to 19.3 t/ha in Napier and 22.0 t/ha in Guinea grass. Such DM growth rates, ranging from 0.8 to 1.4 t DM/wk, are considerably higher than those in Table 8.7 (0.2–0.7 t DM/wk), highlighting the beneficial effects of increased applications of fertiliser nitrogen.

The performance of Napier grass and Guinea grass was compared (Table 8.7) in South Vietnam (Mann 2001). The variety of *Pennisetum purpureum* was King grass while the variety of *Panicum maximum* was small leaf Guinea grass cv 280. They were planted by cuttings into a sandy acid soil after fertilising with 10 t/ha of manure plus 100 kg/ha each of phosphorus and potassium. Nitrogen fertiliser was applied five days after planting and after each harvest, to supply 200 kg/ha per growing season with 50 kg N at planting and the remainder divided equally between harvests. Plots were slashed to 10 cm eight weeks after planting, then at various harvest intervals during the following 24 weeks. Grass from three of the harvest treatments was fed to Friesian heifers, first to appetite (20% above consumption) for 12 days, and second, during digestibility trials, when restricted (85% of *ad libitum* intake).

Yields of dry matter were consistently lower in King grass, being 39%, 41%, 57% and 70% of those in Guinea grass with increasing maturity. However, King grass had the better forage quality – lower contents of dry matter, Neutral Detergent Fibre and and the higher contents of Crude Protein. This occurred despite Guinea grass having a greater proportion of leaf blade.

In the feeding trials, intakes of dry matter were consistently higher in Guinea grass even though their digestibilities of dry matter (and hence Metabolisable Energy content) and Crude Protein were lower than those in King grass. The grasses generally maintained their nutritive value up to harvest intervals of six weeks, after which energy and protein values deteriorated more rapidly. Despite their higher contents in King grass, total yields of energy and digestible protein were considerably lower than in Guinea grass, being 43% to 57% and 50% to 58%, respectively. Yields of digestible protein were highest in immature grasses whereas yields of Metabolisable Energy were generally higher in more mature grasses.

Table 8.7 Forage yield and quality of King and Guinea (cv 280) grasses at various harvest intervals
dry matter (DM); Crude Protein (CP); live weight (LWT); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF). (Source: Mann 2001)

	Grass species	Harvest interval (wks)			
		4	6	8	10
Forage trial					
DM yield (kg/ha/wk)	King	179	236	345	525
	Guinea	460	564	598	747
DM content (%)	King	13.2	13.2	14.9	17.7
	Guinea	19.4	20.4	22.8	23.8
CP content (%)	King	15.5	11.4	7.7	6.8
	Guinea	12.6	9.7	7.2	6.9
NDF content (%)	King	63.6	69.6	72.6	75.3
	Guinea	73.8	76.8	77.6	79.3
Leaf blade (% plant DM)	King	71	60	50	44
	Guinea	81	73	71	60
Feeding trials					
DM intake (kg/100 kg LWT)	King	2.06	2.18	2.00	–
	Guinea	2.48	2.42	2.25	–
DM digestibility (%)	King	65.2	64.6	57.7	–
	Guinea	60.4	61.6	57.8	–
CP digestibility (%)	King	69.7	53.7	44.9	–
	Guinea	60.5	52.5	47.1	–
ME content (MJ/kg DM)	King	9.1	9.0	7.8	–
	Guinea	8.3	8.5	7.8	–
Digestible CP yield (kg/ha per wk)	King	19.3	14.4	11.8	–
	Guinea	35.0	28.6	20.3	–
ME yield (000 MJ/ha per wk)	King	1.63	2.12	2.69	–
	Guinea	3.82	4.79	4.66	–

Frequent harvesting can reduce stand life as in this study, the proportion of dead clumps in King grass increased from 0.4% with 10-week harvesting to 3% with 4-week harvesting. However, there were no dead clumps of Guineas grass in all harvest treatments.

There was little effect of harvest interval on voluntary intake, partly because the heifers had ample opportunity to select the more palatable forage since it was fed at 20% above consumption. Guinea grass, having the greater proportion of leaf, was consumed in greater amounts than King grass.

Optimum harvest management is aimed at achieving the highest biomass yield, which satisfies the animal's needs, usually determined by animal performance. With regard to yields of Metabolisable Energy, optimum cutting frequency seems to be around six weeks, whereas from animal performance, Guinea grass should be harvested every four weeks while Mann (2001) recommended that harvesting King grass can be lengthened to six weeks.

8.2.2 Preparing for sowing

The forage production area may need to be ripped to improve water infiltration. Some forages can be grown from runners or stem cuttings, while others require seeds.

Guidelines for seed bed preparation are:

- they can be roughly prepared with seed broadcast by hand and rolled in
- there can be finely prepared for sowing in rows and with weeding after germination
- seeds can be germinated in a nursery and then transplanted into the forage growing area
- legumes vary in seed bed requirements and have specific rhizobia requirements (to synthesise their own nitrogen from the soil)
- the area must be protected against intruders, such as ants, chickens, wild birds and livestock
- consideration should be given to sowing forages under shade to potentially improve yields through less desiccation of the soil during the dry season.

Depending on availability of land, forages can be cultivated on a large scale, in small plots, in strips (eg along terrace banks), in a multistorey garden (eg in forests or plantations). With very limited land, forages can be integrated into food crops, such as *Leucaena* trees along fence lines.

After the land is prepared, planting should proceed without delay to minimise growth of weeds. It is best to prepare the land after the first rains and have adequate stocks of seeds or runners available for rapid sowing.

Optimum sowing depths and sowing rates vary with forage species. With low seeding rates, seeds can be mixed with a carrier material, such as sawdust, for ease of sowing. The need to regularly prepare seedbeds for sowing could increase soil erosion in high rainfall areas.

Plant nutrient requirements and weed and pest control must be addressed to optimise forage yield and quality. Maintaining pure stands may not be important for forages provided the invading forages do not greatly reduce yields, are still palatable, non toxic and of good quality.

8.2.3 Fertilising the crop

To produce annual yields of 150 t fresh pasture/ha, Napier or Guineas grasses require a fertiliser program that supplies 880 kg N, 252 kg P and 756 kg K/ha over the year (Aminah and Chen 1991). One of the best ways to achieve high forage yields is through using inorganic fertilisers, such as urea and superphosphate. Using cow manure as the only source of nutrients for forages will not supply enough nitrogen and and phosphorus to fast-growing tropical forage grasses.

Fertilisers will boost yield and nutritive value of forage regrowth. Table 8.8 presents data where a tropical pasture sward was fertilised once at two rates (0 and 72 kg N/ha) then harvested weekly. Forage regrowth was two to three times higher on the fertilised sward, as were pasture protein contents.

Table 8.8 Yield and protein content of tropical pasture fertilised at two rates (0 and 72 kg N/ha) then harvested weekly

Fertiliser (kg N/ha)	DM yield (kg DM/ha)		Protein content (%)	
	0	72	0	72
Harvest interval (weeks after fertilising)				
1	200	700	11	16
2	600	2300	10	14
3	1300	2100	9	12
4	1400	2600	8	11

Table 8.9 presents the results of a study of Napier grass fertilised at two rates (0 and 110 kg N/ha at cutting) and harvested either every 40 or 60 days. The forage was conserved as hay and fed to buffalo bulls.

Fertiliser nitrogen improved forage quality, particularly at the shorter cutting interval, allowing stock to consume more as hay. If fed to milking cows, the less mature, fertilised forage would have increased milk response. Even though tropical pastures can respond to higher fertiliser applications, Aminah and Chen (1991) considered the optimum annual level to be 300 kg N/ha, split into five equal applications over the year.

Table 8.9 Quality of Napier grass fertilised at two rates (0 and 110 kg N/ha) and harvested after 40 or 60 days regrowth

dry matter (DM); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF); Total Digestible Nutrients (TDN). Forage was conserved as hay and fed to buffalo bulls.

Regrowth	40 days		60 days	
Fertiliser (kg N/ha)	0	110	0	110
Protein (%)	8.6	12.7	7.1	10.8
NDF (%)	70.6	73.6	78.3	79.1
ME (MJ/kg DM)	7.2	8.4	6.6	6.3
TDN (%)	49	56	46	44
Hay intake (kg DM/day)	7.5	8.9	6.5	7.8

Investing in fertilisers

Fertilisers cost money, but they return more through improved yields and quality of forage, hence more milk. Provided other soil nutrients are not limiting plant growth, urea fertiliser can produce an extra 9 kg forage DM/kg urea or 18 kg DM/kg N applied. When harvested and fed to milking cows, this extra forage can yield an additional 9 L milk/kg urea N (STOAS 1999).

Table 8.10 presents an economic analysis of fertiliser responses in Thailand and Indonesia, based on typical urea prices and milk returns in these countries.

Clearly in both countries investing in urea fertiliser is a good business decision with benefit:cost ratios of 4:1 or 8:1. This extra income can arise from more milk per cow and/or milking more cows per hectare.

Table 8.10 Economic benefits through using urea to fertilise forages fed to milking cows in Thailand and Indonesia, assuming the marginal milk response to urea is 9 L milk/kg urea N

Country (currency unit)	Urea cost		Milk return		Benefit:cost ratio
	per kg	per kg N	per L	per kg N	
Thailand (Bt)	6	13	12	108	8.3
Indonesia (Rp)	1800	3910	1720	15480	4.0

Higher quality forages mean that less concentrates need to be fed to produce the same amount of milk. For example in Thailand, the usual recommendation is to feed 1 kg concentrate per 2 L of milk. Dairy farmers in Latin America feeding well-fertilised Napier grass need only feed 1 kg concentrate per 4 L milk produced (ie half the rate of many small holder farmers in South-East Asia). Furthermore, they can feed 14 milking cows/ha of Napier grass, each producing 15 L/d supplemented daily with 4 kg/cow of concentrates.

Can cow manure supply sufficient fertiliser?

One major limitation of forage production on most small holder dairies in South-East Asia is the poor adoption of inorganic fertilisers. Use of cow manure only to fertilise grasses is common practice in most dairying areas with most farmers not even aware of the economic gains through using inorganic fertilisers. Cow manure supplies organic matter to the forage area, but insufficient nitrogen to maximise forage yields and quality. The following nutrient audit shows that small holder dairy farmers should apply annually at least 100 kg urea/ha to their forage production area, in addition to the recycled manure.

In the case study it is assumed that each small holder farmer has 4 milking cows, with a calving interval of 15 months, and uses all the manure to fertilise forage supplies. Each lactation each milking cow produces 3000 L of milk and consumes 1500 kg of purchased concentrates. Milk contains 0.5% N and 0.1% P while concentrates contain 16% protein (2.6% N) and 1% P.

Choi *et al.* (2004) found each 450 kg lactating cow produced 46 kg/d of manure (32 kg faeces + 14 kg urine) containing 12.9% DM and excreting a total of 0.15 kg N, 0.04 kg P and 0.08 kg K each day. The ratio of total nutrients output in faeces:urine for N are 62:38, for P are 99:1 and for K are 50:50. These data will allow the calculation of nutrient audits if not all the manure is recycled onto the forage growing area. The nitrogen in manure can be lost through volatilisation, nitrification, leaching and surface runoff. The phosphorus in manure can be lost through leaching, surface runoff and soil erosion.

Cow manure alone does not provide sufficient soil nutrients for optimum forage growth (Binh Duong province, Vietnam).

Nutrients leaving the case study farm via milk sales are 15 kg N and 3 kg P/cow per lactation. Nutrients entering the farm through purchased concentrates are 39 kg N and 15 kg P/cow per lactation. By recycling all the manure onto the forage production area, the farm then has a positive balance of 24 kg N and 12 kg P/cow per lactation that is available to grow forages, produce replacement stock (pregnancy and rearing) and grow out the milking cows.

Assuming each milking cow consumes 3 t forage DM/lactation which contain 8% protein (1.3% N) and 0.3% P, each cow then consumes 39 kg N and 9 kg P/lactation from forages. Therefore, every lactation, each cow will remove 15 kg more N than is returned via manure, while there is an excess of 3 kg P from the recycled manure. This does not take into account the loss of N and P through sale of calves and cull cows.

This case study small holder farmer then has a positive phosphorus audit of 36 kg/lactation (or 29 kg P/yr), which is available to provide phosphorus for the non-milk farm products. However, each lactation there is a negative nitrogen audit of at least 60 kg N/lactation, equivalent to 48 kg N/yr, which must be imported onto the farm in the form of nitrogen fertilisers. Assuming the 12 t DM from forages was grown on 1 ha land, from forages yielding annually 9.6 t DM/ha, the forage crop would require at least an additional 100 kg urea/ha over the year on top of the recycled manure. This is likely to be more because much of the nitrogen from urine would be lost through volatilisation and leaching. Effluent disposal systems to minimise such nitrogen losses are discussed in Chapter 19.

Other sources of soil nutrients

There may be other nutrient sources available for use as fertilisers, such as agro-industrial by-products, which could be price competitive with inorganic fertilisers. One such example is a by-product of production of monosodium glutamate (a commonly used

A liquid by-product of monosodium glutamate production, stored in this dam, is a cost effective source of fertiliser nitrogen (Binh Duong province, Vietnam).

feed additive for Asian cooking), sold in South Vietnam as an alternative fertiliser. This product, a liquid that is pumped into ponds for storage (see photo below), can be delivered on-farm for the equivalent of 50 Vietnam dong (VND) per litre, and it contains 3.5% N. Urea fertiliser, however, costs 3,000 VND/kg and contains 46% N. The price per kilogram of nitrogen of these two products are then 1,430 and 6,520 VND, respectively, making urea four to five times more expensive as a source of nitrogen. Before selecting a cheaper fertiliser source, however, complete analyses of the product needs to be made to ascertain whether there may be other constituents which may adversely affect forage yield and quality when the product is applied to supply a predetermined amount of N, P or K.

Simple on-farm fertiliser demonstrations

The calculations in the previous sections are based on a series of assumptions, which will vary depending on the efficiency of manure recycling, particularly how much of the urine actually reaches the forage area. It is one thing to calculate the nitrogen deficit and another to convince farmers to purchase fertiliser for their forage areas.

Many dairy farmers in Western countries base their fertiliser decisions on the nutrient status of the soils. This is not possible for most small holder farmers in South-East Asia because of the lack of soil testing laboratories and/or the cost of such analyses. However, such advice may be available from local agronomists who service cash crops such as rice or cassava.

A visual and very simple method of assessing the likely response to fertiliser applications is to demonstrate it to farmers through test strips, whereby they apply different fertiliser regimes to small sections of their forage area, such as rows 2 or 3 plants wide, to visually assess any response. Erect tropical forages such as Napier grass rapidly respond to improved nitrogen status by producing dark-green coloured foliage plus a more rapid growing, hence taller, plant. By applying different fertiliser regimes after each harvesting in trials (eg urea applied at 0 kg/ha, 50 kg/ha, 100 kg/ha, urea plus phosphorus fertiliser, with and without cow manure), farmers can assess how much urea they should be applying and whether they should be applying P as well as N. Because they can associate extra, darker green forage with more milk, in most cases they should respond accordingly by changing their fertiliser management.

8.2.4 Benefits of mixed swards

A mixed sward of grass and legume can provide high yields of forage with good energy and protein levels. However, the different growing habits of grasses and legumes makes it difficult to maintain the legume component of such a sward. The grasses recommended in Table 8.4 are all erect species whereas the few forage legumes in Table 8.4 are more prostrate. Following regular harvesting, the grasses would then quickly shade the legumes, thus reducing their growth rates. Furthermore, the two forages have different optimum harvesting frequencies. To maintain the longevity of the forage legumes, they should be sown as single species swards. Even then, weed infestation can be a problem.

Shading is less of a problem with tree legumes grown with grasses. The legumes are generally planted in an alley, or rows, and can easily be harvested at different intervals than the grass. The overall photosynthetic efficiency of the grass can be improved when grown in association with tree or shrub legumes, while during dry periods, the trees protect the grass from desiccation. Trees have deeper roots and the shade offers protection from the sun. A well-managed and fertilised grass and tree legume sward should produce the most productive and nutritionally balanced forage mix for milking cows.

One often mentioned example of integrated tropical fodder production is the three strata forage system in Bali, in which 0.25 ha of land is divided into a core, peripheral and circumference area (Nitis 1999). The core area is planted with the main food crop commonly grown by local farmers. The surrounding (peripheral) area is planted with grass and ground legumes as the first stratum, the border around the peripheral (circumference) area is planted with shrub legumes as a second stratum and fodder trees as a third stratum. Grass and ground legumes are harvested during the four-month wet season, shrub legumes during the four-month early dry season and fodder trees during the four-month, late dry season. The total yield of food crop is decreased by less than the reduction in area for cash crop, while forage production increases by 90% and is of higher protein content. Even though the system was developed for fattening beef cattle, it could also be incorporated into small holder cash crop or dairy systems.

8.2.5 Harvesting the crop

When harvesting forages, farmers tend to place too much emphasis on forage yield rather than forage quality. If forages are too mature and of poor quality, cows might produce less milk per hectare per year. In the wet season, there is always a compromise between harvesting high yields of low quality forages (7–8 MJ/kg DM of ME) and harvesting lower yields of higher quality forage (9–10 MJ/kg DM of ME). The data presented in Table 8.11 clearly show that Napier grass must be harvested frequently during the wet season (every 4 weeks) to produce a milking quality forage.

Table 8.11 Quality of Napier grass *(Pennisetum purpureum)* cut at various stages of regrowth during the wet season
DM, dry matter; ME, Metabolisable Energy; TDN, Total Digestible Nutrients.

Regrowth (weeks)	Height (cm)	Crude protein (%)	ME (MJ/kg DM)	TDN (%)	Crude fibre (%)
4	50	10.8	9.6	62	28.5
6	75	8.8	8.1	54	32.2
8	135	8.0	7.9	53	32.8
10	150	7.8	7.7	52	33.0
12	150	4.6	7.5	51	31.9

In a recent review of published data on Napier grass, Muia *et al.* (2000) classified grass quality according to the crude protein (CP) requirements for various categories of milking cows. These were for cows at maintenance (5–7%) CP, or producing low (8–10%) CP, medium (11–13%) CP and high (14–16%) CP yields of milk. Predicted forage maturity, yield and nutritive value for these various swards are presented in Table 8.12.

High yielding cows then require Napier grass no more than 42 cm high and harvested every 30 days. Annual pasture DM yields are then likely to be only 60% of the Napier grass harvested for low yielding cows with annual yields of CP and ME being 105% and 73%, respectively. Therefore, although forage yields will suffer, milk yields will be less adversely affected.

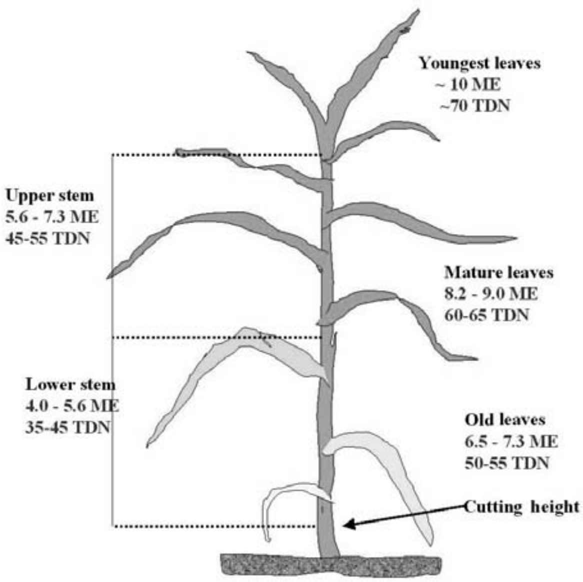

Figure 8.1 Variations in Metabolisable Energy (ME, MJ/kg DM) or Total Digestible Nutrients (TDN, %) of various plant parts of Napier grass (*Pennisetum purpureum*).

Table 8.12 Forage quality and yield of Napier grass *(Pennisetum purpureum)* cut at various protein contents
crude protein (CP); dry matter (DM); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF); Total Digestible Nutrients (TDN). (Source Muia *et al.* 2000)

Forage protein content	5–7%	8–10%	11–13%	14–16%
Age (days)	99	63	53	30
Height (cm)	128	95	61	42
DM content (%)	20	17	16	14
NDF content (%)	68	63	61	54
ME content (MJ/kg DM)	7.1	7.7	8.3	8.9
Yield of DM (t/ha per yr)	28.5	21.8	19.7	13.7
Yield of CP (t/ha per yr)	1.7	2.0	2.4	2.1
Yield of ME (000 MJ/ha per yr)	202	168	164	122

The general recommendations for moderate milk yields (10–15 L/cow per day) in 450 kg dairy cows consuming 13.5 kg DM/d, is for Napier grass containing 8% to 13% protein and 7 to 8 MJ/kg DM ME. This can be supplied from forage harvested at 42 to 70 days, when 60 to 100 cm high, providing a carrying capacity is 4 to 4.5 cows/ha. For high daily milk production (<15 L/cow), harvest intervals would have to be decreased to 30 days. Milk yields per hectare would be high even with low carrying capacity, because of the increased protein yields. However, the increased cost of more frequent harvestings and greater fertiliser applications to maintain soil fertility will reduce the economic benefits of the higher milk yields.

Figure 8.1 shows the variation in nutritive value of various plant parts of Napier grass. This highlights the importance of only selecting the younger plants of better quality sections for feeding high yielding milking cows. Furthermore, the higher the leaf:stem ratio, the higher the nutritive value.

Harvesting tree legumes

With tree forages, regular harvesting of leaves is necessary to maintain favourable leaf to branch ratio. For example, *Leucaena* and *Gliricidia* should be harvested every 6 to 12 weeks. A 12-week harvest interval of *Gliricidia* can produce an annual yield of 9.2 t DM/ha when planted as a block or 1.1 t DM/ha (with forage containing 25% crude protein) when planted as a 40 cm fence around 1 ha of cropping land (Humphries 1999).

It is difficult to recommend specific harvesting regimes for all crops in every situation because the rate of forage growth depends on many factors, such as:

- forage variety – different varieties have differing optimum harvest intervals
- rainfall and/or irrigation
- soil fertility and additional fertiliser used
- harvest interval.

Wilting to improve forage intake

The high moisture content of young, freshly harvested forages limits the appetite of milking cows through high loads of water in the rumen (see Chapter 11). Wilting the forages for up to 24 hours removes intracell moisture without adversely affecting forage quality, provided the forage does not become heated. Data collected during the wet season in Indonesia are presented in Table 8.13. Conditioning is the process of physically damaging the stems, using pieces of wood, to fracture the epidermal layer and so aid the wilting process.

Table 8.13 The effect of wilting on the dry matter content of freshly harvested Napier grass (*Pennisetum purpureum*) and other forages at three sites in Indonesia

* Relative difference is difference in water extraction, expressed as percentage of that in the freshly harvested forage. Conditioning is the process of physically damaging the stems, using pieces of wood, to fracture the epidermal layer and so aid the wilting process. (Source: Moran and Mickan 2004)

Site	Plant part	Treatment	DM (%)	Difference	Relative difference in water extraction*
1	Leaves	Freshly harvested	25.3	5.2	7.0
1	Leaves	Wilted (26 hr)	30.5		
1	Stems	Freshly harvested	15.8	3.7	4.4
1	Stems	Conditioned and wilted (26 hr)	19.5		
2	Leaves	Freshly harvested	16.0	20.1	23.9
2	Leaves	Wilted (26 hr)	36.1		
2	Tops	Freshly harvested	11.5	13.9	15.8
2	Tops	Wilted (24 hr)	25.4		
2	Stems	Freshly harvested	9.0		
2	Whole plant	Conditioned and wilted	23.8		
2	Stubble	Rice straw	38.8		
2	Tops	Freshly harvested King grass	22.4		
3	Whole plant	Freshly harvested King grass	11.6, 10.4		
3	Whole plant	Freshly harvested Setaria	17.0		
3	Whole plant	Freshly harvested Glyricidia	25.9		

The degree of wilting differed markedly between Sites 1 and 2, in that wilting in Site 1 removed 4% to 7% of the original water in the freshly harvested forages whereas the longer duration of sunshine at Site 2 removed 16% to 24% of the original water.

The lowest dry matter content in any of the freshly harvested whole plants was in King grass, with only 10% to 11% DM. Clearly the dry matter intake of such material would be severely reduced unless the material was wilted prior to feeding.