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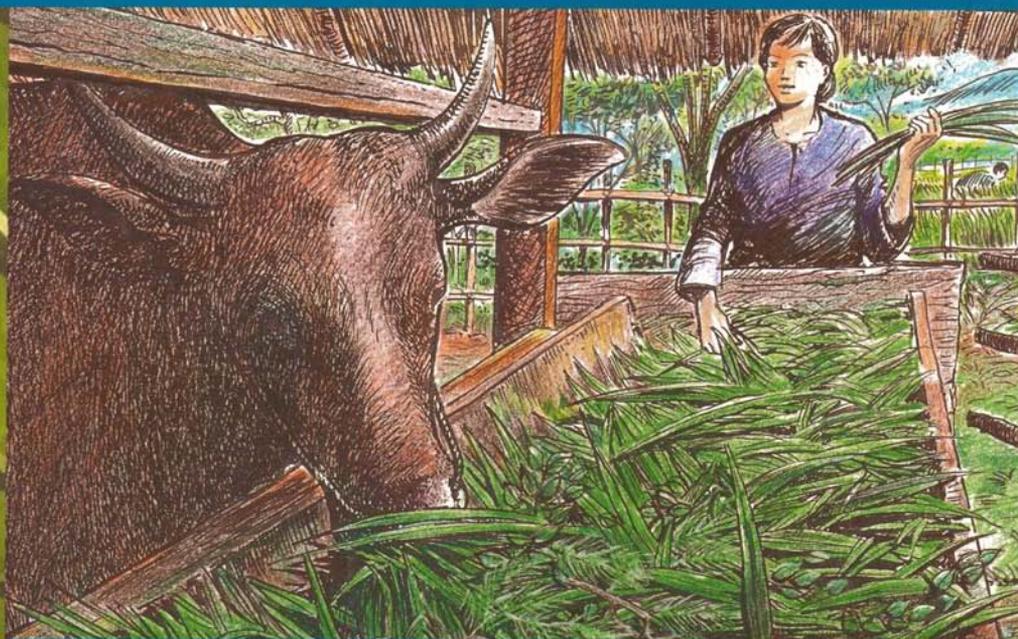
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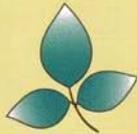
# Developing forage technologies with smallholder farmers

How to grow, manage and use forages



Werner W. Stür and Peter M. Horne

Published by ACIAR and CIAT.  
ACIAR Monograph No. 88



## **The Forages for Smallholders Project (FSP)**

The Forages for Smallholders Project (FSP) is a network of smallholder farmers, development workers and researchers in Indonesia, Lao PDR, Malaysia, Philippines, Thailand, Vietnam and southern China. The focus of the project is to develop forage technologies in partnership with smallholder farmers in upland areas, where forages have potential to improve livestock feeding and management of natural resources.

From 1995 to 1999, the FSP was funded by AusAID (Australian Agency for International Development) and managed by CIAT (Centro Internacional de Agricultura Tropical) and by CSIRO Tropical Agriculture (the Commonwealth Scientific and Industrial Research Organization of Australia). The Asian Development Bank (ADB) is providing funding for a new phase of the Project which commenced in January 2000 with CIAT as the managing agent.



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This booklet is the second in a series of booklets aimed at development workers. The first in the series was 'Developing forage technologies with smallholder farmers how to select the best varieties to offer farmers in Southeast Asia'. A third booklet- 'Developing agricultural solutions with smallholder farmers – participatory approaches for getting it right the first time' is in preparation. All of these booklets will be available in Chinese, English, Indonesian, Lao, Thai and Vietnamese.



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# Acknowledgments

This booklet is based on the experiences of researchers and farmers working with the AusAID-funded Forages for Smallholders Project (FSP) in Southeast Asia from 1995 to 1999. This project was a partnership of smallholder farmers, development workers and researchers who were using participatory approaches to developing forage technologies on farms (see inside cover for details). These initiatives are continuing through a regional project funded by the Asian Development Bank (ADB) and a bilateral project in Lao PDR funded by AusAID.

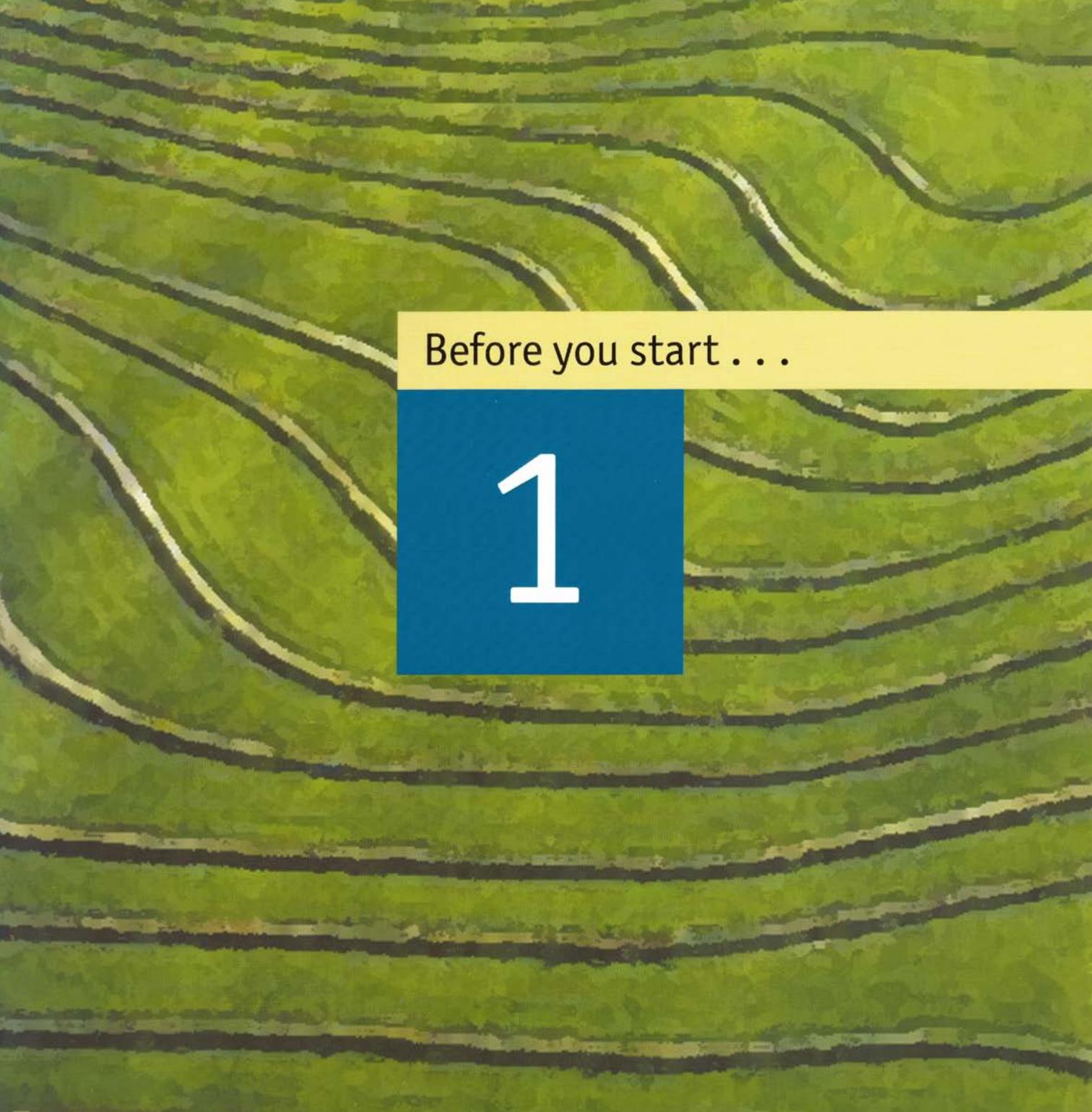
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The excellent cartoons which contribute so much to the informal feel of the booklet were drawn by Dave Daniel.

The publication of this booklet has been generously funded by ACIAR and we thank Peter Lynch for his encouragement.

An aerial photograph of terraced green hills, likely a rice paddy field, with a yellow banner at the top and a blue square containing the number 1 in the center.

Before you start . . .

1

## Forages - providing solutions for smallholder farmers!

Smallholder farmers traditionally have fed their animals on freely-available forage resources which have no value to smallholders except as livestock feed. These include crop residues and natural vegetation such as grasses, herbs and tree leaves. As livestock numbers and cropping areas have increased these once abundant feed resources have become increasingly limited. Consequently, farmers have to spend more time feeding their animals, either by grazing them in distant areas or by cutting feed far from their homes. Many farmers are facing the dilemma of whether to reduce the number of animals they keep or to find new feed resources. Supplementing traditional feed resources with planted forages is a simple solution to this problem.



Returning from grazing in communal grassland in Sepaku, Indonesia. [JH]

For most farmers planting forages is a new concept. It is not like evaluating a new variety of rice. Most farmers in Southeast Asia have never before considered planting feed for their animals. When offered new forages, they will commonly ask: 'Will these forages grow well on my farm?' and 'Will my animals like these forages?' To answer these questions farmers usually start by planting forages in small plots near their houses. Only when they are convinced of the benefits of forages as livestock feed, will they look for



ways of expanding their forage area and integrating forages with other crop and farm activities. Some will grow forages purely for livestock feed, such as in cut-and-carry plots. Others will grow forages in ways that provide additional benefits such as growing forages in contour hedgerows which not only provide livestock feed but also reduce soil erosion.

This process of working with farmers to integrate forage technologies into their farming systems is described in detail in another booklet in this series 'Developing agricultural solutions with smallholder farmers - participatory approaches for getting it right the first time'.

This booklet focuses on issues facing smallholder farmers in low-input upland systems. We have written it specifically for development workers who are providing these farmers with the information and the planting material they need to develop forage solutions on their farms. It does not attempt to cover all aspects of forage agronomy and seed production but aims to provide development workers with a tool box of information, methods and ideas to help them get started and respond to new situations as they emerge.



Forages can provide substantial benefits to farmers. [NR]

## How can forages help farmers?

The main problems that forages can help farmers solve are:

### **General feed shortages**

There are many forages that can be planted to provide additional feed throughout the year. Often these are planted in cut-and-carry plots near animal pens but there are many other ways of planting forages on farms which will help to increase feed availability.

### **Dry season feed shortages**

Often the main problem with feeding animals in the dry season is not a lack of feed but the poor quality of the available feed. The utilisation of these low-quality feeds can be improved by giving animals a protein supplement such as leaves of tree legumes.

### **Not enough labour for feeding animals**

Planted forages can provide easily-available feed at times when labour is in short supply. Often these are cut-and-carry plots planted close to animal pens.

### **Declining soil fertility of crop land**

Planting forages enables farmers to keep their animals in pens for longer periods and therefore collect manure easily. This manure can be used as fertiliser to improve crop yields. The use of forage legumes in cropping systems, for example as improved fallows, supplies nitrogen for soil improvement in addition to supplying high-quality feed for animals. Grasses can also improve soil fertility by increasing soil organic matter.



Cut-and-carry forages near the house. [WS]

## Soil erosion

Forages can be planted in many ways to stop erosion, such as contour hedgerows and ground covers.

## Weeds in annual and tree crops

Some forage legumes are well adapted to be grown as cover crops in annual and tree crops, controlling weeds and improving soil fertility.

## Protection of animals from theft and injury

Animals that graze far from villages are more vulnerable to injury or theft. If forages are grown close to the house animals can be more easily protected.

## Damage to crops from wandering animals

Uncontrolled grazing of livestock is a major problem for farmers in upland areas of Southeast Asia. Wandering animals frequently cause damage to crops and trees. Planting forages gives farmers options for better control of their livestock because of easier access to feed. Living fences can also be used to delineate field boundaries and protect crops from wandering animals. Tree legumes can be incorporated into living fences to provide the benefits of high-protein feed and fuel wood.

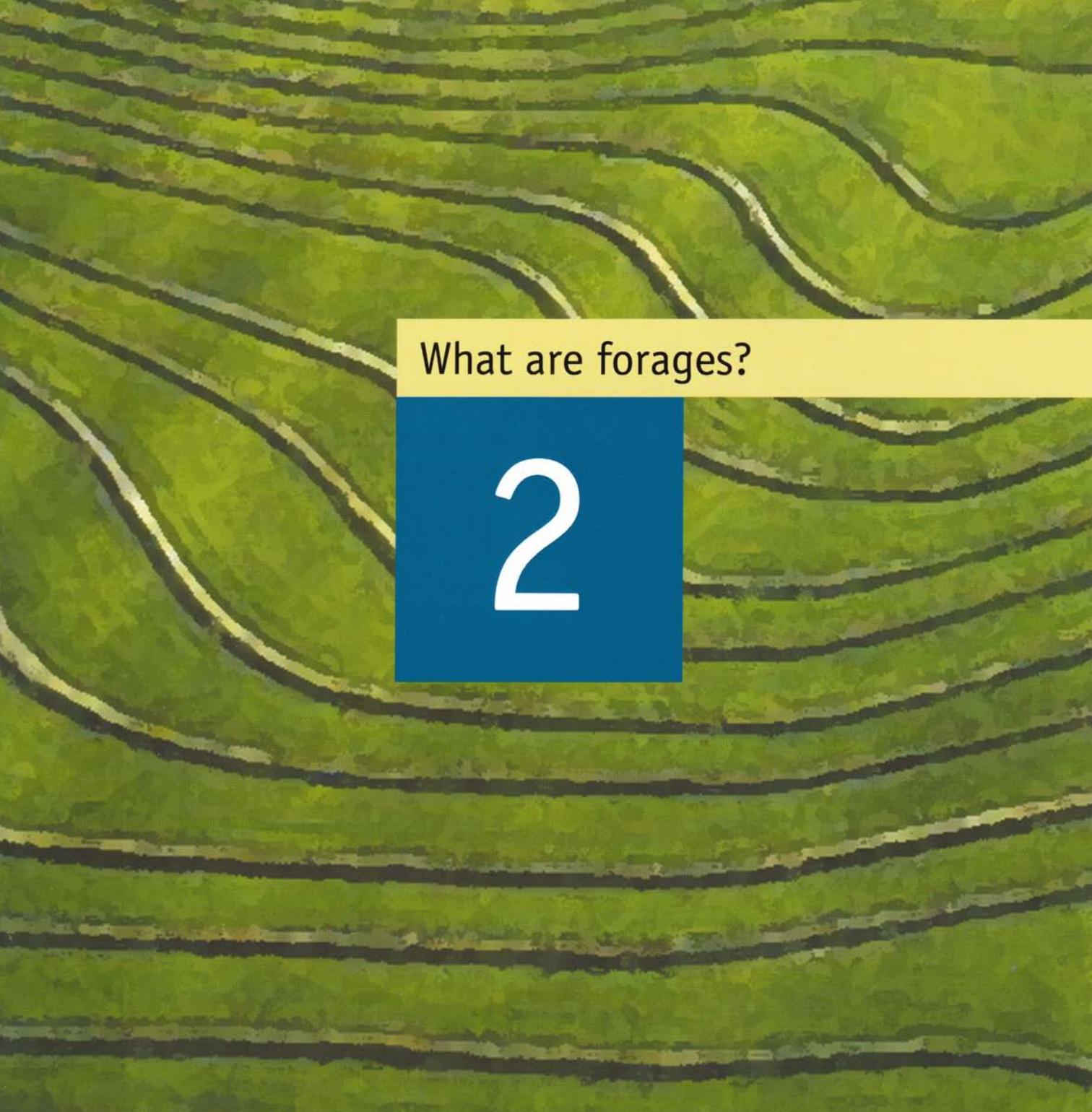


Forages can be planted to reduce soil erosion. [WS]



Planted forages can save labour. [JH]

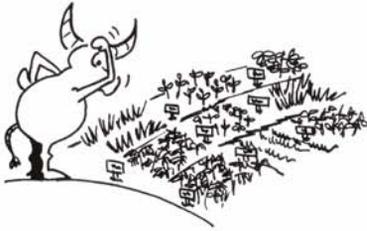
Farmers will continue to use natural vegetation, crop residues and crop by-products as animal feed. The current role of planted forages is to supplement the existing feed resources. As farmers experience the benefits of planted forages, some may choose to use forages to intensify their livestock production, such as moving into smallholder dairy production or cattle fattening.

An aerial photograph of terraced green hills, likely a rice paddy field, with a winding path or stream cutting through the terraces. The hills are covered in lush green vegetation, and the path is a light-colored, narrow strip that curves through the landscape.

What are forages?

2

# What are forages?



*Brachiaria humidicola* 'Yanero'. [WS]



*Paspalum atratum*  
'Terenos'. [WS]

Forages are grasses and legumes that can be used for feeding animals and for better management of the environment. There are many species of grasses and legumes and each of these species can have one or more varieties. Another booklet in this series 'Developing forage technologies with smallholder farmers - how to select the best varieties to offer farmers in Southeast Asia' provides more details on how to select the varieties that are best adapted to the soil, climate and the needs of the farmer.

**Take Note!**



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*It is important to offer farmers a 'basket of choices' (several forage varieties), not only one variety.*

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Grasses and legumes come in many different forms:

## Grasses

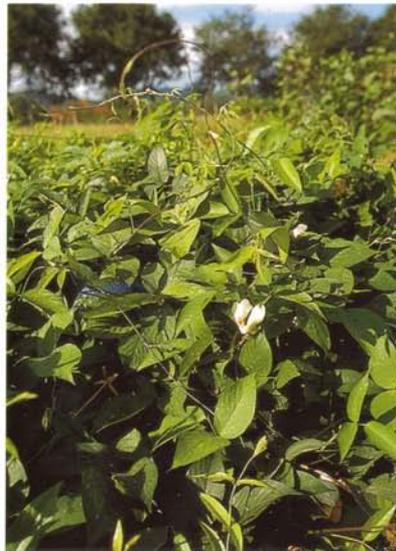
- Short, spreading grasses with horizontal stems (stolons and rhizomes) which grow roots and can form new plants (e.g. *Brachiaria humidicola*).
- Tussock grasses which form distinct clumps (e.g. *Paspalum atratum*).

## Legumes

- Short, spreading legumes with horizontal stems (stolons and rhizomes) which grow roots and can form new plants (e.g. *Arachis pintoi*).
- Twining legumes (e.g. *Centrosema macrocarpum*).
- Erect bushy legumes (e.g. *Stylosanthes guianensis*).
- Shrub legumes (e.g. *Desmodium cinerea*).
- Tree legumes (e.g. *Calliandra calothyrsus*).



*Arachis pintoi* 'Itacambira'. [JH]



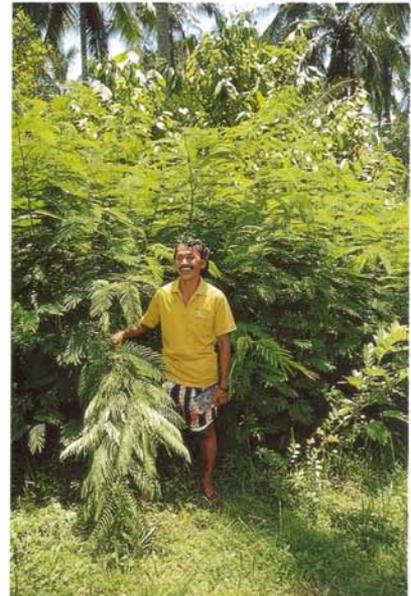
*Centrosema macrocarpum* 'Ucayali'. [JH]



*Stylosanthes guianensis* 'Stylo 184'. [WS]



*Desmodium cinerea* 'Las Delicias'. [WS]



*Calliandra calothyrsus* 'Besakih'. [WS]

The growth form and life span of forages affects how they can be grown and used on farms. For example, short stoloniferous grasses and legumes are particularly well suited to grazing and erosion control. Tall, upright grasses are easy to cut and can be grown in hedgerows. Long-lived tree legumes are ideal for living fences. The ways of growing different types of forages on farms are described in the section 'Where can forages be grown on farms'.

## Why do we need both grasses and legumes?

### Grasses give higher yields

Grasses produce more biomass than legumes and are the main feed for ruminant livestock (see Table below). Yields of grasses range from 400 - 2,000 kg of fresh, green feed for every 100 m<sup>2</sup> per year depending mainly on soil fertility and rainfall distribution.

*Take Note!*



*Dry matter (DM) yields of forage are approximately 20-25% of the fresh, green feed.*

Grasses give higher yields than legumes.

Soil fertility level	Grasses	Legumes
	(kg of green feed per 100 m <sup>2</sup> per year)	
low fertility	200 - 400	100 - 200
medium fertility	400 - 1000	200 - 300
high fertility	1000 - 2000	300 - 600

## Legumes improve feed quality and soil fertility

Animals need a lot of protein to grow well, work hard or produce milk. They can get some protein from grasses, but in most cases this is not enough for good growth. Legumes can provide this extra protein, as they have much higher levels of protein in their leaves than grasses (see Table below). Legume leaves also provide essential minerals and vitamins for animal growth.



Animals need a lot of protein to grow well, work hard or produce milk. [JH]

### Legumes have more protein than grasses

	Grasses	Legumes
Protein (%) <sup>1</sup>	5 - 15	15 - 25
as N (%) <sup>1</sup>	0.8 - 2.4	2.4 - 4.0

<sup>1</sup>Conversion from N % to protein % = N % x 6.25

These higher levels of protein are the result of 'nitrogen fixation' and can improve both animal production and soil fertility. Legumes return nitrogen to the soil through fallen leaf, old nodules and through manure and urine of grazing animals.

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### *Nitrogen fixation*

*Forage legumes are plants that can convert nitrogen in the air into protein. This process is called 'nitrogen fixation'. Legumes 'fix' nitrogen through a relationship with special bacteria, called Rhizobium, that live in nodules attached to the plant's roots. Active nodules are usually pink when cut open.*

---



**Take Note!**

In some circumstances it may be possible to support good livestock production using only grass, but only if the grass is well fertilised, cut or grazed frequently and irrigated. This is rarely possible on smallholder farms in Southeast Asia.

Legumes are an ideal supplement to low-quality grasses or crop residues, particularly in the dry season.

## Should we grow grasses and legumes in mixtures?

Mixed grass-legume pastures are common in temperate climates (e.g. rye grass - clover mixtures), where the legume provides additional protein for animals and nitrogen for the pasture through manure and urine. In Southeast Asia, farmers seldom mix grasses and legumes in the same plot or row. Tropical grasses and legumes have very different growth habits and are mostly difficult to manage together. One exception is *Arachis pintoi* which grows well in mixtures with grasses. There are many other options for integrating forage legumes on smallholder farms in tropical areas (see Section 6).

**Take Note!**



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*Grass-legume mixtures are seldom used on smallholder farms in Southeast Asia. There are many other options for integrating forage legumes on farms.*

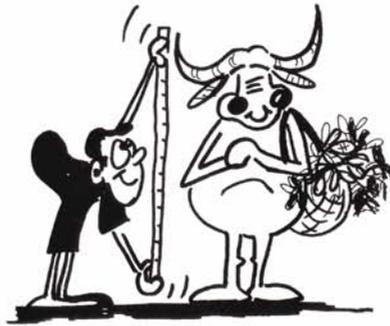
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An aerial photograph of terraced green hills, likely a tea plantation, with a winding road or path cutting through the terraces. The hills are covered in vibrant green vegetation, and the terraces are separated by dark, narrow paths.

How can forages help improve the nutrition of farm animals?

3

# How can forages help improve the nutrition of farm animals?



Forages are the primary feed of ruminants but they can also be fed to monogastric animals such as pigs and poultry. Monogastric animals can only eat small amounts of forage and need other high-energy feeds to grow well. For example, dried legume leaf meal made from *Stylosanthes guianensis* 'Stylo 184' is used in feed rations for chickens (3 - 5%) in southern China. Another legume commonly used to produce dried leaf meal is *Leucaena leucocephala*. Fresh legume can be fed to chickens, ducks, pigs and other monogastric animals in small quantities. Fresh grass and legume leaf can be fed to plant-eating fish such as grass carp.



Feeding 'Stylo 184' to pigs in Vietnam. [WS]

Introduced forages such as *Panicum maximum* 'Si Muang' and *Paspalum atratum* 'Terenos' are important feed sources for fish in northern Vietnam.



Feeding 'Si Muang' to grass carp. [PK]

Ruminants such as cattle, buffalo, sheep and goats can survive eating only low-quality feeds such as naturally occurring grasses, crop residues and tree leaves.

## Why can ruminants survive eating only low-quality feed?

Ruminants have a large stomach ("the rumen") which contains a liquid mixture of bacteria, protozoa and fungi that help break down the fibrous parts of the plants they eat.

In simple terms, think of the rumen as being a large drum for digesting fibrous plants. The drum has a hole at the front end for letting in the chewed feed, and an exit to pass the partially digested material to the rest of the digestive system where more nutrients are absorbed.

If the feed eaten has a high digestibility (e.g. young, leafy grass) it can be broken down quickly, making space in the rumen which allows the animal to eat more feed. However, if the feed eaten has a low digestibility (fibrous feeds such as rice straw) it will take a long time to break down, the rumen will fill up and the animal will not be able to eat any more until the feed in the rumen is broken down. Therefore, the rate of feed intake by ruminants is limited by the time it takes for the feed in the rumen to be digested.



*Young leaves*



*Old leaves and stems*



---

*The rate of feed intake by ruminants is limited by the time it takes for the feed to break down in the rumen.*

---



**Take Note!**



## How much feed do ruminants need to eat?

To grow well, the amount of good-quality, dry feed ruminants need to eat is approximately 2.5 - 3.5 % of their body-weight each day. This is equivalent to 10 -15 % of their body-weight in fresh forage each day. A cow weighing 300 kg needs to eat 7 - 10 kg of dry matter each day, which is equivalent to 30 - 45 kg of fresh forage.

## What is a good-quality feed?

A 'good-quality' feed is

1. palatable,
2. easily digested, and
3. high in protein.

**Take Note!**



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*Young forages are more palatable, digestible and nutritious than old forages.*

---

## 1. What is palatability?

The 'palatability' of a forage is how much animals like to eat it. Some plants are obviously unpalatable and rejected by all animals. This may be because they have a bitter taste, a strong smell, too much stem, sharp leaves or are



old and tough. Some animals find particular forages palatable while other animals do not. The tree



legume *Gliricidia sepium*, for

example, is always eaten by goats and sheep but is often rejected by cattle, who are not used to it. Animals are cautious when given a new feed but can get used to its taste with time (1-2months). Farmers commonly mix feeds and this helps animals adapt to new feeds. Animals also learn to eat new feeds from other animals that are eating these feeds.

## 2. What is digestibility?

The 'digestibility' of a feed is the percentage of the feed which is broken down and absorbed by the animal. This is affected by the:

- plant parts - leaves are more digestible than stems;
- age of the forage - young forages are more digestible than old forages;
- species - some grasses and legumes are more digestible than others. Forage legumes are generally more digestible than grasses.



### 3. Why is protein important?

Protein is essential for:

- Efficient break-down of feed in the rumen. If the diet is poor (protein level less than 7%) the micro-organisms in the rumen cannot break down the feed efficiently and the animal loses weight.
- Growing and productive animals. If we only want to maintain an animal's condition, a small amount of protein is enough. If we want the animal to grow quickly, work hard or produce milk then much more protein is needed in the diet.

### What do ruminants need to grow well?

Ruminants need large quantities of good-quality feed. Without this, they will not grow quickly or be able to work hard. Cows will not produce enough milk for their calves and will not produce as many calves. If ruminants are fed low-quality forage (or other low-quality feed), which breaks down slowly in the rumen, they cannot eat enough feed to grow well, work hard or produce enough milk for young animals (see following Figure on page 27).

The relationship between forage quality and animal production

If you feed your animals forages that are			
you will get . . .	mainly old grass (leaf and stem)	mainly young grass (leaf and stem)	mainly young grass and legume (leaves only)
Feed quality	low	medium	high
Digestibility of feed	low	moderate	high
Breakdown rate in the rumen	slow	moderate	fast
Daily DM feed intake as % of body weight	less than 1.5%	1.5% - 2.5%	2.5% - 3.5%
which will give . . .			
	POOR animal production	MODERATE animal production	GOOD animal production



## How can farmers use forages to make their animals grow better?

Some simple feeding practices can improve animal production:

1. Ensure that animals have constant access to feed.
2. Provide good quality feed.
3. Ensure that animals can select what they eat.
4. Provide protein supplements.
5. Provide better dry season feed.
6. Give the best feed to the most productive animals.

### **1. Ensure that animals have constant access to feed**

Ruminants cannot eat continuously but need times to "ruminates" (regurgitate some of the feed, chew it some more and swallow it again to assist breakdown of the feed). Just because an animal has stopped eating, it does not mean that it has had enough to eat. Up to 50% of feeding time can be taken up with ruminating.



To grow well animals need access to good-quality feed day and night. This rarely happens on smallholder farms in Southeast Asia. Either the animal is not allowed to graze all day or the quality of the forage is poor. Animals that are tethered on short ropes and are not moved frequently, do not get enough feed. If the existing forage resource is of poor quality or too short or sparse to allow the animal to get a good amount of forage with each bite, a longer time is needed for grazing (see Table below).



Animals need to have feed in their trough all the time. [JH]

**Ruminants need longer to graze on poor-quality forages than good-quality forages**

Forage quality	Grazing time needed per day
Good	6-9 hours
Poor	10-12 hours

---

*If you want your animals to grow better ensure that they have continuous access to feed by:*

- *allowing them to graze for as long as possible;*
  - *cutting extra feed for animals to eat at night;*
  - *ensuring that animals which are kept in pens day and night (e.g. goats or sick cattle), have good quality feed in their trough all the time.*
- 



*Try this idea!*



## 2. Provide good quality feed

To ensure that animals eat good-quality forage:

### **Offer young forages instead of old forages**

Young forages are leafy and the stems are still soft. Leaves are more digestible and nutritious than stems. Older forages have a higher yield but much of this is unpalatable, low-quality stem.

### **Add legumes to the diet**

These provide extra protein, minerals and vitamins.

### **Provide a mixture of different forages**

It is a common practice for farmers to mix leaves of many plants when feeding cut-and-carry forage. This provides a healthy balance of nutrients and introduces animals to nutritious feed which they may otherwise reject.

Some farmers chop up low-quality feeds (for example mature 'Napier' grass or maize stems) to make them palatable. Although chopping stems will enable animals to eat it, chopping does not improve its nutritive value. The result will be low animal production unless high-protein and high-energy feed supplements are provided.



Feed young forage for good growth. [JH]



### 3. Ensure that animals can select what they eat

Ruminants are surprisingly selective in what they eat (see Table below). When grazing a low-quality feed resource or eating cut feed, ruminants select the best parts (such as young leaves) first and, if offered enough, they end up with a better quality diet. It is important to give animals the opportunity to select what they eat.

Animals select the best parts from the feed on offer

Feed characteristic	Average quality of feed	
	offered	eaten
Leaf (%)	25	93
Nitrogen (%)	1.2	2.5
Digestibility (%)	45	65

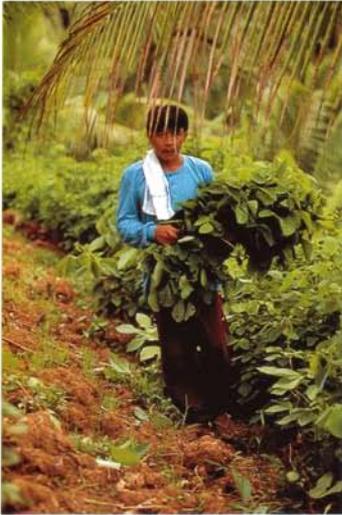
An example from dairy cows grazing tropical pastures

*How do you know that you are giving your animal enough feed?*

*If your animal eats all the feed you have given it, including the poorer parts such as stems, then you have not given it enough! To grow well animals must be able to select the best parts of a feed.*



*Try this idea!*



Collecting legume leaf for cattle in the Philippines. [JH]

#### 4. Provide protein supplements

Most grasses do not have enough protein to support good animal production. Protein supplements, such as peanut hay and rice bran, may be available on farm. They can also be bought as a mixed concentrate or as single products such as fish meal. For smallholder farmers these protein sources are often not available or too expensive. An alternative source of protein on smallholder farms is forage legumes which can be fed fresh or in dried form, as hay or leaf meal.



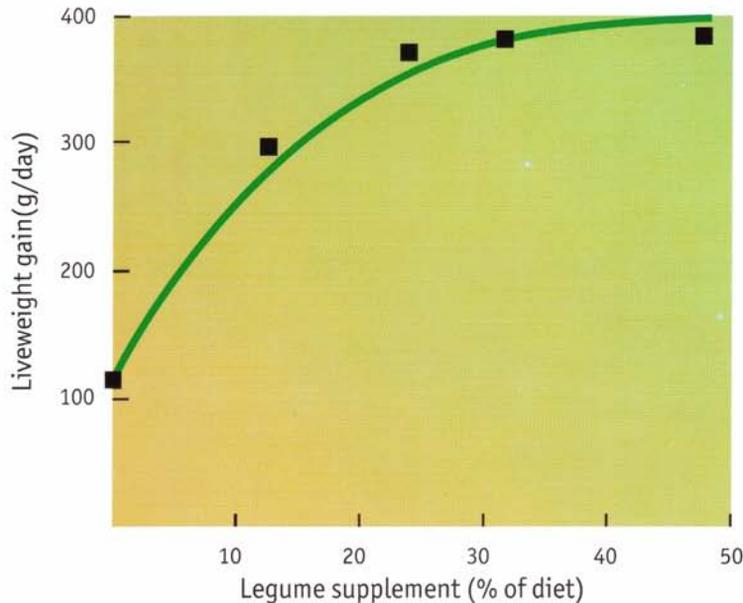
It is often recommended to feed ruminants a diet that contains 10-30% legume leaf. While 30% is ideal, even small quantities of legume leaf in the diet can give large improvements in animal production. In the example (see the following Figure on page 33) of feeding *Gliricidia sepium* leaf to young bulls, adding 10% legume leaf to the diet had a large effect, doubling liveweight gain. Adding more than 30% gave little extra benefit.

**A Question!**



*How much legume leaf should I feed to my animals?  
10-30% legume in the diet can more than double  
animal production.*

### Legume supplementation can greatly improve liveweight gain of cattle



An example of *Gliricidia sepium* leaf supplementation on the growth of young bulls given a basal diet of 'King' grass.



Sheep like tree legume leaves (here *Gliricidia sepium*). [WS]

Legume supplementation benefits animal health. It also increases feed intake and production of milk in lactating mothers. This improves the chances of survival and growth of their offspring. In the example (see following Table on page 34), supplementing ewes with 25% of legume leaf in the diet increased lamb birth-weight, survival and growth. Feeding 50% legume in the diet gave no extra benefit.

---

***Even small amounts of good-quality legume in the diet give large benefits!***

---



**Take Note!**

### Survival of young animals improves with legume supplementation of their mothers

Legume leaf (%) in diets of ewes	Lamb survival (%)	Average weight of lambs (kg)	
		at birth	after 15 weeks
0	33	1.2	5.4
25	75	1.9	9.9
50	75	1.9	10.0

An example of the effects of supplementing ewes with *Gliricidia* leaves on lamb survival and growth.

## 5. Provide better dry season feed

The problem with feeding animals in the dry season is not only a lack of feed but also the poor quality of the available feed.

The utilisation of low-quality feeds in the dry season can be improved by:

### **Growing forages that can keep green leaf into the dry season**

Some forages are able to keep green leaves longer into the dry season than other forages. Examples are *Brachiaria decumbens*, *Andropogon gayanus* and *Stylosanthes hamata*.



### Growing tree legumes as a protein supplement

Some tree and shrub legumes, such as *Leucaena leucocephala*, have root systems that can reach moisture deep in the soil. This allows them to grow and retain their leaves long into the dry season. These are an excellent supplement to crop residues and crop by-products such as sugarcane stems which are a useful energy source but lack protein.

### Conserving legumes as hay or dried leaf meal

Legumes can be harvested, dried and chopped during the wet season to produce dried leaf meal and this can be either sold or used on farm to provide additional protein during the dry season. Legumes commonly used for leaf meal production are *Stylosanthes guianensis*, *Desmanthus virgatus* and *Leucaena leucocephala*.



Feeding *Calliandra calothyrsus* 'Besakih' to cattle (Bali, Indonesia). [WS]

---

*There are no miracle forages that are productive throughout a long dry season.*

---



**Take Note!**



## 6. Give the best feed to the most productive animals

Only when forage is of high quality can it supply enough nutrients for high animal production. Cows with calves, bulls for fattening or working animals require more better quality feed than non-productive animals.

The example (see Table below) shows that milk production is very sensitive to forage quality. Feeding low-quality forage has reduced feed intake from 9.5 - 7.5 kg per day and milk production from 5 litres to 1 litre per day.

**Milk production is much higher with higher quality feed**

Forage type	Protein content (%)	Digestibility (%)	Feed intake (kg DM/day)	Milk production (litres/cow/day)
Legume+ young grass	12	60	9.5	5
Grass only	8	50	7.5	1

An aerial photograph of terraced green hills, likely a vineyard or agricultural field, with a winding path or road cutting through the rows. The hills are covered in lush green vegetation, and the path is a light-colored, narrow strip that curves through the landscape.

What other benefits can forages provide on farms?

4

# What other benefits can forages provide on farms?



Living fences can protect crops (Aceh, Indonesia). [WS]



*Leucaena leucocephala* provides good firewood. [PH]

Forages can improve the management of natural resources on farms by:

1. reducing soil erosion,
2. improving soil fertility, and
3. controlling weeds.

Farmers also use forages to overcome particular problems on their farms, such as:

- Reducing the labour required to look after animals by planting forages near their houses is one of the most frequent reasons farmers give for adopting forage technologies. Planting forages near the house reduces the time required to cut and collect feed for sick, pregnant or working animals or for animals that are penned when crops are being planted or harvested.
- Protecting crops from wandering livestock by planting forage trees in fence lines around their fields.
- Providing firewood for cooking by planting tree legumes as an alternative source of fuel to timber from forests.

- Providing cash income by planting forages to sell planting material or animal feed (e.g. fresh forage or dried legume leaf meal)

## 1. How can forages be used to reduce soil erosion?

Forages grown in hedgerows, as ground covers and as cover crops can be very effective in reducing water run-off and soil erosion. Forage grasses can be planted in gullies to control erosion.



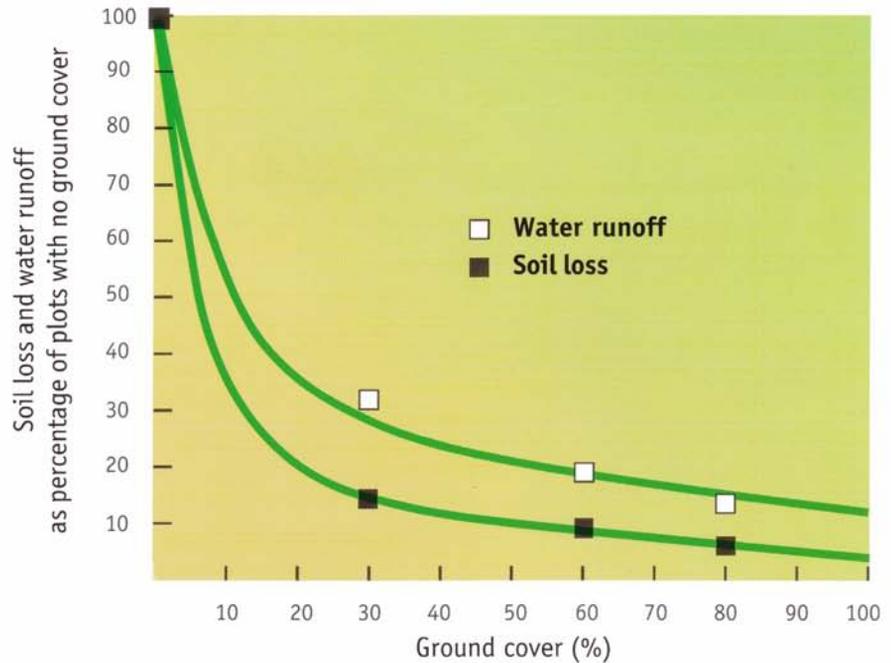
Some farmers are able to sell forages for feed or planting material. [WS]



Contour hedgerows are very effective in reducing soil erosion (East Kalimantan, Indonesia). [WS]

The following figure shows how forages, providing 80% ground cover, reduced erosion to 5% of that on bare plots. Even 30% legume ground cover reduced soil loss substantially. Water runoff was greatly reduced, increasing the availability of soil moisture for crops.

Even small areas of forage can greatly reduce soil erosion and water runoff



An example where forage legumes were grown in small plots giving different amounts of ground cover.



## 2. How can forages be used to improve soil fertility?

Many farmers plant forages near their houses so they can keep their animals closer to home. This has many benefits but one of the most important is that manure is concentrated and collected more easily. Farmers can use this manure to improve the yield of vegetables, food crops, fruit trees and forages. Often, manure is the only fertiliser available for sustaining agricultural production in remote upland areas.

Another way to improve soil fertility is by planting forage legumes to provide additional nitrogen to the farming system. Forage legumes can substantially improve soil fertility, but only if a substantial amount of the leaf is returned to the soil as litter or mulch. A more common way of using forage legumes to improve soil fertility is to feed the legume leaf to animals and use the manure as fertiliser.



Manure collection system (Sepaku, Indonesia). [WS]



Manure improves soil fertility and crop yields (Palawan, Philippines). [JH]

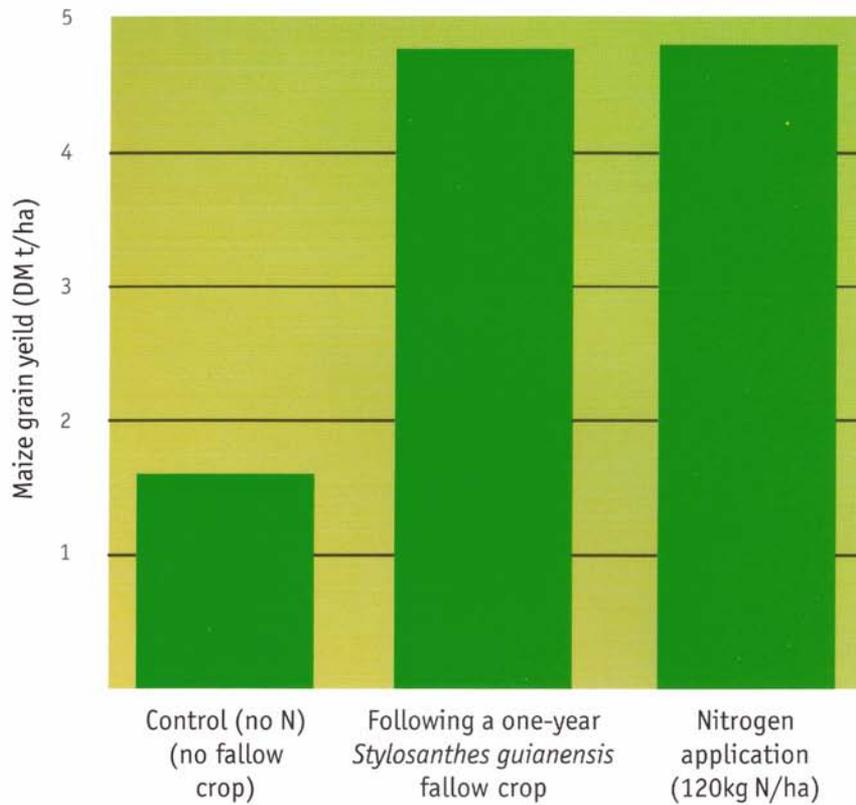


'Stylo 184' grown as a cover crop or improved fallow (Marenu, Indonesia). [WS]

The following figure shows the benefit of an improved legume fallow on soil fertility as compared with a natural fallow. The legumes were used for feed for 8 months and the following 4-month regrowth was incorporated into the soil before planting a maize crop. Grain yield of maize, following the one-year *Stylosanthes guianensis* fallow, was 4.8 t/ha compared with only 1.7 t/ha following the natural fallow. The nitrogen contribution of the legume fallow was equivalent to 120 kg/ha of nitrogen.

Forage grasses can also significantly improve soil fertility, particularly in very poor soils. Their strong, fibrous root systems improve soil structure, efficiently extract nutrients and increase organic matter content through breakdown of roots and leaves. For centuries, ley farming systems (pasture fallow systems) have used these benefits of grasses to sustain crop yields but have been lost in modern agriculture.

**Even short legume fallows can greatly increase yield of subsequent crops**



An example from an experiment comparing the effects of different legume fallow crops on subsequent maize yield.

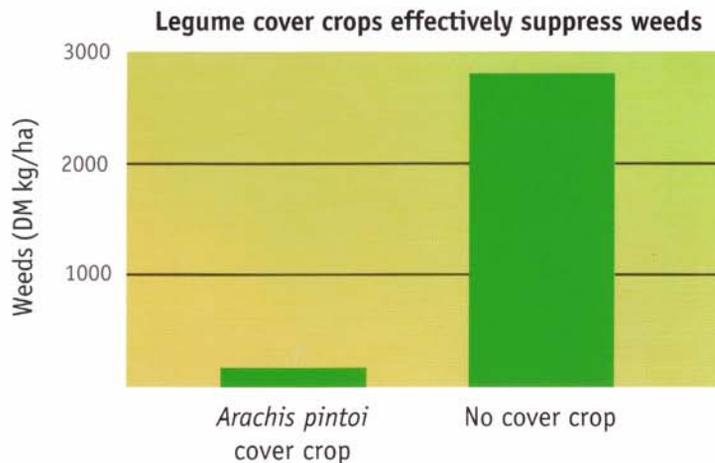


*Arachis pintoi* 'Itacambira' effectively controls weeds (Guba, Philippines). [WS]

### 3. How can forages be used to control weeds?

Forage legumes grown as fallows and cover crops can control weeds in cropping areas and under tree crops.

An example is a cover crop of *Arachis pintoi* which controlled weeds in a coffee plantation (see Figure below). Two months after the last round of weeding, the cover crop effectively suppressed weed growth while the natural vegetation (weeds) had increased to almost 3 t/ha in areas without cover crop.



An example of *Arachis pintoi* grown as a cover crop in a coffee plantation.

An aerial photograph of a terraced agricultural field. The rows of crops are arranged in wavy, undulating lines that follow the contours of the land. The colors range from vibrant green to a darker, almost blackish-green, suggesting different crop types or stages of growth. The overall pattern is rhythmic and organic.

How should forages be planted?

5

# How should forages be planted?



Rooted tillers of *Setaria sphacelata* 'Lampung'. [WS]



Seed of *Centrosema pubescens* 'Barinas'. [JH]

Establishing forages is simple, but often farmers have never planted forages before and so they may initially need some advice. As farmers are experts in growing crops, vegetables and trees we do not have to explain to them how to grow plants! All they will want to know are the particular requirements of forages.

Forages can be planted from seed or from vegetative materials such as stem cuttings, stolons and rooted tillers (see Tables on pages 47 and 48).

Most legumes can be reliably established from seed. Establishing grasses from seed is less reliable because grass seed is:

- difficult to store for long periods without losing viability,
- small and slow to establish,
- sometimes of poor quality because seed production of grasses can be difficult in the humid tropics,
- easily washed away by heavy rain, and
- often stolen by ants after sowing.

Well-developed forage seed production and distribution systems exist in some countries such as Thailand. These help overcome many of the difficulties and have made establishing grasses from seed a good option for smallholders in those areas.

#### Easy ways to plant the recommended grass varieties

Grasses	Stem cuttings	Stolons	Rooted tillers	Transplanted seedlings <sup>(1)</sup>	Direct sowing of seed
<i>Andropogon gayanus</i> 'Gamba'			••		•
<i>Brachiaria brizantha</i> 'Marandu', 'Karanga', 'Serengeti'			••		••
<i>Brachiaria decumbens</i> 'Basilisk'			••		•
<i>Brachiaria humidicola</i> 'Tully', 'Yanero'		••	•		•
<i>Brachiaria mutica</i> 'Para'		••	•		
<i>Brachiaria ruziziensis</i> 'Ruzi'		•	•		••
<i>Digitaria milanjiana</i> 'Jarra'		••	•		•
<i>Panicum maximum</i> 'Si muang'			••		••
<i>Paspalum atratum</i> 'Terenos'			••		••
<i>Paspalum guenoarum</i> 'Bela Vista'			••		••
<i>Pennisetum purpureum</i> 'Napier', 'Mott', and <i>Pennisetum</i> hybrids 'King'	••		•		
<i>Setaria sphacelata</i> 'Solander'			••		••
<i>Setaria sphacelata</i> var. <i>splendida</i> 'Lampung'			••		
<i>Stenotaphrum secundatum</i> 'Vanuatu'		••			

•• = highly recommended • = recommended no • = not recommended or not possible

<sup>1</sup>Most forages can be established from transplanted seedlings but for many there are easier alternatives.

### Easy ways to plant the recommended legume varieties

Legumes	Stem cuttings	Stolons	Rooted tillers	Transplanted seedlings <sup>(1)</sup>	Direct sowing of seed
<i>Arachis pintoi</i> 'Amarillo', 'Itacambira'		••			•
<i>Calliandra calothyrsus</i> 'Besakih'				••	•
<i>Centrosema macrocarpum</i> 'Ucayali'					••
<i>Centrosema pascuorum</i> 'Cavalcade'					••
<i>Centrosema pubescens</i> 'Barinas'					••
<i>Codariocalyx gyroides</i> 'Belize'					••
<i>Desmanthus virgatus</i> 'Chaland'					••
<i>Desmodium cinerea</i> 'Las Delicias'				••	•
<i>Flemingia macrophylla</i> 'Chumphon'					••
<i>Gliricidia sepium</i> 'Belen Rivas', 'Retalhuleu'	••			••	•
<i>Leucaena leucocephala</i> 'K636', 'K584'				••	•
<i>Macroptilium gracile</i> 'Maldonado'					••
<i>Sesbania grandiflora</i> 'Turi'				••	••
<i>Stylosanthes guianensis</i> 'Stylo 184'					••
<i>Stylosanthes hamata</i> 'Verano'					••

•• = highly recommended    • = recommended    no • = not recommended or not possible

<sup>1</sup>Most forages can be established from transplanted seedlings but for many there are easier alternatives.

## Planting from vegetative material

Smallholder farmers usually prefer planting from vegetative material as:

- it is easy and reliable (particularly for most grasses),
- it gives rapid establishment,
- weeding between rows is easy,
- land does not have to be fully cultivated,
- planting material is locally available, and
- it can even be planted late in the wet season while seed has to be sown early in the wet season.



Planting grasses from rooted tillers is easy and reliable. [JH]

Vegetative planting materials:

- should be planted as soon as possible after collection,
- must be kept moist and cool until planted, and
- establish best if planted when the soil is wet.

It is important to collect vegetative planting material from many plants to maximise genetic variation. This reduces the risk of susceptibility to disease and insect damage.

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*Farmers often prefer to establish forages using vegetative planting materials rather than seed.*

---



**Take Note!**



## Planting from seed:

### 1. use good-quality seed

Sowing poor-quality seed is a waste of time and money! How do we know if the seed is of good quality? Is there anything we can do to improve the quality of seed? This section helps you answer these questions.

To establish forages from seed, farmers need seed that is:

1. 'clean' and
2. able to germinate.

### What is meant by 'clean' seed?

Grasses tend to flower over a long time. At harvest time what looks like seed actually consists of a mixture of buds, flowers, empty seed structures and true seed (seed structures that contain a caryopsis). The true seeds will include some that are immature, but only those containing a mature caryopsis ('mature seed') have any chance to produce a seedling. All the rest is rubbish. Grass seed can be winnowed to remove this rubbish, leaving only the mature, 'clean' seed.

*Try this idea!*



---

*How do I tell if my grass seed is clean?*

*You can easily feel the hard caryopsis in mature seed by pressing the seed with your fingers. Immature seed structures are empty and can be removed by winnowing.*

---

Legumes are simpler because most seeds are 'naked' and what looks like seed, actually is seed. Also, there are usually fewer immature seeds and these are smaller, visibly shrivelled and easily cleaned by sieving.

## What germination percentage can we expect?

No forage seed will give 100% germination. You can expect 20-40% germination from clean grass seed and 40-80% germination from clean legume seed. Lower germination percentages than these could be the result of:

1. Dormancy in grasses.
2. Hard-seededness in legumes.
3. Poor storage conditions

### 1. Dormancy in grasses

Recently harvested seed of some grasses will not germinate immediately. This is called "dormancy" and will break down naturally by storing the seed for 3-6 months. There is no simple way to test grass seed for dormancy and it cannot be easily treated. In most cases dormancy is not a problem because seed harvested one year is not sown until the following year. Grasses that can have a strong dormancy are *Brachiaria brizantha*, *B. decumbens* and *B. humidicola*. One legume that can have a strong dormancy is *Arachis pintoi*.



Winnowing grass seed to leave only mature, clean seed. [WS]

*Panicum maximum* 'Si Muang'      *Centrosema pubescens* 'Barinas'



Legumes tend to have a higher germination percentage than grasses. [WS]



## 2. Hard-seededness in legumes

Seed of some legume species will not germinate quickly because it has a hard seed coat which prevents water entering the seed. If a high proportion of legume seed has a hard seed coat, initial establishment will be poor. The seed has to be treated to break the hard coat and allow water to enter (see page 59).

Seed treatment is not necessary if the germination percentage is more than 40%. Sowing a mixture of 'hard' and 'soft' seed can be an advantage since not all seed will germinate immediately. 'Hard' seed becomes 'soft' in soil and will germinate given enough time.

Not all legume species are hard-seeded. Legumes with no or little hard-seededness, such as *Arachis pintoi*, do not need to be treated before sowing. Other legumes (see Table on page 53) have varying degrees of hard-seededness and may need to be treated before sowing.



**Which legumes may have a hard seed coat?**

Species	Degree of hard-seededness
<i>Arachis pintoi</i> 'Amarillo', 'Intacambira'	—
<i>Calliandra calothyrsus</i> 'Besakih'	—
<i>Centrosema macrocarpum</i> 'Ucayali'	•
<i>Centrosema pascuorum</i> 'Cavalcade'	•
<i>Centrosema pubescens</i> 'Barinas'	•
<i>Codariocalyx gyroides</i> 'Belize'	•
<i>Desmanthus virgatus</i> 'Chaland'	••
<i>Desmodium cinerea</i> 'Les Delicas'	—
<i>Flemingia macrophylla</i> 'Chumphon'	•
<i>Gliricidia sepium</i> 'Belen Rivas', 'Retalhuleu'	—
<i>Leucaena leucocephala</i> 'K636', 'K584'	••
<i>Macroptilium gracile</i> 'Maldonado'	•
<i>Sesbania grandiflora</i> 'Turi'	—
<i>Stylosanthes guianensis</i> 'Stylo 184'	•
<i>Stylosanthes hamata</i> 'Verano'	••

— = no or low likelihood of a hard seed coat    • = may have a hard seed coat.

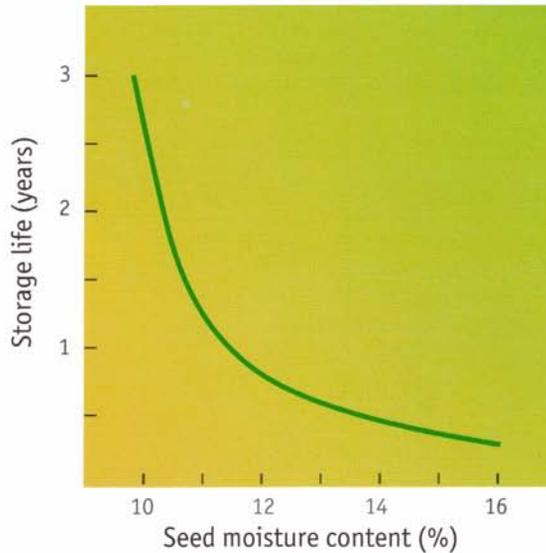
•• = very likely to have a hard seed coat.



### 3. Poor storage conditions

Seed is alive but it will die quickly if it is not dried properly and stored in dry, cool conditions. The most important factor is to keep the moisture content of the seed below 10%. For every percentage increase in seed moisture content above 10%, the storage life of seed is halved (see following Figure)!

Seed dies quickly if not stored in dry conditions



**Warning!**



---

*Seed is alive - make sure you keep it that way!*

*Seed left in an open bag on a desk or in a refrigerator will die quickly. Seed must be dry and sealed in thick plastic bags or tins.*

---

Forage seeds must be thoroughly dry before going into storage. Once in storage they must be protected from regaining moisture from the air. This is especially important for grass seeds (which are soft and absorb moisture easily) and for legume seeds which have been scarified so moisture can enter the seed easily. In humid conditions, this seed will quickly absorb moisture from the atmosphere and will die in as little as three months.

Careful attention must be given to packaging of dry seed to prevent it from absorbing moisture from the air. Thick, well sealed plastic bags or tins with air-tight lids provide a long-term practical solution, especially for small seed lots.

Storing seed in a cool place, such as an air-conditioned room or a refrigerator, can more than double the storage life of seed. However, the relative humidity in air-conditioned rooms and refrigerators can be high and seed will absorb moisture quickly unless sealed to keep it dry.



Seal dry seeds in thick plastic bags. [WS]

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*Keep seed dry and cool!*

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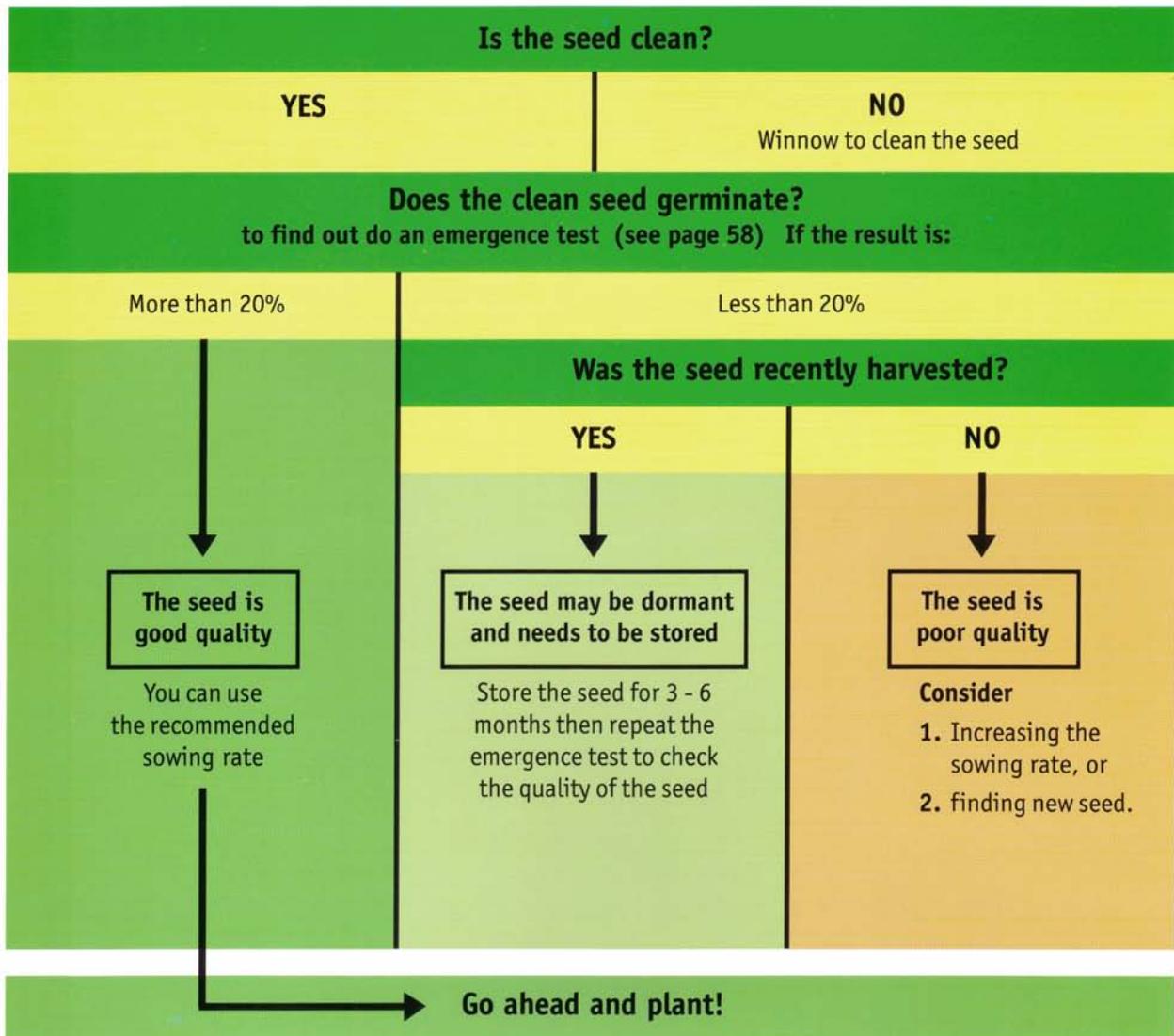


*Take Note!*

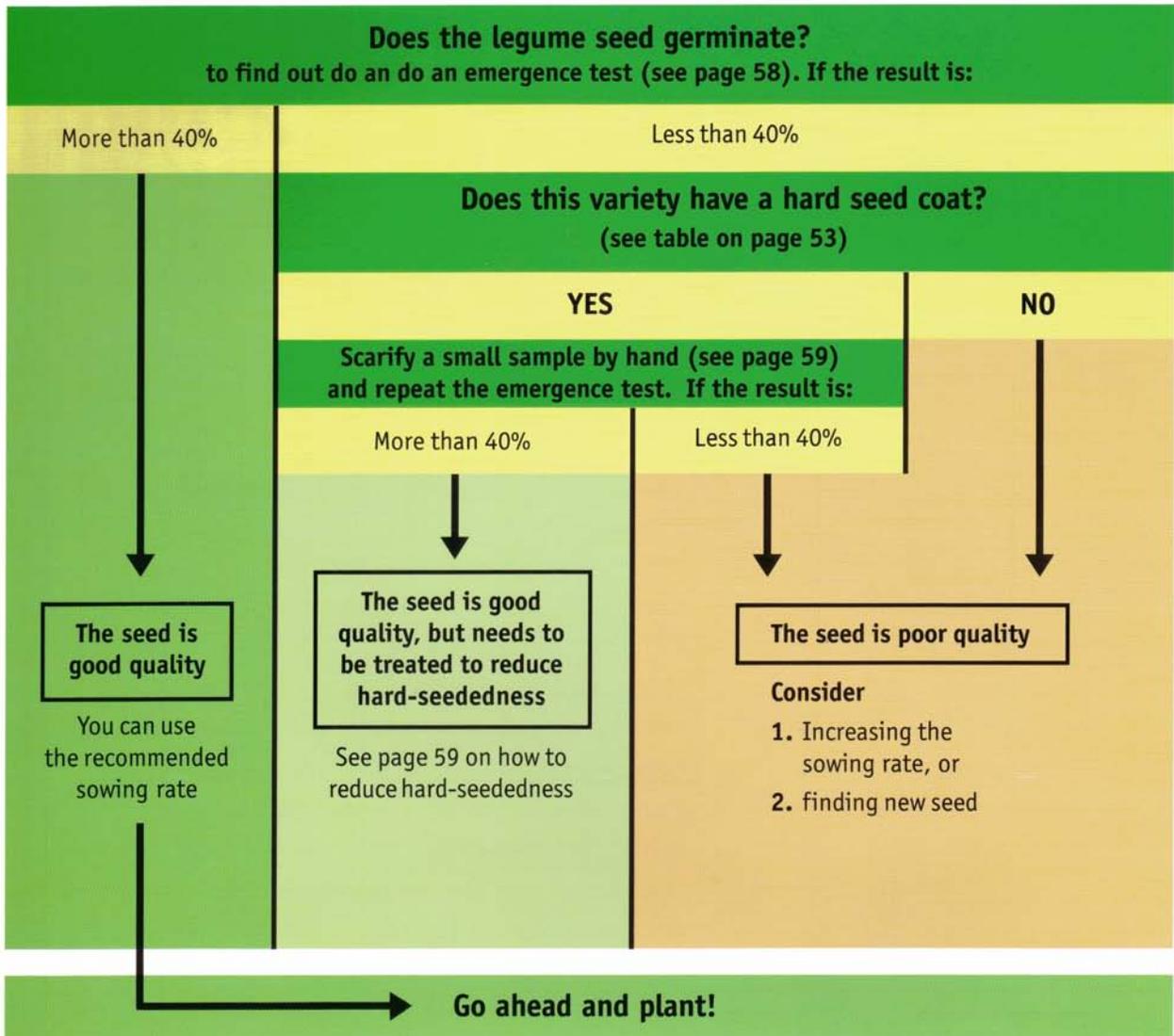
## **How can I check the quality of my seed?**

The following two diagrams show how you can check the quality of your grass or legume seed. Two techniques you will need to learn to be able to check the quality of your seed are an emergence test, and ways of breaking the hard seed coat of some legumes. These techniques are described on pages 58 and 59.

## How can I check the quality of grass seed?



## How can I check the quality of legume seed?



## 1. How to do an emergence test?

To check if your seed will germinate in the field you will need to do an emergence test. An emergence test is carried out in soil with a random sample of the seed you intend to plant in the field. The result of the emergence test is therefore very similar to the actual germination in the field and will help you decide what sowing rate you should use.

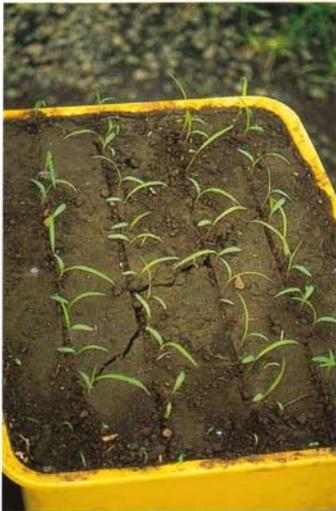


*Follow these steps!*

---

*To conduct an emergence test, follow these steps:*

- 1. Use flat trays (for example 25 cm x 40 cm and 5 cm deep, made of wood or plastic) with holes in the bottom for drainage.*
  - 2. Fill the trays with local soil.*
  - 3. Use a random sample of the seed you want to plant in the field. Do NOT select only the best-looking seeds for the test.*
  - 4. Plant 100 seeds of the test species in rows, 0.5 cm deep. Cover the seed with soil. Mark the rows.*
  - 5. Make sure that the seed has good contact with the soil by pressing lightly on the soil after sowing.*
  - 6. Keep at room temperature in a well-lit place (such as next to a window) and water gently every day to keep the soil moist but not waterlogged.*
  - 7. Count the number of seedlings emerging. It may be necessary to continue the emergence test for up to 21 days for grasses and 10 days for legumes.*
- 



Emergence test with *Panicum maximum* 'Si Muang'. [WS]

## **2. How to break the hard seed coat of legumes?**

If the emergence test shows that hard-seededness was the reason for the low germination percentage, then you will have to treat all of the seed before sowing. Treating the seed coat of hard-seeded legumes to allow water to enter the seed is called 'softening'. There are two ways to soften seed. One is to physically damage the seed coat by abrasion, called 'scarifying'. The other is to cause the 'lens' of the seed (a naturally occurring point of weakness in legume seeds) to open by suddenly changing the temperature around the seed.

There is no fixed method for treating seed because each species and each batch of seed is different. Test different treatments for breaking the hard coat on small seed lots (maybe 50g) and check the germination using emergence tests. Only when you are confident that your method gives good results should you treat all of the seed.

There are many methods of softening legume seed but the simplest, safest and most reliable are:

### **1. Rubbing the seed with sandpaper to scratch the seed coat (scarifying).**

Useful for small samples only (such as for emergence tests).

### **2. Cutting the seed coat with a scalpel or nail-clipper.**

Only useful for small samples of large seeds such as *Leucaena leucocephala*.

### 3. Using hot water treatments.

An easy method is to immerse seed in boiling water for very short periods of time (e.g. 2-5 seconds for seed of *Leucaena*), followed immediately by dipping in cold water to cool the seed.

A commonly recommended alternative is to immerse seed in water of approximately 80°C for 5-10 minutes, then in cold water to cool it.



***Warning!***

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***Treating seed with hot water always causes some damage to the seed and risks killing a large portion of the seed. ALWAYS test hot water treatments on a small sample of the seed before treating all of your seed.***

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### 4. Mechanical scarification.

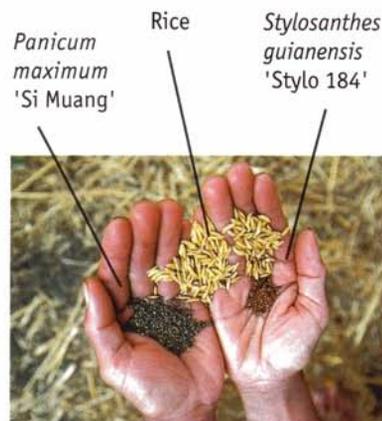
Simple machines (for example rotating drums with abrasive surfaces such as sand paper) can be used to mechanically scarify large quantities of seed.

## Planting from seed:

### 2. use the right sowing rate

Sowing rates of good quality seed should be in the range of 2-5g per 10m of row. If you use these seeding rates you will be sowing 40-200 seeds per metre of row. These sowing rates are a good starting point for on-farm evaluations. Farmers and development workers will learn from experience how much seed of different varieties is needed to ensure good establishment in their conditions.

Smaller seeds (e.g. *Panicum maximum*) should be sown at the lower rates and larger seeds (e.g. *Centrosema pubescens*) at the higher rates (see Tables on pages 62 and 63). Seed with good germination can be sown at the lower rates while seed with poor germination should be sown at higher rates.



Most forage seeds are very small. [JH]

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***A good sowing rate to use when evaluating new forage varieties is in the range of 2-5 g of seed for every ten metres of row.***

---



***Try this idea!***

There are some exceptions:

- *Arachis pintoii*: Sow 10-20 seeds per metre of row depending on the quality of seed. Be sure to test the seed as the quality of *Arachis* seed deteriorates quickly and you may have to increase the sowing rate.
- Tree legumes: It is best to grow seedlings in a nursery first and transplant them.

### Seed size of grasses

Grasses	Seed size				Seeds per gram <sup>1</sup>
	small	medium	large	very large	
<i>Andropogon gayanus</i> 'Gamba'	✓				500 - 700
<i>Brachiaria brizantha</i> 'Marandu', 'Karanga', 'Serengeti'		✓			100 - 150
<i>Brachiaria decumbens</i> 'Basilisk'		✓			150 - 220
<i>Brachiaria humidicola</i> 'Tully', 'Yanero'		✓			180 - 230
<i>Brachiaria mutica</i> 'Para'	✓				700 - 900
<i>Brachiaria ruziziensis</i> 'Ruzi'		✓			160 - 220
<i>Digitaria milanjiana</i> 'Jarra'	✓				1,800 - 2,200
<i>Panicum maximum</i> 'Si muang'	✓				800 - 1,200
<i>Paspalum atratum</i> 'Terenos'	✓				300 - 360
<i>Paspalum guenoarum</i> 'Bela Vista'		✓			200 - 260
<i>Pennisetum purpureum</i> 'Napier', 'Mott' and <i>Pennisetum</i> hybrids 'King'	<b>No seed</b>				
<i>Setaria sphacelata</i> 'Solander'	✓				900 - 1,800
<i>Setaria sphacelata</i> var. <i>splendida</i> 'Lampung'	<b>No seed</b>				
<i>Stenotaphrum secundatum</i> 'Vanuatu'	<b>No seed</b>				

<sup>1</sup> Seed size varies considerably within a variety; the number of seeds/gram quoted is an approximate guide only.

### Seed size of legumes

Legumes	Seed size				Seeds per gram <sup>1</sup>
	small	medium	large	very large	
<i>Arachis pintoi</i> 'Amarillo', 'Itacambira'				✓	6 - 8
<i>Calliandra calothyrsus</i> 'Besakih'				✓	18 - 20
<i>Centrosema macrocarpum</i> 'Ucayali'				✓	20 - 25
<i>Centrosema pascuorum</i> 'Cavalcade'			✓		40 - 60
<i>Centrosema pubescens</i> 'Barinas'			✓		30 - 40
<i>Codariocalyx gyroides</i> 'Belize'		✓			250 - 300
<i>Desmanthus virgatus</i> 'Chaland'		✓			200 - 250
<i>Desmodium cinerea</i> 'Las Delicias'		✓			350 - 400
<i>Flemingia macrophylla</i> 'Chumphon'			✓		50 - 80
<i>Gliricidia sepium</i> 'Belen Rivas', 'Retalhuleu'				✓	7 - 12
<i>Leucaena leucocephala</i> 'K636', 'K584'				✓	15 - 25
<i>Macroptilium gracile</i> 'Maldonado'		✓			260 - 300
<i>Sesbania grandiflora</i> 'Turi'				✓	20 - 30
<i>Stylosanthes guianensis</i> 'Stylo 184'		✓			260 - 360
<i>Stylosanthes hamata</i> 'Verano'		✓			300 - 400

<sup>1</sup> Seed size varies considerably within a variety; the number of seeds/gram quoted is an approximate guide only.



Good seedbed preparation gives better establishment (Pakchong, Thailand).[WS]

## Planting from seed:

### 3. use good field management

There are some simple methods farmers can use to ensure good establishment from seed:

#### **Sow in a fine, firm seedbed**

Most forage seeds are small. In poorly-prepared soil, the small seeds can easily be buried too deep in the soil for the seedlings to emerge. Seeds also need good contact with the soil to be able to absorb moisture and this can only happen in a fine, firm seedbed. You can improve emergence by lightly compacting the soil after sowing (for example by walking on top of the rows).

#### **Sow seed just under the surface of the soil**

If small forage seeds are sown on the soil surface they are easily washed away by heavy rain, stolen by ants or killed by hot, dry conditions. If sown too deep, the small seedlings cannot emerge from the soil.

**Take Note!**



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*Most forage seeds are small. They should be sown no more than 1-2 cm below the surface, otherwise the small seedlings cannot emerge.*

---

## Sow in rows

Farmers often grow forages in single rows along boundaries or between crops. If forages are grown in plots, 50cm is a good row spacing for most species. If you want quicker ground coverage choose a closer row spacing. Always sow along the contour (not up and down the hill!) to minimise soil erosion during establishment.



Sowing in rows makes it easier to sow the seed evenly, to identify the young forage seedlings when weeding, and to control soil erosion.



Sowing seeds in rows has many advantages. [WS]

---

*An easy way to plant forages is to prepare a fine, firm seedbed, make shallow rows in the surface with a small stick, sow the seed in the rows, lightly cover the seed with soil and walk over the rows to firmly press the soil on top of the seed.*

---



*Try this idea!*

## Protect young seedlings from weeds

Forage seedlings grow slowly during the first few weeks. Weeds often grow faster than the forage seedlings. Weeding is easier if the forages are sown in rows.



Early weeding gives forages a better start. [WS]



Start with a small area (Bhutan). [PH]

### Protect your soil against erosion

Small forage seeds can be easily washed away in heavy rain (particularly on sloping lands) or covered by washed soil. Erosion can be reduced by:

- leaving uncultivated contour strips,
- leaving crop residues on the soil surface,
- cultivating, ridging and planting forages along the contour, and
- sowing into an existing crop.

## What else can we do to ensure good establishment?

### Start with a small area

It is easier to develop a small area successfully than a large area. This is particularly important when a farmer is planting forages for the first time. It gives farmers an opportunity to get familiar with the forages and they can use the small area as a source of planting material.



**Take Note!**

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*It is better to have a small success than a big failure!*

---

### Sow forages into an established crop

Soil preparation is labour-intensive. It is sometimes possible to plant a crop and then establish forages into the crop to gain more benefits from land preparation and fertiliser application. An example is establishing a legume fallow into an annual crop such as maize or upland rice. The best time to establish forages into crops is immediately after a round of weeding to take advantage of soil

disturbance and reduced weed competition. Sowing forages into crops too early can result in lower crop yield. Sowing too late can result in poor forage establishment. Farmers need to experiment to find the best time for sowing forages into their crops. A general rule is to sow seed following a round of weeding at a time when the crop is well established but before it completely shades the soil. If broadcasting seed on the soil surface, farmers will need to use higher seeding rates since there will be higher losses than when the seed is covered with soil.

### **Apply manure or fertiliser if available**

In most situations, forages can be successfully established without manure or fertiliser. Obviously, forages will grow better if manure or fertiliser is applied. Manure may be the only available source of nutrients for smallholder farmers. Manure releases nutrients to the soil slowly, giving long-term benefits. If fertiliser is available, grasses will benefit most from nitrogen and legumes will benefit most from phosphorus applications. Nitrogen should not be applied to legumes since they fix nitrogen from the air and adding nitrogen will encourage grasses and weeds.



*Stylosanthes guianensis* sown into upland rice [Laos] [MS]



Manure is distributed in the field before planting (Bhutan). [PH]

## Should legume seed be inoculated?

The legumes recommended in this booklet series have been selected for their ability to nodulate effectively in a wide range of soils in Southeast Asia with naturally occurring rhizobia. Some legumes do not nodulate effectively unless particular strains of *Rhizobia* are present in the soil. This is indicated by yellowing of the leaves. The easiest solution is to look for an alternative legume species that can nodulate effectively.

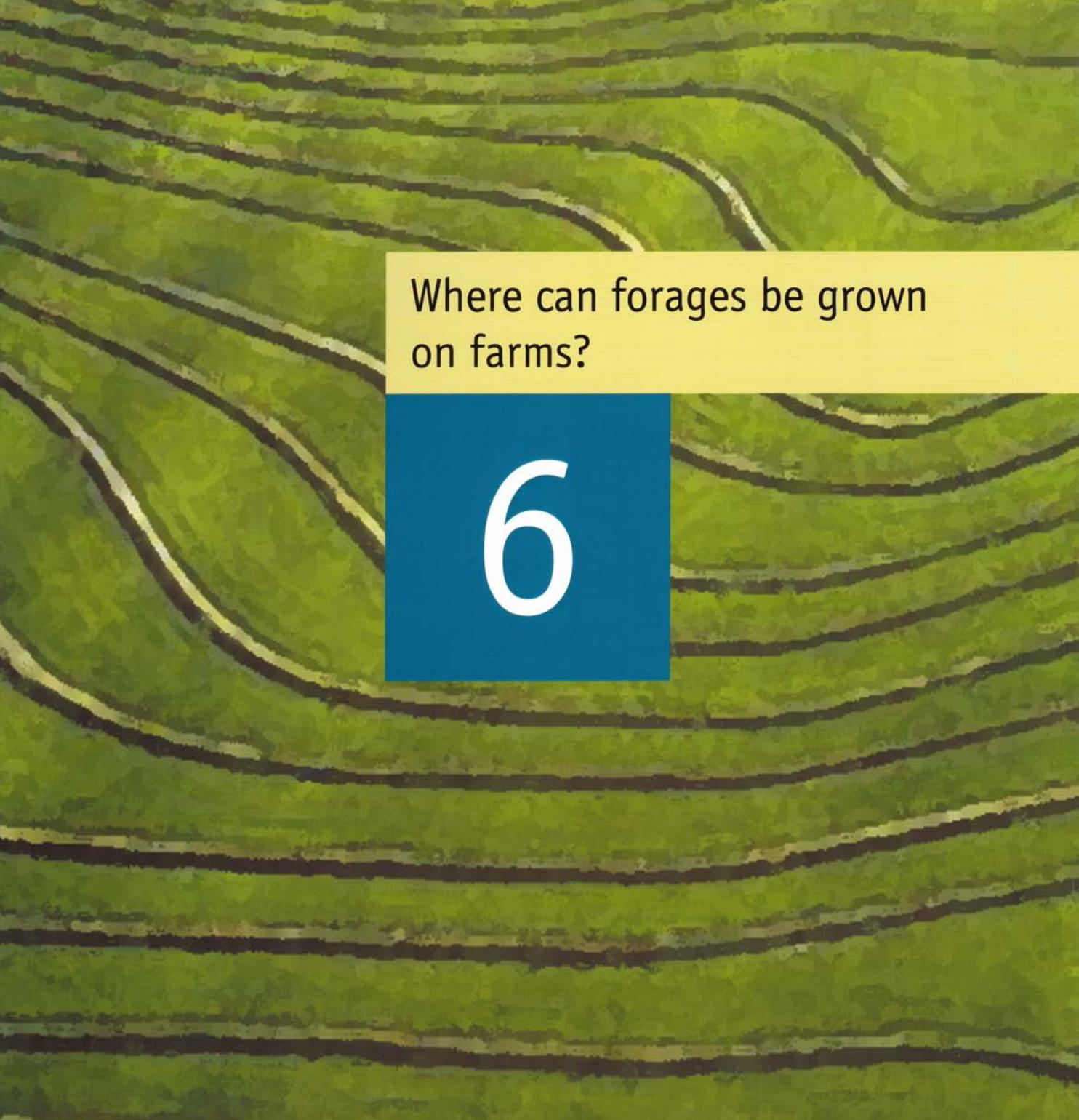
**A Question!**



***Nodulation problems?***

***The easiest solution is to select other legumes which do nodulate effectively in your soil.***

It is possible to overcome nodulation problems by applying the correct *Rhizobia*, either as a commercial inoculant to the seed before planting or by applying soil collected from around the roots of a well-nodulated plant of the same species. Often neither approach is practical for smallholders in the humid tropics. The correct inoculants for forage legumes are not commercially available in the region and importation, storage and distribution of inoculants is difficult since they need refrigeration. Getting soil from well-nodulated plants and moving it to a new area is possible on a small scale. For example, where tree legumes (e.g. *Leucaena leucocephala* 'K636') are raised in plastic bags adding a small amount of soil, collected from underneath well-growing trees, can overcome nodulation problems.

An aerial photograph of terraced green hills, likely a vineyard or agricultural field, with a yellow text box and a blue number box overlaid.

Where can forages be grown  
on farms?

6

# Where can forages be grown on farms?



Moderately intensive upland [WS]



Shifting cultivation [PH]

There are many ways of growing forages on farms. They can be integrated into cropping areas or grown in special purpose forage areas. The most suitable ways of integrating forage grasses and legumes will depend on the needs of each farmer. Every farmer and every farm is different. The main options for growing forages on farms are:

- Cut-and-carry plots
- Grazed plots
- Living fences
- Hedgerows
- Improved fallows
- Cover crops in annual crops
- Cover crops under trees
- Ground covers for erosion control



Grasslands [PH]



Lowland [PH]



Intensive upland [WS]

## Which forage options are best for different farming systems?

In Southeast Asia, farmers are adopting forages in all upland farming systems, ranging from shifting cultivation to intensive cropping systems (see pictures). When farmers first start to evaluate forages, they grow them in small plots near their houses. Only when they are convinced of the benefits of these varieties do they look for ways of integrating them into their farms.

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*Farmers first evaluate forage varieties in small plots before considering how to integrate them into their farms!*

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**Take Note!**

In all farming systems, most farmers first plant forages in cut-and-carry plots or rows, providing easy access to feed and supplementing existing feed resources. With time, they start to evaluate other forage options such as hedgerows in sloping lands, living fences and cover crops. Another booklet in this series 'Developing agricultural solutions with smallholder farmers-participatory approaches for getting it right the first time' describes participatory approaches to developing forage technologies on farms.



Offer your animals a 'basket of choices'. [PH]

## More about each forage option . . .

This section gives more details about the different ways of growing forages on farms, the benefits of each option and the types of forages that are best suited to each option.

In all of these situations, farmers:

- Like to grow several forage varieties rather than a single variety because they like diversity in their farming system and they like to feed forage mixtures to their animals.
- Will choose varieties that fit with the way they want to grow and use them. For example, they may choose several tussock grass varieties to grow in rows around their fields to provide cut feed.
- Will also choose varieties to provide feed at different times of the year. For example some varieties grow best during the rainy season while other varieties are needed to provide green feed during the dry season.

A Table showing which varieties are best suited to each forage option is provided in the booklet 'Developing forage technologies with smallholder farmers-how to select the best varieties to offer farmers in Southeast Asia'.



## Cut-and-carry plots

<p><b>What are they?</b></p>	<ul style="list-style-type: none"> <li>• Cut-and-carry plots are small plots of high-yielding forages which provide easy access to cut feed for animals housed all day or at night. They allow farmers to keep their animals in pens for longer periods and collect more manure.</li> </ul>
<p><b>What problems can they solve?</b></p>	<ul style="list-style-type: none"> <li>• General feed shortages.</li> <li>• Dry season feed shortages (tree legumes).</li> <li>• Feeding sick and lactating animals.</li> <li>• Not enough labour for feeding animals (cutting forage in plots near the house takes less time than cutting naturally-occurring grasses far from home).</li> <li>• Declining soil fertility of cropland (through easy collection of manure from pens).</li> </ul>
<p><b>What type of forages are suitable?</b></p>	<ul style="list-style-type: none"> <li>• Tall grasses and tree legumes that             <ul style="list-style-type: none"> <li>– are easy to cut,</li> <li>– have fast regrowth,</li> <li>– are persistent under cutting, and</li> <li>– respond to improved fertility (eg. added manure)</li> </ul> </li> <li>• Examples are <i>Pennisetum purpureum</i> 'Napier' and <i>Leucaena leucocephala</i> 'K636'.</li> </ul>
<p><b>What else is there to consider?</b></p>	<ul style="list-style-type: none"> <li>• Cut-and-carry systems quickly deplete the soil of nutrients and yields decline rapidly unless manure or fertiliser is applied (see Section 7 'How should forages be managed').</li> </ul>



Cutting *Paspalum atratum* 'Terenos' for night feeding of cattle (Makroman, Indonesia). [WS]



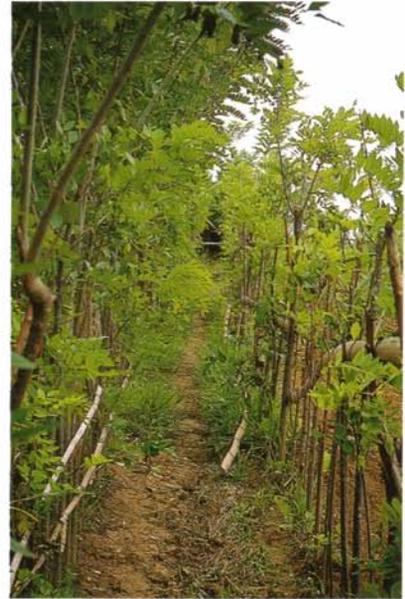
Grazed plots of *Brachiaria decumbens* 'Basilisk' under coconuts (North Sulawesi, Indonesia). [WS]

## Grazed plots

<p><b>What are they?</b></p>	<ul style="list-style-type: none"> <li>● It is seldom possible for smallholders to improve large areas of natural grassland with planted forages. More commonly, grazed plots are small, fenced areas of grasses or grass-legume mixtures near pens where animals can be grazed occasionally (for example, sick animals or cows with newly-born calves).</li> </ul>
<p><b>What problems can they solve?</b></p>	<ul style="list-style-type: none"> <li>● Not enough labour for feeding animals.</li> <li>● General feed shortages.</li> </ul>
<p><b>What type of forages are suitable?</b></p>	<ul style="list-style-type: none"> <li>● Short, stoloniferous grasses and legumes which can tolerate heavy grazing and suppress weeds.</li> <li>● Grasses and legumes can be grown in mixtures but need careful grazing management.</li> <li>● Medium-height grasses may be used but these cannot withstand heavy grazing and have to be managed carefully.</li> <li>● For example, <i>Brachiaria humidicola</i> 'Yanero' and <i>Arachis pintoi</i> 'Itacambira'.</li> </ul>
<p><b>What else is there to consider?</b></p>	<ul style="list-style-type: none"> <li>● Grazed plots must be fenced to protect them from wandering animals.</li> <li>● Oversowing legumes into native grassland is sometimes recommended as a way of improving the feed resources. This is rarely successful in communal grazing lands because farmers do not have control over wandering animals which results in overgrazing of legumes.</li> </ul>

## Living fences

<p><b>What are they?</b></p>	<ul style="list-style-type: none"> <li>• Living fences are lines of trees that mark the boundaries around fields and houses, and along paths.</li> </ul>
<p><b>What problems can they solve?</b></p>	<ul style="list-style-type: none"> <li>• Damage to crops from wandering can animals.</li> <li>• Dry season feed shortages (tree legumes are a source of high-protein leaf for dry season supplementation).</li> </ul>
<p><b>What type of forages are suitable?</b></p>	<ul style="list-style-type: none"> <li>• Tree legumes, particularly those that can be planted from stems and are tolerant of cutting.</li> <li>• <i>Pennisetum</i> species can form a dense living fence to keep chickens out of vegetable gardens.</li> <li>• For example, <i>Gliricidia sepium</i> 'Retalhuleu'.</li> </ul>
<p><b>What else is there to consider?</b></p>	<ul style="list-style-type: none"> <li>• Tree legumes established from seed grow slowly and need to be protected from wandering animals for at least one year while the living fences are being established. Farmers prefer to use species that can be easily established from stem cuttings, as these do not need as much care.</li> <li>• Tree legumes in living fences give the added benefits of firewood and shade.</li> <li>• Tree legumes will not provide feed in the short term but are long-lived.</li> </ul>



Use of *Gliricidia sepium* as a living fence (Sepaku, Indonesia). [WS]



Contour hedgerows of *Pennisetum purpureum* 'Napier' for controlling soil erosion and for feeding to goats (Malitbog, Philippines). [WS]

## Contour hedgerows

<p><b>What are they?</b></p>	<ul style="list-style-type: none"> <li>● Hedgerows are forages grown in rows between crops, often along the contour on sloping land. They are also grown along fence lines or between fields.</li> </ul>
<p><b>What problems can they solve?</b></p>	<ul style="list-style-type: none"> <li>● Soil erosion.</li> <li>● General feed shortages.</li> <li>● Dry season feed shortages (tree legumes are a source of high-protein leaf for dry season supplementation).</li> <li>● Declining soil fertility of crop land (tree legume leaves can be used as a mulch to improve fertility of surrounding crops).</li> </ul>
<p><b>What type of forages are suitable?</b></p>	<ul style="list-style-type: none"> <li>● The most suitable forages for hedgerows are grasses and tree legumes that             <ul style="list-style-type: none"> <li>– do not spread beyond the hedgerow,</li> <li>– form a semi-permeable barrier to slow run-off and erosion,</li> <li>– are long-lived, and</li> <li>– do not compete strongly with adjacent crops.</li> </ul> </li> <li>● For example, <i>Paspalum atratum</i> 'Terenos' and <i>Desmodium cinerea</i> 'Las Delicias'.</li> </ul>
<p><b>What else is there to consider?</b></p>	<ul style="list-style-type: none"> <li>● Forages planted in hedgerows must be cut regularly during the cropping season to prevent them competing with the crop. They also need regular maintenance to ensure they are effective barriers against erosion. The extra demand on labour is a reason often given by farmers for not adopting hedgerow technologies.</li> <li>● Effective erosion control requires a semi-permeable barrier and ground cover. Tree legumes on their own do not effectively control erosion but can be made more effective by planting double rows, regular cutting to develop multi stems, planting closely within rows or by placing cut branches along the tree row.</li> <li>● Contour strips of natural vegetation are effective alternatives for controlling erosion but provide little feed.</li> </ul>

## Improved fallows

<p><b>What are they?</b></p>	<ul style="list-style-type: none"> <li>● Improved fallows are legumes grown in crop land that is left uncropped for one or more seasons.</li> </ul>
<p><b>What problems can they solve?</b></p>	<ul style="list-style-type: none"> <li>● Declining soil fertility of crop land.</li> <li>● Weeds in cropping systems.</li> <li>● General feed shortages.</li> <li>● They can also be used to produce legume leaf meal which is used as a feed supplement for animals such as chickens and pigs.</li> </ul>
<p><b>What type of forages are suitable?</b></p>	<ul style="list-style-type: none"> <li>● Legumes which             <ul style="list-style-type: none"> <li>– are vigorous enough to suppress weeds, and</li> <li>– are easy to manage in the following crop.</li> </ul> </li> <li>● For example, <i>Stylosanthes guianensis</i> 'Stylo 184'.</li> </ul>
<p><b>What else is there to consider?</b></p>	<ul style="list-style-type: none"> <li>● Areas sown with improved legumes need protection from wandering animals.</li> <li>● Improved fallows can make subsequent cultivation easier by keeping the soil covered and 'soft'.</li> <li>● Legumes for improved fallows can be established by sowing into the previous crop, when the crop is well established and has just been weeded. However, if sown too early the legume may compete with the crop and reduce yields.</li> <li>● An unusual type of fallow in Indonesia is based on <i>Leucaena leucocephala</i> as a naturally regenerating tree legume in upland farming systems. Trees are cut at ground level before planting upland crops. The regrowth of the trees is used for feeding animals and the wood is used for cooking or sold for cash. After the cropping phase, the trees are allowed to regrow to form a thicket.</li> </ul>



*Stylosanthes guianensis* 'Stylo 184' grown after maize to control weeds, improve soil fertility and to collect seed (Cagayan de Oro, Philippines). [WS]



*Stylosanthes guianensis* 'Stylo 184' grown under cassava to control weeds, improve soil fertility and provide feed for goats (Makroman, Indonesia). [WS]

### Cover crops in annual crops

<p><b>What are they?</b></p>	<ul style="list-style-type: none"> <li>● Cover crops in annual crops are legumes grown under crops such as maize. They are cut frequently during the cropping phase. After harvesting they provide a ground cover until the next crop.</li> </ul>
<p><b>What problems can they solve?</b></p>	<ul style="list-style-type: none"> <li>● Weeds in annual crops.</li> <li>● Declining soil fertility of crop land.</li> <li>● Soil erosion.</li> <li>● General feed shortages (the legumes can be used as a source of high-quality cut feed).</li> </ul>
<p><b>What type of forages are suitable?</b></p>	<ul style="list-style-type: none"> <li>● Legumes that:             <ul style="list-style-type: none"> <li>– are vigorous,</li> <li>– can withstand frequent cutting, and</li> <li>– are easy to manage to minimise competition with the crop.</li> </ul> </li> <li>● For example <i>Centrosema pubescens</i> 'Barinas' and <i>Stylosanthes guianensis</i> 'Stylo 184'.</li> </ul>
<p><b>What else is there to consider?</b></p>	<ul style="list-style-type: none"> <li>● To prevent the legumes competing too strongly with the crop, they need to be cut regularly. This requires some labour input, but it may be less than is needed to remove the usual weeds that occur in the crop. Farmers can use the cut forage as a source of high-quality feed for their animals.</li> </ul>

## Cover crops under trees

<b>What are they?</b>	<ul style="list-style-type: none"> <li>● Cover crops under trees are legumes grown under tree crops such as fruit trees and coconuts.</li> </ul>
<b>What problems can they solve?</b>	<ul style="list-style-type: none"> <li>● Weeds under trees.</li> <li>● Declining soil fertility.</li> <li>● General feed shortages (the legumes can be used as a source of high-quality cut feed).</li> </ul>
<b>What type of forages are suitable?</b>	<ul style="list-style-type: none"> <li>● Legumes that:             <ul style="list-style-type: none"> <li>– are vigorous,</li> <li>– are persistent and long-lived, and</li> <li>– have a spreading growth habit.</li> </ul> </li> <li>● For example <i>Arachis pinto</i> 'Itacambira' and <i>Centrosema macrocarpum</i> 'Ucayali'.</li> </ul>
<b>What else is there to consider?</b>	<ul style="list-style-type: none"> <li>● The legumes need to be managed to minimise competition when the trees are young.</li> <li>● Grazing may cause damage to young trees.</li> </ul>



*Arachis pinto* 'Amarillo' grown in a pepper plantation (pepper climbing on *Gliricidia sepium*) to control weeds and provide feed for goats (North Cotabatu, Philippines). [WS]

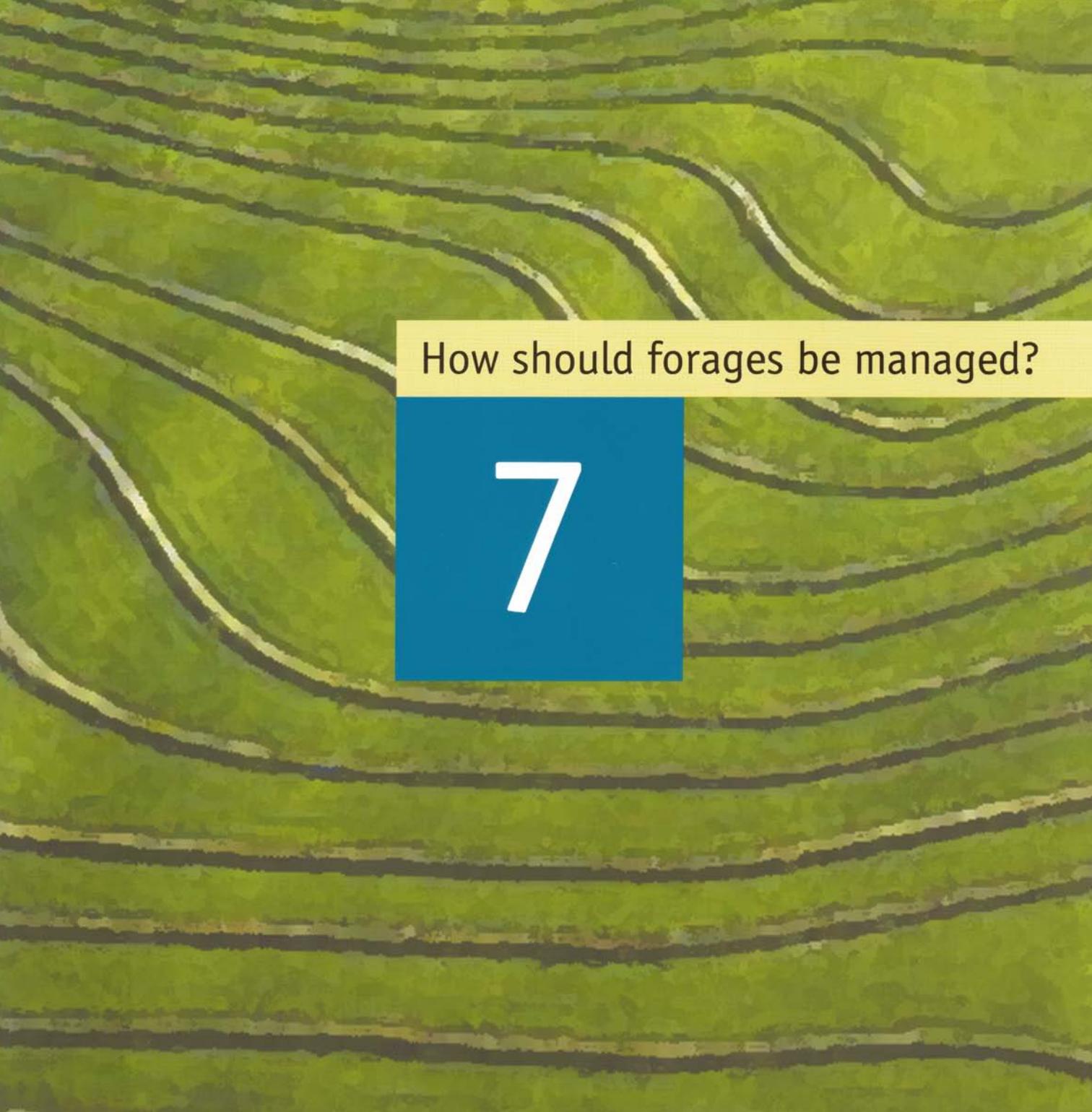




*Arachis pinto* 'Itacambira' grown along roadsides to control soil erosion and provide feed for animals (Malitbog, Philippines). [WS]

### Ground covers for erosion control

<b>What are they?</b>	<ul style="list-style-type: none"> <li>● Ground covers for erosion control are legumes and grasses grown on sloping land.</li> </ul>
<b>What problems can they solve?</b>	<ul style="list-style-type: none"> <li>● Soil erosion (both prevention of erosion and rehabilitation of degraded land).</li> <li>● Ground covers can provide some additional feed for animals and improve soil fertility.</li> </ul>
<b>What type of forages are suitable?</b>	<ul style="list-style-type: none"> <li>● Short, stoloniferous grasses and legumes.</li> <li>● For example, <i>Brachiaria humidicola</i> 'Yanero' and <i>Arachis pinto</i> 'Itacambira'.</li> </ul>
<b>What else is there to consider?</b>	<ul style="list-style-type: none"> <li>● Although ground cover species tolerate heavy grazing, they need to be protected from wandering animals during establishment.</li> </ul>

An aerial photograph of terraced green hills, likely a rice paddy field, with a yellow banner at the top and a blue square containing the number 7 in the center.

How should forages be managed?

7

# How should forages be managed?



Managing forages is easy. If farmers have never planted forages before they may need advice about the specific requirements of different varieties. The following management principles will help farmers to improve

- forage quality and yield,
- forage persistence, and
- animal production.

## How often should we cut forages?

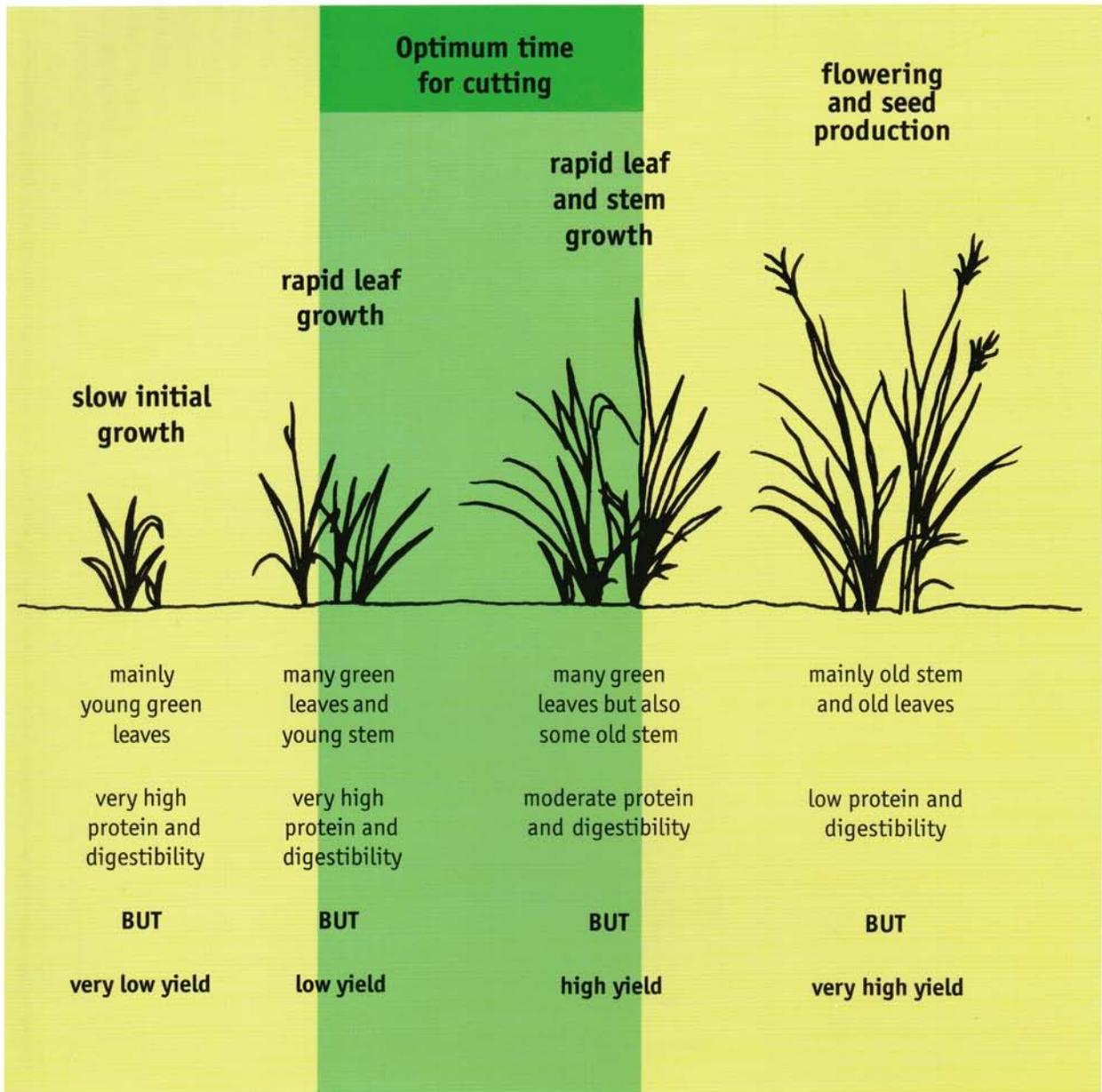
The decision on how often to cut forages is not based simply on yield and feed quality. It also depends on the needs of the farmer at that time, which may be more important than any other considerations.



If we only consider what is best for forage and animal production, the decision on when to cut forages is a compromise between forage yield and quality (see following figure on page 84). For the first few days after cutting, forages regrow slowly as they have few leaves to intercept light for photosynthesis. This is followed by a few weeks of rapid leaf growth and production of good quality feed. If left uncut any longer, the quality of the forage drops as:

- the plants produce more and more stem, particularly when they start flowering,
- digestibility of stem is much lower than leaf,
- digestibility of old grass is much lower than young grass, and
- protein content decreases as the plant ages, particularly in grasses.

The best time for cutting is a compromise between yield and forage quality



### Cutting forages frequently gives high quality but low yield

Cutting frequency	DM yield (t/ha/year)	Leaf (% of total yield)	Protein (%)	Digestibility (%)
3 weeks	10	60	14	60
6 weeks	15	40	10	55
9 weeks	20	25	7	45

An example of 'Napier' grass cut every 3, 6 or 9 weeks.

An example of the changes in yield and feed quality, as a grass matures, is shown in the above Table. Napier grass was cut every 3, 6 or 9 weeks. The highest yields were obtained when the grass was cut every 9 weeks, but this also produced the lowest quality feed.

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*If you want high quality feed, cut young forage.  
If you want high yields, let the forage grow longer.*

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**Take Note!**



Young 'Napier' [JH]



Old 'Napier' [JH]

## How high should we cut forages?

Most forages can tolerate low cutting but they will produce higher yields and live longer if they are cut a little higher (see Table below). There are no fixed rules and farmers need to develop their own cutting management as they gain experience with a new species or variety. For example, 'Napier' grass should occasionally be cut close to the ground to stimulate growth of new tillers from the base.

**Suggested cutting heights for different types of forages**

<b>Legumes</b>	<b>Cutting height (cm)</b>	<b>Examples</b>
Short stoloniferous legumes	5 - 10	<i>Arachis pintoii</i>
Erect bushy legumes	20 - 30	<i>Stylosanthes guianensis</i> <i>Desmanthus virgatus</i>
Shrub and tree legumes	50 - 100	<i>Gliricidia sepium</i>
<b>Grasses</b>	<b>Cutting height (cm)</b>	<b>Examples</b>
Short stoloniferous grasses	5 - 10	<i>Brachiaria humidicola</i>
Other grasses	10 - 30	<i>Brachiaria decumbens</i> <i>Panicum maximum</i> <i>Pennisetum purpureum</i>

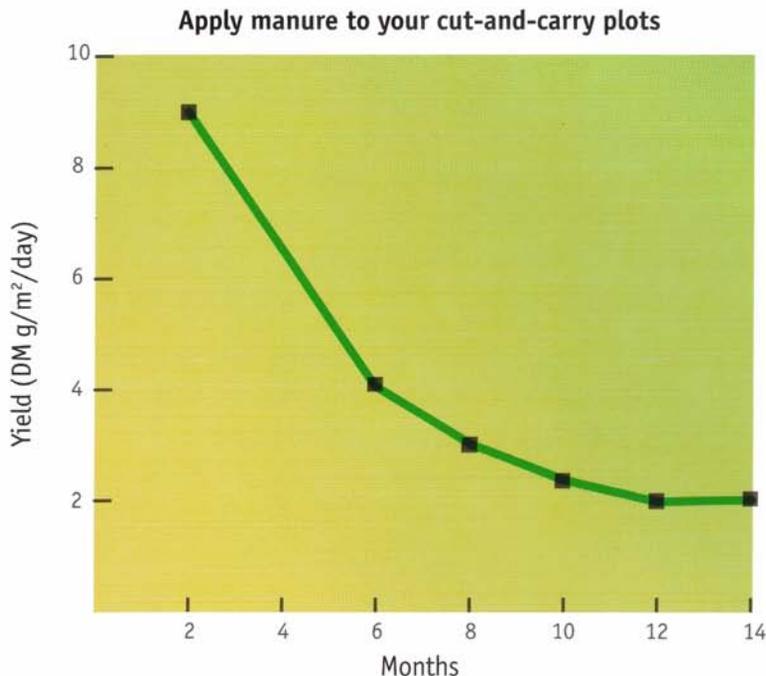
## How much manure or fertiliser should we apply?

With grazing, a lot of the nutrients eaten by animals are returned to the soil through urine and manure. This does not happen in cut-and-carry systems where the nutrients are carried to the animal shed. Unless nutrients are returned to the forage area, both forage yield and forage quality will decline rapidly.

In the example (see Figure below), the yield of unfertilised 'Napier' grass declined from high initial yields to very low yield within one year.



Manure helps to maintain high forage yields. [JH]



An example of 'Napier' cut every 8 weeks without applying fertiliser.



Farmer cutting forages as supplementary feed for his cattle (Sepaku, Indonesia). [JH]

Forages remove more nutrients than crops such as maize and rice since the whole plant is cut and removed. In the example (see Table below), 'Napier' cut regularly for one year produced 18 t/ha of dry matter. This removed large quantities of nitrogen (N), phosphorus (P) and potassium (K) as well as other nutrients from the soil which would be expensive to replace with commercial fertiliser.

#### Cut-and-carry systems remove a lot of nutrients from the soil

Nutrients removed from 1000m <sup>2</sup>	Fertiliser equivalent
32 kg/year N	70 kg/year Urea
2 kg/year P	10 kg/year TSP
21 kg/year K	42 kg/year KCl

An example of the amount of nutrients removed by 'Napier' grass yielding 18 t/ha DM per year in a cut-and-carry system.

**Take Note!**



***Most upland soils in Southeast Asia are infertile and if nutrients are not returned to cut-and-carry plots, forage yield will quickly decline.***

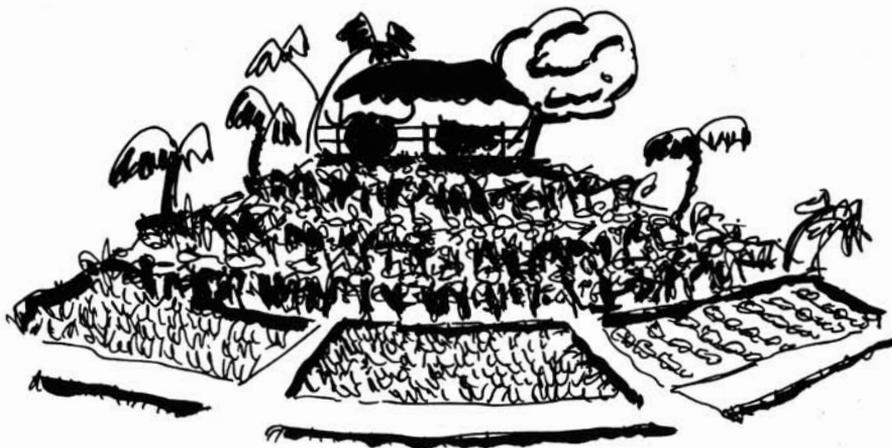
Legumes fix N through their root nodule bacteria and so do not need nitrogen from the soil. However, legumes need more P than grasses to grow and provide energy for the bacteria, and so usually respond well to P. Nitrogen fertiliser should not be applied to legumes. If nitrogen is applied to legumes, the nodule bacteria stop fixing nitrogen and make use of the applied fertiliser.



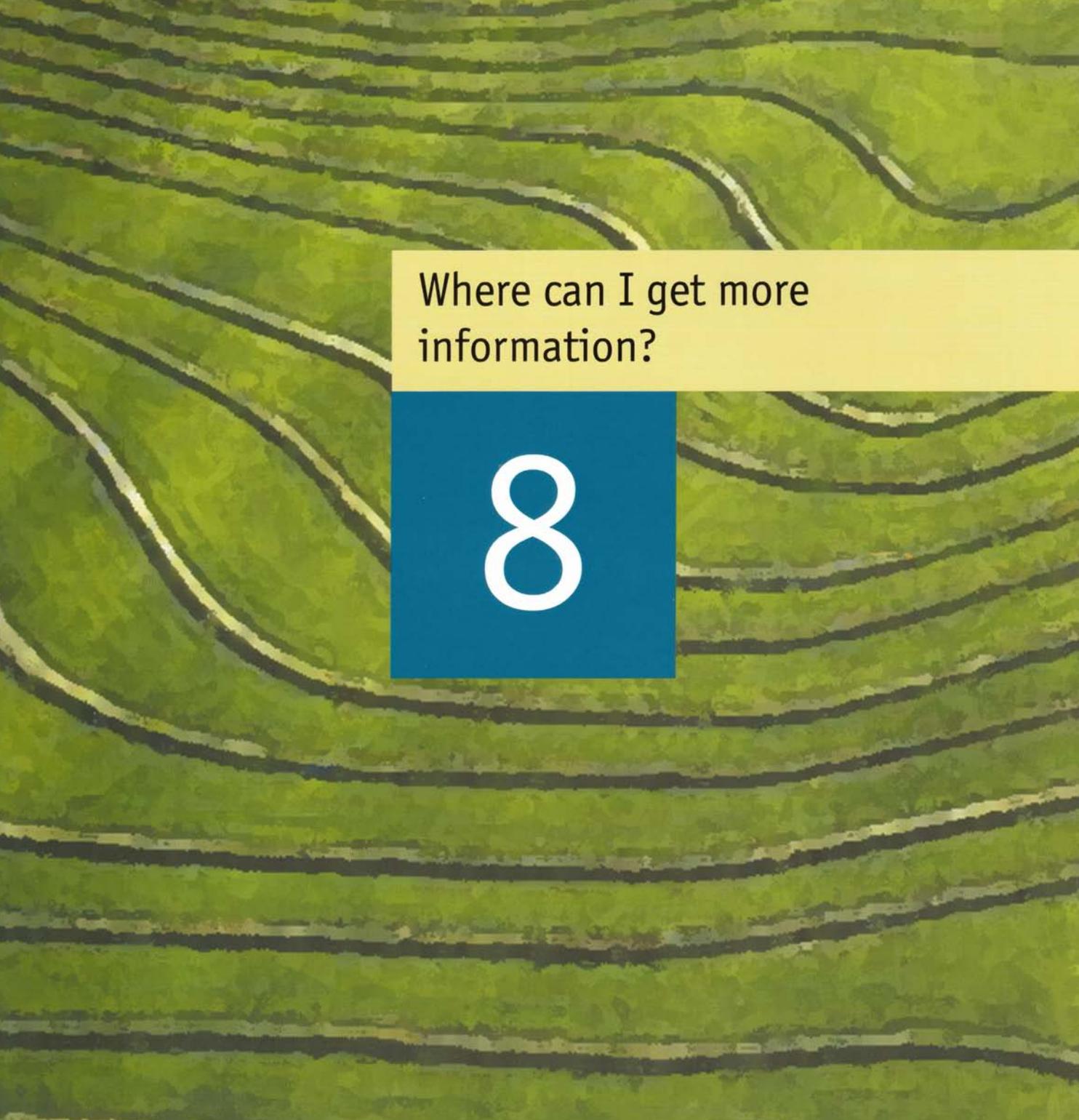
If farmers want to apply fertiliser to improve the yield of their forages, they will get the best response from applying nitrogen (e.g. urea) to grasses and phosphorus (e.g. TSP) to legumes.

For most smallholder farmers, applying fertiliser to forages in cut-and-carry systems is impractical or uneconomical. Often their only option is to return manure to the forage area. Farm manure is a very good fertiliser since it is locally available, cheap and releases nutrients slowly, giving a lasting effect on plant growth. It is easy for farmers to return manure to the cut-and-carry plots if they are close to the animal pens. Another alternative is to plant the forages downhill from the animal pens, where they can use the nutrients flowing from the pens.

**Planting forages downhill from animal pens improves forage growth and nutrient recycling**



Inevitably some farmers will become more specialised. With increasing sophistication and the expectation of rising production, the use of farm manure may not be sufficient to prevent soil fertility deficiencies from emerging (e.g. potassium). These deficiencies may need to be corrected with inorganic fertiliser.

An aerial photograph of terraced green hills, likely a vineyard or agricultural landscape. The hills are covered in vibrant green vegetation, and a winding road or path is visible, cutting through the terraces. The overall scene is peaceful and scenic.

Where can I get more information?

8

## Where can I get more information?



If you are looking for more information about forages or you are looking for planting material of the forage varieties described in this booklet, the best first contacts are listed below. Although these addresses and contact names will change with time, they will guide you in the right direction to find the information you want.

For more information visit the CIAT web site  
<http://www.ciat.cgiar.org>

## **Thailand**

Division of Animal Nutrition  
Department of Livestock Development  
Phya Thai Road, Bangkok 10400  
Tel: (66 2) 6534491  
Current contact: Chaisang Phaikaew

Pakchong Animal Nutrition Research Centre  
Pakchong, Nakornratchasima 30130  
Tel: (66 44) 311 612  
Current contact: Ganda Nakamanee

## **Philippines**

Livestock Research Division  
Philippine Council for Agriculture, Forestry and  
Natural Resources Research and Development  
P.O. Box 425, Los Baños, Laguna 4030  
Tel: (63-49) 536 0014  
Current contact: Ed Magboo

FARMI,  
Leyte State University  
6521-A Baybay, Leyte  
Tel: (63-53) 536 2433  
Current contact: Francisco Gabunada

CIAT- Forages for Smallholders Project (FSP)  
c/o IRRRI, DPAO Box 7777 Metro Manila Philippines  
Tel: (63-2) 845 0563 Ext. 406  
Current contact: Ralph Roothaert

## **Indonesia**

Subdirektorat Pakan  
Direktorat Budidaya Peternakan  
Direktorat Jenderal Produksi Peternakan  
Departemen Pertanian  
Jl. Harsono RM No. 3  
Jakarta 12550  
Tel: (62 21) 781 5686  
Balai Pengkajian Teknologi Pertanian  
BPTP Gedong Johor  
Jalan Karyayasa No. 1B  
Medan, North Sumatra 20143  
Tel: (62 61) 787 0710  
Current contact: Tatang Ibrahim

Dinas Peternakan TK. 1 Kaltim  
Jalan Bhayangkara No. 54,  
Samarinda, East Kalimantan 75121  
Tel: (62 541) 43921  
Current contact: Ibrahim

Maimunah Tuhulele  
Pd. Jati Murni  
Blok I/12 Pd. Gede 17431, Bekasi  
Jakarta  
Tel: (62 21) 844 5229

## **Vietnam**

National Institute of Animal Husbandry  
Ministry of Agriculture and Rural Development  
Thuy Phuong, Tu Liem  
Hanoi  
Tel: (84 4) 834 4775  
Current contact: Le Hoa Binh

Tay Nguyen University  
Highway No. 14, Km 4  
Buon Ma Thuot, Daklak  
Tel: (84 50) 853 781 / 853 279  
Current contact: Truong Tan Khanh

College of Agriculture & Forestry  
Thu Duc  
Ho Chi Minh City  
Tel: (84 8) 896 3353  
Current contact: Bui Xuan An

Hue University of Agriculture & Forestry  
Centre for Rural Development in Central Vietnam  
24 Phung Hung St.  
Hue  
Tel: (84 54) 825 049  
Current contact: Le Van An

## **Lao PDR**

National Livestock Centre Nam Suang  
National Agriculture and Forestry Research Institute  
P.O. Box 811 Vientiane  
Tel: (856 21) 222 796  
Current contacts: Vanthong Phengvichith,  
Phonepaseuth Phengsavanh

## **China**

Tropical Pasture Research Center  
CATAS  
Hainan, Danzhou 571737  
Tel: (86 890) 330 0440  
Current contact: Yi Kexian

## **Malaysia**

MARDI Kubang Keranji  
Stesen Penyelidikan Padi  
Peti Surat 154  
15710 Khota Bharu  
Tel. (60 9) 765 900  
Current contact: Aminah Abdullah

## **For general enquiries:**

CIAT Regional Office  
P.O. Box 783 Vientiane  
Lao PDR  
Tel: (856 21) 222 796  
Fax: (856 21) 222 797  
E-mail: [ciat-asia@cgiar.org](mailto:ciat-asia@cgiar.org)  
Current contact: Peter Kerridge