

# Improved fallows for western Kenya

*an extension guideline*

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# Contents

<b>Acknowledgements</b> .....	<b>iv</b>
<b>Foreword</b> .....	<b>v</b>
<b>Keep in mind</b> . . .	<b>vii</b>
<b>1 Western Kenya</b> .....	<b>1</b>
1.1 Geography, climate and vegetation .....	1
1.2 Population and socio-economic characteristics .....	1
1.3 Agricultural land use .....	2
<b>2 Improved fallows</b> .....	<b>6</b>
2.1 Concept .....	6
2.2 Fallow species .....	6
2.3 Types .....	13
2.4 Benefits of improved fallows .....	15
2.5 Adoption potential .....	29
<b>3 Establishing and managing the fallow</b> .....	<b>38</b>
3.1 Seeds .....	38
3.2 Planting the fallow .....	40
3.3 Pests .....	43
3.4 Managing and harvesting the fallow .....	45
<b>4 For more help</b> . . .	<b>46</b>
<b>Selected reading</b> .....	<b>47</b>

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## Foreword

Farmers in western Kenya are facing problems brought on by rapid population growth that are negatively affecting the productivity of agriculture and natural resources of the area. The situation has serious implications for the economy and the ability of the people to be self-sufficient in their food supply. With shrinking land holdings and lack of credit facilities, crop yields and animal productivity are declining. Traditional agricultural production practices that preserved and sustained the natural resource base are dying out. Continuous cropping with little or no inputs is now the norm. Households lack sufficient supplies of food, fuelwood and fodder, and declining income levels limit the options farmers have to reverse this trend.

If we take into consideration the current population growth rate of 3.2% per annum for western Kenya, demands for food and other resources will almost double by the year 2020 as the population increases to 15 million. Struggling to survive, people find it difficult to manage the critical trade-offs between sustainable resource use and immediate short-term needs. The fundamental biophysical factor that limits per-capita food production is depleted soil fertility on smallholder farms. Offering the potential to rebuild the worn-out soils are improved fallows, which integrate into the farming system selected trees and shrubs that are planted and managed for rapid growth and harvest.

This extension guide reflects the current state of the practice in western Kenya of using improved fallows to build up soil fertility. The practices are the product of over 7 years of collaborative research, extension and on-farm testing by researchers, non-governmental organizations and farmers. This extension guideline is one step in disseminating innovative agroforestry technologies that can meet the different needs of the farmers and improve the natural resource base. It is intended to serve as a useful guide for extension staff working in the Ministry of Agriculture and Rural Development, non-governmental organizations, community-based organizations and farmers in western Kenya. Not all improved fallow practices are suited to all locations and all farmers. The farmers and extension staff are expected to be active partners in identifying, evaluating and adapting

## *Improved fallows for western Kenya*

the practices that can address their specific needs and the resources they have at hand. It is thus, through iterative on-farm testing and collaborative research, that the technologies will be improved.

As more is learned about existing and new, improved fallow practices under different farmer circumstances and conditions, we plan to revise and update the guideline to reflect changing needs and priorities. We highly recommend that practitioners be innovative and creative in using the information presented. Only in this way can we improve and diversify options to develop improved fallow practices that will be sustainable into the future. Any ideas, suggestions and experiences to improve this extension guideline are welcome. They should be addressed to the coordinators of the agroforestry research programme at Maseno, Kisumu.

## Keep in mind . . .

- Most soils in western Kenya do not have adequate amounts of nitrogen and phosphorus required for good crop growth and yield. In some areas, soils also lack potassium.
- Planted and managed fallows of leguminous shrubs are better than natural fallows for enhancing soil fertility, especially for restoring nitrogen and improving other soil properties and for easing the work of tilling the soil.
- Soils poor in phosphorus cannot be enriched with phosphorus through improved fallows because they can only recycle what is available in the soil. It is therefore often necessary to apply phosphorus fertilizer to crops planted after the fallow period.
- Crop nutrient losses caused by soil erosion can be reduced by using erosion control structures such as trenches ('fanya juu') and barriers of plants like Napier, calliandra or tithonia established along contour lines across the slope.
- In addition to improving soil fertility, planted fallows can be used to control striga weed (*Striga hermonthica*). They can also control other weeds such as couch grass, especially if the fallows are repeated frequently or are of long duration—18 months or more.
- In areas where improved fallows grow well and achieve good weed control, minimum tillage can be practised, saving labour at planting time and at times even the first weeding.
- If the fallow plant, such as *Sesbania sesban*, is host to nematodes, crops such as bean and tomato should not be planted immediately after the fallow. Instead, maize, sorghum or groundnut should be planted in the first season and bean and tomato in the second season.
- Planting fallows of two or more different but compatible plant species can control nematodes and other insect pests. This method may also keep the soil fertile for a longer period.
- Improved tree fallows can significantly contribute to the production of fuelwood for a household.
- To ensure your own seed supply of improved fallow species, plant at least 20 plants scattered in crop fields, farm boundaries, along contour lines and around the homestead.



# 1 Western Kenya

## 1.1 Geography, climate and vegetation

Western Kenya, in this guideline, is the region bordering Uganda to the west and Tanzania to the south; it comprises Nyanza and Western Provinces. It lies between latitude 1° 8' N and 1° 24' S and between longitude 34° and 35° E. The elevation ranges from 1000 to 1600 m. It occupies an area of 20,719 km<sup>2</sup>, which consists of very gently undulating landscapes with slopes between 2 and 8%. Poorly drained land makes up about 30% of the total area. It occurs in bottomlands, minor valleys, plains, swamps and floodplains.

The main annual rainfall ranges from less than 1000 mm near the shores of Lake Victoria to 2000 mm away from the lakeshore. It occurs in two rainfall seasons: from March to June (long rainy season) and from September to November (short rainy season), thus constituting a bimodal rainfall pattern. Temperatures are mostly warm, modified by season and altitude; the average maximum is 29 °C and the average minimum 15 °C. The coolest period is July and August, the hottest December and January before the onset of the long rainy period.

Most of the natural vegetation of western Kenya has disappeared because of intensive agricultural activities. Areas unsuitable for crop cultivation are planted to various species of trees, eucalyptus and cypress being predominant.

## 1.2 Population and socio-economic characteristics

Western Kenya, the home of over 8 million people, is one of Kenya's most densely populated regions. Population densities range from 500 to 1200 people per km<sup>2</sup>, with the highest densities in Vihiga and Kakamega Districts of Western Province. Farm sizes are small, ranging from 0.2 to 2.5 ha, and the mean household size is 7 people. Most households rely on the farm for only about 15% of their cash income. Remittances from relatives and small amounts of off-farm income form the remainder. Farmers' highest priority is investment in their children's education.

Incentive for investing capital and labour in farming activities is lacking, because expected profits are low. Investments in farming (dairy, tea, coffee) are often made only after the farmer retires from formal employment. Formal agricultural credit systems are poorly developed.

### **1.3 Agricultural land use**

#### ***Agro-ecological zones of western Kenya***

The agro-ecological zones (AEZs) found in western Kenya are the lower midlands (LM), the upper midlands (UM), the lower highlands (LH), and the tropical alpine (TA). The zones are based on the probability of an area meeting the temperature and water requirements of the major crops. The agro-climatic characteristics of each AEZ are as follows:

##### LOWER MIDLAND ZONE

In the lower midland zone the altitude ranges from 800 to 1500 m. Temperatures are warm, with an annual mean ranging from 21 °C to 24 °C. The mean minimum temperature is above 14 °C. Cotton is the major crop grown in this zone. Parts of Bondo, Bungoma, Busia, Butere-Mumias, Homa Bay, Kakamega, Kisumu, Kuria, Lugari, Migori, Mount Elgon, Nyando, Rachuonyo, Siaya, Suba, Teso and Vihiga Districts fall in this zone.

##### UPPER MIDLAND ZONE

The altitude range in the upper midland zone is from 1300 to 1900 m. Mean annual temperature ranges from 18 °C to 21 °C. The zone is suitable for growing arabica coffee. It too includes parts of Bungoma, Butere-Mumias, Homa Bay, Kakamega, Kisumu, Kuria, Migori, Mount Elgon, Nyando, Rachuonyo, Suba and Vihiga Districts.

##### LOWER HIGHLAND ZONE

The altitude in the lower highland zone ranges from 1800 to 2400 m. It is a moderately cool zone, with the annual mean temperature ranging from 15 °C to 18 °C. Major cash crops grown in the area are tea and

pyrethrum. This zone is found in Bungoma, Gucha, Kisii, Mount Elgon and Nyamira Districts.

#### TROPICAL ALPINE ZONE

The few areas in the tropical alpine zone are found only in Bungoma and Mount Elgon Districts, close to Mount Elgon. The altitude ranges from 3000 to 4400 m. It is a cold zone, whose annual mean temperature ranges from 2 °C to 10 °C, with a daily maximum below 13 °C. Night frosts are common and the low temperatures do not favour planting crops and trees.

#### **Crops**

Agriculture in western Kenya is dominated by subsistence farming. Maize is the preferred staple and main crop, often intercropped with bean. About a third of the farmers buy hybrid maize for at least one crop a year, but maize yields are low (on average 1 tonne per hectare per season). Banana, cassava, cowpea, groundnut sorghum and sweet potato are grown on a small scale but are important supplements. Cash crops include tea, sugar cane, cotton and pyrethrum. Production of these crops is limited to a few areas, and coffee has virtually disappeared because the marketing infrastructure has been poor. Local vegetables and fruits are also grown for home consumption and for sale.

#### **Livestock**

Because the amount of land is limited, livestock numbers are small. Most farmers own chickens and many own local zebu cattle (1–4 per household), which they keep mostly as liquid capital, by selling them when necessary, and for beef, milk and manure. Only 5 to 7% of the farmers possess a cow of an improved breed, although this number is increasing. Goats and sheep are much less common than cattle. While free grazing is a common practice in the drier zones within the Lake Victoria Basin, controlled grazing using tethering and zero-grazing systems are common in the more densely populated zones of the region.

### **Soils**

As land is continuously cultivated for food production, often without fertilizer or with very little use of it, the soils in many areas are infertile and lack important plant nutrients such as nitrogen, phosphorus and potassium. This is particularly noticeable in areas where the main soil types are Acrisols and Ferralsols (FAO–UNESCO) or Oxisols (Soil Taxonomy) (see Sanchez and others 1996). Loss of nutrients through crop harvesting, leaching (nutrients are moved deep into the soil beyond the crop rooting zone) and erosion have also contributed to the low and declining soil fertility. Other factors that contribute to low crop yield, especially of cereals, include infestation by the parasitic weed *Striga hermonthica*, the maize stalk borer and maize streak virus.

Phosphorus deficiency is widespread in western Kenya as well as in other countries in eastern and central Africa. An exception is Kisii District, where the soils generally have sufficient available levels of phosphorus.

As improved fallows do not provide sufficient phosphorus, fertilizers or phosphate rock must be added to correct the deficiency. Mapping soil phosphorus deficiency at large-scale levels such as district or watersheds has long been a problem. Fortunately, the World Agroforestry Centre and its partners have developed a technique combining Landsat imagery and reflectance spectrometry that can determine soil phosphorus levels rapidly in the field and in soil samples in the lab. This rapid, inexpensive method can provide maps that will help farmers and extension workers make wise decisions as to which soils need phosphorus application.

### **Soil management**

Owing to the low soil fertility, most households produce maize enough to last for only about 3 to 5 months of the year. Annual food shortages, especially of maize and beans, are a common occurrence, particularly from April to June. These shortages force the families to buy additional maize from the market (often brought in from other areas) until the next crop harvest or endure hunger on a poor diet.

One way of improving crop yield is to use organic and inorganic fertilizers. Use of organic fertilizers such as animal or plant manure is limited, however, by the small quantity available on farms and its quality is often low. Use of commercial inorganic fertilizers is constrained by both the lack of money to purchase them and the unreliable returns to packages recommended with hybrid crop seed.

Traditionally, farmers would restore soil fertility by leaving part of their land uncultivated for many years while new and more fertile land was cultivated for food production. The rapid increase in human population has, however, reduced the amount of land available to the farmer and destabilized this traditional system of maintaining soil fertility. Consequently, long-duration natural fallows are no longer possible. They are replaced by short-duration ones, lasting one or two seasons only. Continuous cultivation of land also is now a common farming practice. In western Kenya, about half of the farmers leave 10 to 25% of their cropland fallow during the short-rains period, but since the fallow period does not last long enough to improve soil fertility sufficiently, the yields of subsequent crops are typically as low as those of the preceding seasons.

To ease this problem, scientists at the National Agroforestry Research Centre in Maseno have found that the functions of natural fallows—the traditional way of restoring soil fertility—can be improved and accelerated by using short-duration improved fallows of selected leguminous trees and shrubs and herbaceous cover crops. So long as soils have enough phosphorus, such fallows can provide a practical means of restoring soil nitrogen through biological nitrogen fixation when they are grown in rotation with crops. Improved fallows are also complementary to other methods farmers may use to improve soil fertility, such as rotating crops, composting, adding mineral fertilizer or animal manure or both, and using green manure.

## 2 Improved fallows

### 2.1 Concept

Natural fallow is land resting from cultivation, usually used for grazing or left to natural vegetation for a long period to restore soil fertility lost from growing crops. Improved fallow is also land resting from cultivation but the vegetation comprises planted and managed species of leguminous trees, shrubs and herbaceous cover crops. These cover crops rapidly replenish soil fertility in one or at most two growing seasons in western Kenya. They shorten the time required to restore soil fertility; they help to improve farmland productivity because the plant vegetation that follows them is superior in quality; and they increase the range of outputs, because the woody fallow species can also produce fuelwood and stakes.

Trees, shrubs and herbaceous cover crops can be introduced at several different times but the most common practice is in the long-rains season (usually after the first or second weeding, depending on the rainfall conditions of the area). They are left to grow alone in the short-rains and cut the following year at the beginning of the long-rains season (fig. 1). Fallows can also be left for longer periods (1 to 3 years). This is particularly recommended for fields of extremely low soil fertility or infested by the striga weed, couch grass or other weeds that are difficult to control.

### 2.2 Fallow species

A fallow is 'improved' over natural bush fallow only if the plant species used are more efficient than the species in the local vegetation—at least in improving the chemical and physical properties of the soil. A good fallow plant must have several of the following characteristics:

- Its growth is quick, closing the canopy quickly, to suppress weeds and control erosion.
- It yields much biomass of good quality that decomposes fast and becomes fertilizer for the crops.

Serious agricultural problems in western Kenya are soil fertility, weed and erosion.



*Maize in fields with low fertility yields poorly.*



*Striga is a serious weed problem, especially on soils with low fertility.*



*Sloping land becomes heavily eroded.*



Erosion on sloping land can be controlled by digging and planting trenches.

**Improved fallows have multiple benefits.**



*A good maize crop with dark green leaves follows an improved fallow.*



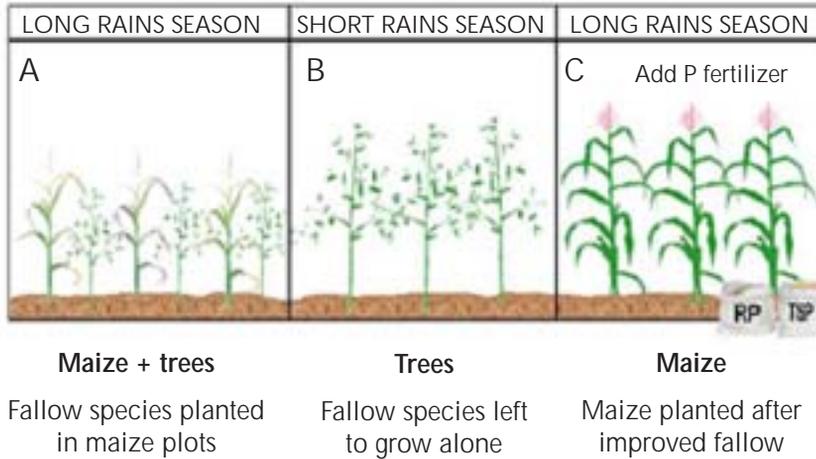
*Improved fallows can increase maize yields.*



*Improved fallows can provide stakes . . .*



*. . . and firewood.*



**Figure 1.** Proposed improved fallows system with cropping sequence. The period from A to C is 9 to 12 months. Phosphorus (P) may be added as rock phosphate (RP) or triple superphosphate (TSP).

- It is deep rooted so that it picks up well the nutrients that are leached and deep in the soil.
- It fixes nitrogen biologically from the atmosphere, building up good nutrients overall.
- It is easy to establish and manage.
- It supplies extra products such as stakes, grain and fodder that make its use attractive.
- It will not spread as a weed into cultivated areas.
- It easily produces seeds with long viability.
- It is adapted well to resist the pests and diseases in the area.

**Woody species**

- Cajanus cajan* (pigeon pea)
- Calliandra calothyrsus* (calliandra)
- Crotalaria grahamiana* (crotalaria)
- Crotalaria mucronata*
- Crotalaria paulina*
- Crotalaria striata*

## *Improved fallows for western Kenya*

*Desmodium uncinatum* (desmodium)

*Gliricidia sepium* (Mexican lilac)

*Sesbania sesban* (sesbania)

*Tephrosia candida* (tephrosia or fish poison)

*Tephrosia vogelii*

### **Herbaceous species**

*Canavalia ensiformis*

*Colopogonium mucunoides* (mucuna)

*Dolichos lablab*

*Macroptilium atropurpureum* (siratro)

Many leguminous plant species have been identified as suitable for use in establishing short-duration improved fallows. Key species are listed here. Many are illustrated in the colour plates.

At the end of the fallow period—usually between 6 months and 1 year— the trees, shrubs or herbaceous legumes are cut down and the biomass (leaves, twigs, branches) is incorporated into the soil while the land is being prepared for the next crop. Such fallows, if well established, can add between 100 and 200 kilograms of nitrogen per hectare per year. This amount of nitrogen can produce 4 to 5 tonnes of maize grain per hectare in one season if phosphorus, potassium or other nutrients are not limiting. For example, in a farmer-managed trial with 82 farmers, maize yield during the season following improved fallows of several species (*Crotalaria grahamiana*, *Sesbania sesban*, *Tephrosia vogelii*) averaged 4.1 tonne per hectare but only 1.7 tonnes per hectare under the normal farmer practices of no inorganic fertilizer inputs or use of farmyard manure. After improved fallows of such fast-growing species, maize yield can be twice as much as the yield of maize that is continuously cropped and with no fertilizer added. Although the residual effect from a short-duration improved fallow may last one to two seasons, the effect of an 8-month fallow can last for one or more seasons, depending on the level of degradation of the soil. Farmers tend to replant improved fallows every season, either on the same plot or by shifting plots.

Thousands of farmers in western Kenya are now practising improved fallow systems and have increased their crops yields tremendously.

Figure 2 shows the various districts of western Kenya where the uptake of improved fallows is significant. This uptake of the technology has been achieved through close collaboration between the World Agroforestry Centre and its many research and development partners in the region.

## 2.3 Types

### ***Single-species fallow***

A single-species fallow is established with only one plant species in the whole field. Typically, this system is recommended for species that grow fast and develop dense canopies that shade and kill weeds. Such species are *Crotalaria grahamiana*, *Crotalaria paulina* and *Colopogonium mucunoides* (mucuna).

### ***Mixed species***

It is possible, and even preferable, to establish improved fallows by planting alternate rows of two or more different fallow species. The species grow together without affecting each other. This practice is particularly good for slow-growing species that will not strongly compete. Mixed-species fallows may offer one or more of the following benefits:

- If one species fails to germinate or establish poorly because of adverse weather conditions such as drought, poor seed or insect and pests attack, the other species may not suffer as much or be subject to the same attack.
- Different species may produce a wider range of products, such as fuelwood, stakes or leafy biomass.
- Depending on the site and the duration of the fallow, they tend to prolong the residual effect of the fallow, because they make plant nutrients available for a longer period.
- They make optimum use of available resources such as light and space.
- Virtually any mixed crop has the advantage over a monocrop of reducing the risk of pest damage to the species themselves, such as the attack of mesoplatys beetle on *Sesbania sesban*.



**Figure 2.** Districts in western Kenya where the World Agroforestry Centre and its research and development have promoted improved fallows between 1997 and 2002. This map is continuously being updated as work progresses and partnership expands.

The following are some successful combinations for mixed-species improved fallows:

sesbania + siratro  
 sesbania + groundnut  
 sesbania + *Tephrosia vogelii* or *Tephrosia candida*  
 sesbania + crotalaria (*Crotalaria grahamiana*)  
 tephrosia + crotalaria

## 2.4 Benefits of improved fallows

### *Soil fertility improvement*

**Nitrogen.** Yellowish leaves and stunted growth of crops, seen particularly in maize, indicate an inadequate supply of nitrogen. Planted and managed fallows can increase the amount of available nitrogen in the topsoil through biological fixation from the atmosphere. The atmosphere contains about 78% nitrogen, part of which can be taken up by leguminous plants that fix it through the bacteria in their roots. These fallow species can also absorb nitrogen from deep soil layers, beyond the reach of the roots of annual crops. The fixed and absorbed nitrogen becomes available to crops when the fallow leaves, pods and roots decompose. The amount of nitrogen added to the soil through fallows can be as much as 100 or even 200 kg per hectare. This amount is adequate for the first subsequent maize crop and even several more crops at a moderate grain yield of 3 to 4 tonnes per hectare if other nutrients are not limiting. The following list shows the amount of nitrogen that some fallow plant species can accumulate in their biomass in 8 months. Between 60 and 80% of this nitrogen is fixed—obtained biologically from the atmosphere.

#### *Amount of nitrogen fallow plants can accumulate in 8 months*

<u>Species</u>	<u>kg/ha</u>
<i>Cajanus cajan</i>	164
<i>Crotalaria grahamiana</i>	199
<i>Macroptilium atropurpureum</i>	158
<i>Sesbania sesban</i>	124
<i>Tephrosia vogelii</i>	173

**Phosphorus.** Plants deficient in phosphorus can be identified by the purplish-green colour along the edges of the leaves. The concentration of available phosphorus in the soils of most farms in western Kenya is low. Unfortunately, fallow species contain little phosphorus and cannot, therefore, overcome phosphorus deficiency in planted food crops. For instance, 6tonnes of dry matter per hectare of sesbania can provide only 12 kg phosphorus per hectare. This is less than what is required for good crop yield, which for maize, for example, is about 22–25 kg phosphorus per hectare per season. It is therefore often necessary to add more phosphorus to the soil before planting crops after fallowing. This can be done by using triple superphosphate (TSP) or diammonium phosphate (DAP) inorganic fertilizer, or phosphate rock such as Minjingu from northern Tanzania, which is becoming available in western Kenya.

Minjingu phosphate rock (MPR) is a finely ground powder containing 13% phosphorus (or two thirds the percentage of TSP). It can be applied by evenly spreading it over the whole plot and incorporating it into the soil together with leaves from fallow plants while the land is being prepared for planting. It can also be put into the planting hole. When using it to grow maize, apply rates that will provide 22 to 25 kg of phosphorus per hectare per season, especially on soils with very low available phosphorus. Farmers using MPR in western Kenya mix 2 kg of MPR with a wheelbarrow of farmyard manure or compost and place one handful of the mixture in each planting hole. Farmers' observations are that one 50-kg bag of MPR is enough for one acre of land. The research recommendation for phosphorus is 22–25 kg/ha, which 3–4 bags of MPR can provide.

**Potassium.** Plants suffering from an inadequate supply of potassium are identified by leaves that are yellowed and scorched and burned looking at their tips and along the leaf edges, while the inside remains green. Some tree and shrub species such as tithonia and sesbania accumulate potassium in their leafy biomass. When this biomass decomposes, the potassium becomes available to crops. Using these species in improved fallow systems can reduce the potassium deficiency for the next crop. For example, in a potassium-deficient site in Vihiga District, improved

## Types of fallows



*A woody mixed fallow of Sesbania and Crotalaria.*

*A herbaceous single-species fallow of Colopogonium mucunoides (mucuna).*



*A woody single-species fallow of Tephrosia.*



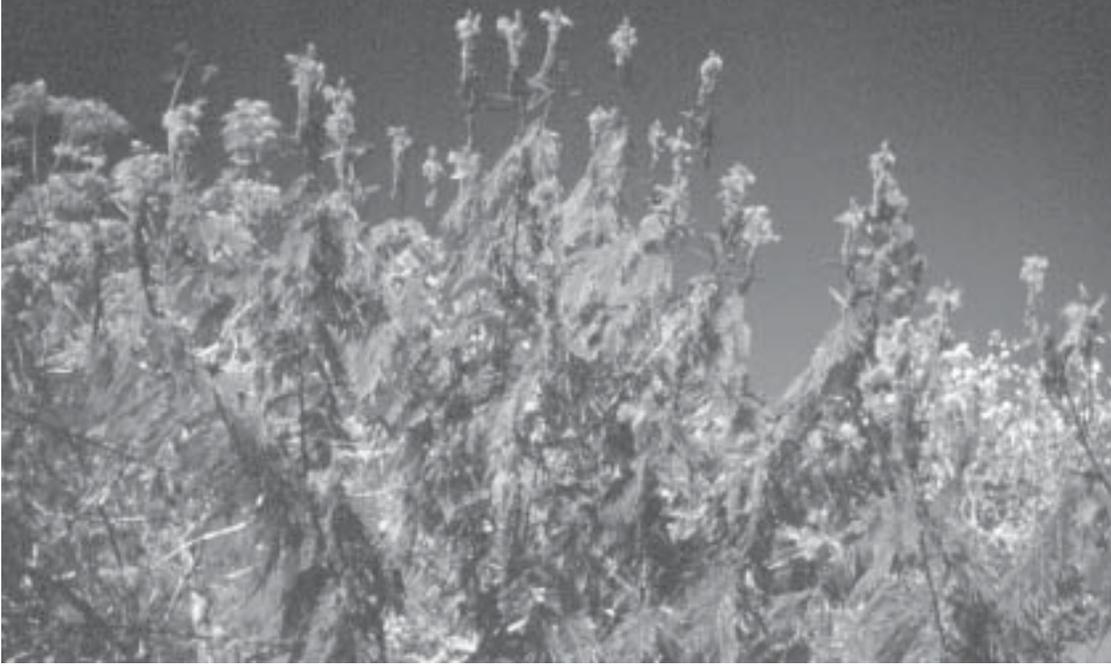
Common improved fallow species



*Cajanus cajan* flowers    pods



leaves



*Calliandra calothyrsus* shrub



flowers



Pods



leaves



*Crotalaria grahamiana* pods

flowers



leaves



*Crotalaria paulina* plants



flowers



Pods



*Tephrosia vogelii* plant



flowers

*leaves*



*Pods*

*Tephrosia  
candida  
plant*





*Desmodium uncinatum* leaves

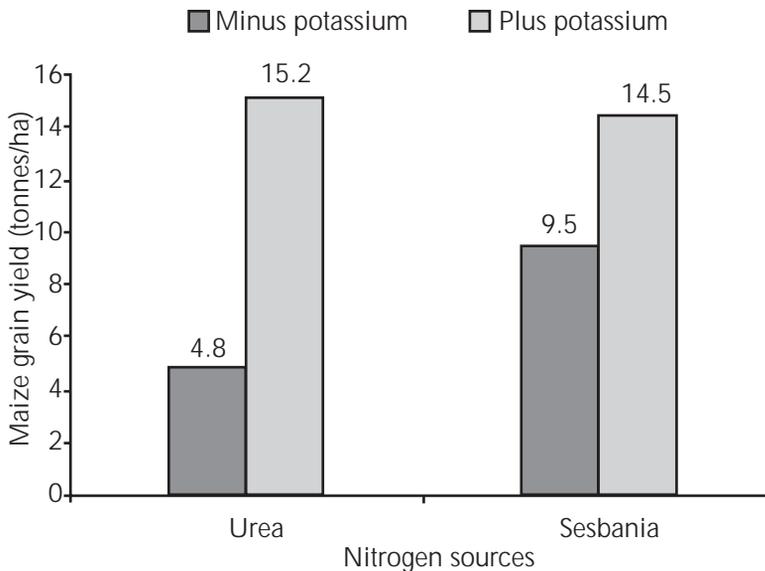


*Gliricidia*  
*sepium*  
flowers

fallow of sesbania was able to improve maize yield by 50% compared with the use of urea alone, which contains no potassium (fig. 3).

Estimates are that about 25% of the soils in western Kenya are deficient in potassium.

The smaller increment in maize grain yield after the sesbania fallow indicates that the amount of potassium in the sesbania biomass was already appreciable. The large yield increase after adding potassium to the urea treatment indicates that the soil was deficient in potassium. Nevertheless, improved fallows only recycle potassium present in the soil. Unlike fallows do with nitrogen, they cannot fix or obtain potassium from the atmosphere. Over time, potassium can be lost from the system through harvest of wood from the trees and shrubs used in improved fallows. Loss can also occur with harvest of crops, more so with the higher yields associated with improved fallows—creating potassium deficiency. For sustainable production, it is essential to minimize potassium loss by recycling as much of the crop residues as



**Figure 3.** Cumulative maize grain yield for 8 seasons in two cropping systems—with urea and with improved sesbania fallow crop rotation—with and without adding potassium. The nitrogen supplied in both treatments is the same.

possible, including livestock manure, and periodically applying fertilizers such as potassium chloride (commercially sold as muriate of potash) that contain potassium.

**Magnesium** is another nutrient like potassium that can become deficient over time if fertilizers, organic or inorganic, are not used in addition to improved fallows. Fortunately, most of the phosphorus and potassium fertilizers also contain and provide magnesium.

### ***Economic benefits***

Improved fallows can be more profitable than continuous cropping and natural fallow practices. Results of an on-farm trial show that crotalaria fallow 7–9 months old is more profitable than continuous maize cropping (table 1). This is the case for both the returns to land (an important indicator where land is scarce) and returns to labour (an important indicator where labour is scarce). The benefit resulting from adding phosphorus is, however, low because at present in western Kenya the cost of fertilizing is high. Fertilizer prices, therefore, need to come down if farmers are to benefit from applying it.

**Table 1.** Economic benefits of 7–8-month-old *Crotalaria grahamiana* fallow in western Kenya

Farming systems	Returns to land (KES/ha) <sup>a</sup>	Returns to labour (KES/day) <sup>a</sup>
Continuous cropping, no phosphorus	18,300	111.80
Continuous cropping, 50 kg phosphorus per hectare	14,175	100.50
Crotalaria fallow, no phosphorus	11,325	148.50
Crotalaria fallow, 50 kg phosphorus per hectare	26,250	148.50

<sup>a</sup> KES = Kenya shillings, valued here at 75 to 1 US dollar

Farmer assessments indicate that yield increases of between 100–200% are achievable. Economic returns vary for different farmers. One species may outperform others in one site, but not in another. Returns may be high using fallows alone, but in some cases adding phosphorus will be necessary to achieve positive returns.

Improved fallow systems require additional labour for sowing of the tree seeds, cutting the fallows, and in preparing the land following a fallow. However, for a fallow of 1000 m<sup>2</sup>, this implies additional labour of 1 day for cutting, 1 additional day for land preparation, and only a couple of hours for direct sowing of tree seed (the latter would increase if seedlings were transplanted). Of course, labour is then freed up during the season in which the fallow is allowed to grow on the field.

### ***Tree products***

Shrubs and trees used in improved fallow systems can also provide firewood, contributing significantly to the fuelwood needs of many households in western Kenya, where the shortage of fuelwood is severe.

As growing climbing bean varieties becomes more popular with farmers, they will need more stakes to support the plants, as is customarily done for growing tomato. The woody plant species used for improved fallow such as sesbania and tephrosia can provide stakes. Species particularly good for staking materials are *Calliandra calothyrsus* and *Tephrosia candida*.

### ***Weed control***

An additional benefit of planted fallows that can be observed in the field is that relative to natural fallows they reduce the amount of weeds. *Crotalaria* and *mucuna* are especially effective. This is so because the fallow plants grow fast and prevent weed species from growing, which in turn reduces the amount of time required for weeding.

The parasitic weed striga (*Striga hermonthica* and *Striga asiatica*), known locally as 'kayongo' or 'oluyongo', infests an estimated 160,000 hectares of farmland in the Lake Victoria Basin. The weed attaches itself to roots of the host cereal plant from which it draws all of its water and

nutrients as well as part of its carbohydrate requirements. Additionally, it exerts a strong phytotoxic effect on the host, causing yield losses far greater than from pure plant competition, reducing crop yield the most where soil fertility is low. It causes serious damage to maize, sorghum, millet, sugarcane and rice. Striga in the field can be readily recognized by its showy pink flowers. Other indications of its infestation are stunted growth and moisture deficiency of host plants, even when the soil moisture supply is normal. Pulling the weed out by hand to eradicate it is effective, but it requires a lot of labour, particularly in large farms, and is extremely tedious. Chemicals can control striga, but they are too expensive for most farmers to use.

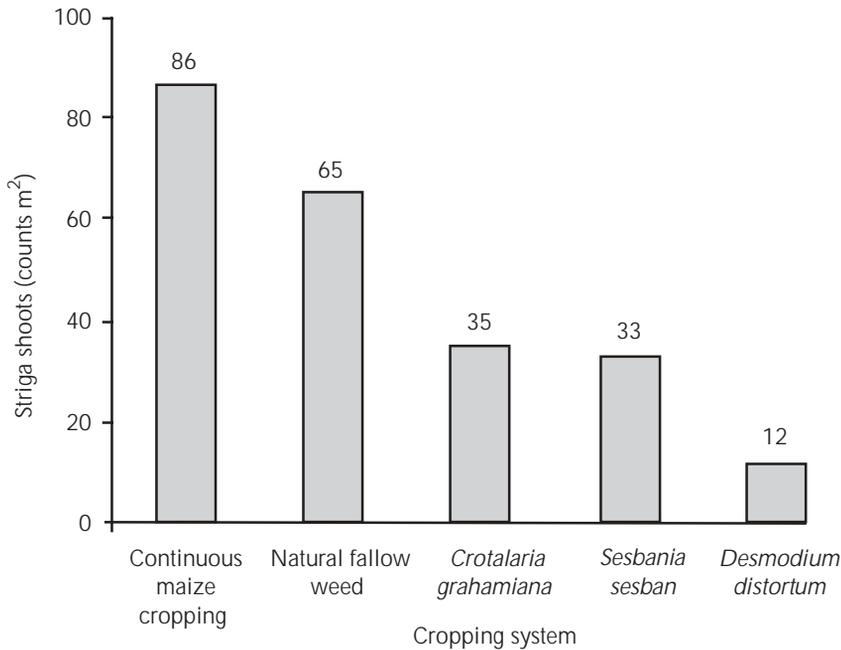
Fortunately, improved fallows can control striga. *Sesbania sesban*, *Crotalaria grahamiana* and *Desmodium distortum* can stimulate the germination of striga seeds in the soil. The germinated plants soon die because the fallow species are not their natural hosts. This reduces the number of striga seeds in the soil, and consequently cereal crops planted after the fallow period are much less severely damaged.

The number of striga seeds germinating after 8-month fallows of these species is considerably fewer than in fields that have been under continuous cropping or natural fallow (fig. 4). The smaller number of striga plants in maize plots planted after fallows of desmodium, sesbania and crotalaria indicates that most of the striga seeds had germinated and died in the previous season. This 'suicidal germination' effect can be increased by using traditional practices such as hand pulling and burning the weed and by applying farmyard manure to crop fields.

### ***Minimum tillage and erosion control***

The fallows also improve the organic matter content of the soil and improve moisture retention, making minimum tillage possible. Minimum or zero tillage has long been known to enhance soil physical properties. For minimum tillage to work well, the fallow must establish well and weeds need to be controlled. Otherwise, crop yield might not be as good as with conventional tillage.

For example, following an 8-month fallow of *Crotalaria grahamiana*, crop seeds were drilled into the soil without tilling it. With this practice,



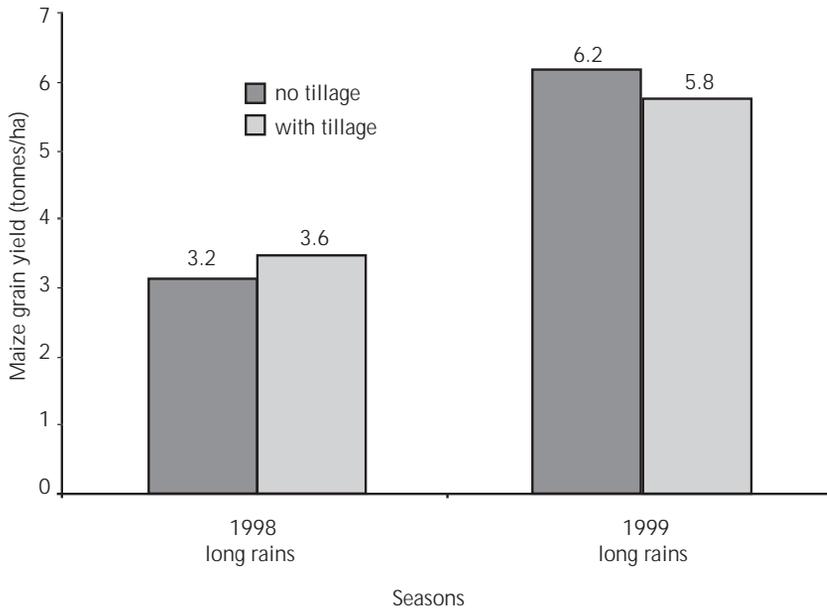
**Figure 4.** Effect of different cropping systems on striga weed germination.

maize yield for two successive seasons was comparable to that where the land was tilled with a hand-held hoe ('jembe') after the shrubs were cut back (fig. 5).

Minimum tillage following improved fallows can also help control soil erosion on sloping land. For instance, on land with a slope of 3 to 4% in Vihiga District, minimum tillage significantly reduced soil erosion in maize fields—whether the maize followed a crotalaria fallow or was continuously cropped. Soil erosion after crotalaria fallow, either with or without minimum tillage, was several times less than after continuous cropping.

## 2.5 Adoption potential

Although thousands of farmers in western Kenya are now practising improved fallows, resulting in important increases in their crop yields, a number of factors still hinder large-scale adoption of this technology.



**Figure 5.** Maize grain yield following *Crotalaria grahamiana* 8-month fallow with and without conventional tillage with hand-held hoe ('jembe') in western Kenya.

### ***Farmer management and assessment of improved fallows***

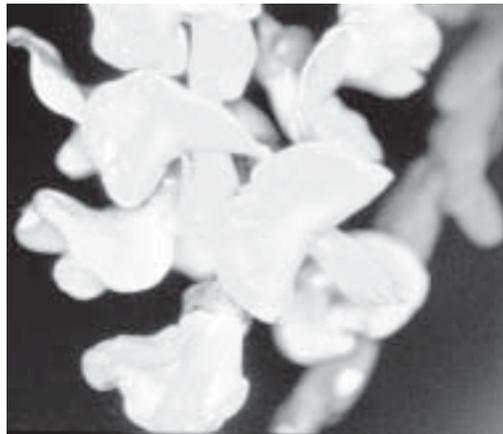
A sample survey in western Kenya found that 53% of farmers planting improved fallows were women and 47% were men. Two years after experimenting with the practice, about one quarter could be termed strong adopters (planting in both of the years), half were medium adopters (planting in 1 of the 2 years) and one quarter had abandoned the practice. Men and women were about equally divided among the three groups.

Farmers' criteria for selecting which plots to plant were those with low soil fertility and those where striga weed was present.

Farmers' management of improved fallows differed in some important respects from researchers' recommendations. Even though researchers recommended planting during the long rains season, one quarter of the farmers planted during the short rains season and the area they planted



*Sesbania sesban* plant



flowers

## Pests that may infest fallow species



Root-knot nematode



*Leaf-eating beetle*



*Amphicalla pactolicus* pupating on pods of *Tephrosia vogelii*



*Caterpillar  
larvae of  
Amphicalla  
pactolicus  
feeding on  
crotalaria*



*Stem borer on Crotalaria grahamiana*

**Farmers of the future growing up with improved fallows (here *Crotalaria grahamiana*) in western Kenya**



was almost as large as during the long rains season. This may have reflected farmers' eagerness to try out the practice during both seasons or their differing views on the relative reliability of the two seasons.

Moreover, 45% of the plots were planted before the rains began instead of into a standing maize crop following the start of the rains as recommended. Planting the trees early was particularly common during the short rains, probably because farmers feared that the trees would not survive if planted late.

Whereas researchers recommended that trees be grown for at least 9 months to provide a good yield response, on 24% of the plots the fallows were left for 6 months or less. This brief fallow period may have provided little improvement in soil fertility. Farmers may have cut the trees early because of poor tree growth, late tree planting, lack of land, or shortage of labour to cut them at the recommended time, which is just before planting maize. Surprisingly, on many plots (40%) the trees were cut during the cropping season rather than just before it. Cutting the trees during the cropping season was most common during the short rains season, perhaps to ensure that the plot was cleared before the long rains season, even though this was several months away.

Farmers' evaluations of the importance of benefits they obtained from improved fallows indicated that improved soils and crop yields were the most important, followed by fuelwood and reduced growth of weeds (mainly striga). These benefits were each mentioned by over 90% of the farmers; other benefits, mentioned by fewer than half, included tree seed production and pest resistance.

Women rated improved fallows significantly higher than men did on improving soils and on reducing weeds. This finding reflects the fact that women spend much more time in cropping activities than men and would thus be more likely to ascertain and appreciate the effects of improved fallows on soils and weeds.

*Crotalaria grahamiana* and *Tephrosia vogelli* were the species most commonly planted. Others included *Crotalaria ochroleuca*, *Crotalaria paulina*, *Sesbania sesban* and *Tephrosia candida*. A few farmers preferred mixing tree species to avoid the risks involved with growing a single

species. They also wanted to be able to compare the performance of different species.

Farmers gave *Sesbania sesban* and *Crotalaria grahamiana* the highest mean ratings for improving soils and crop yields, followed by *Tephrosia candida* and *Tephrosia vogelii*. *Sesbania sesban*'s high ratings may be because it is the only indigenous species and farmers have had a longer time to observe its positive effects on soils and crops. Farmers noted that *Crotalaria grahamiana* produced the highest biomass and was easy to incorporate into the soil. *Crotalaria grahamiana* rated highest on reducing weed growth, because it rapidly covers the soil. *Sesbania sesban* performed best on fuelwood, although farmers rate its wood quality fairly low compared with that of other trees that they use for fuelwood. *Crotalaria grahamiana* was appreciated for its seed production, as several organizations buy the seed for distribution to other farmers. *Tephrosia vogelii* was the most appreciated species for reducing pests, as it repels moles.

*Sesbania sesban* and *Crotalaria grahamiana* had the highest general preference scores followed by *Tephrosia candida* and *Tephrosia vogelii*. Species including *Crotalaria ochroleuca* and *Crotalaria paulina* received fairly low ratings, in part because they do not produce good fuelwood. *Sesbania sesban*'s high ratings on performance contrast with its low use by farmers in improved fallows. *Sesbania sesban* accounted for only 2.5% of the area under fallows in 1998, mainly because of its slow growth and because much labour is required for raising sesbania seedlings in a nursery.

### ***Expansion of improved fallows***

- Monitoring in 17 villages found about 22% of farmers had been consistently using improved fallows with another 7% beginning to test the technology in 2001.
- Adoption rates were higher where farm sizes were larger and farmers had more contact with informed and knowledgeable extension or research services.
- The average area planted to improved fallows among farmers planting them increased from 363 m<sup>2</sup> during the long rains 1998 to 511 m<sup>2</sup> during the long rains 1999.

- Although women farmers had smaller improved fallow plots than men in 1998, the situation was reversed in 1999.
- The poor are adopting improved fallows at about the same rate as the middle and higher wealth groups. Between the long rains of 1998 and the long rains 1999, poor adopters had larger areas under improved fallows than did the medium or better-off farmers.
- Improved fallows may be used by farmers who use other methods of soil fertility management as well as by farmers who previously did not use other practices.

***Factors affecting the decision to continue planting improved fallows, following experimentation***

- *District.* Farmers in Siaya were more likely to continue planting improved fallows than farmers in Vihiga, probably because of greater contact with researchers and greater interest and cohesion among farmers.
- *Surplus or uncultivable land.* Farmers with surplus or uncultivable land are more likely to plant fallows than farmers who are short of land.
- *Farm size.* The larger the farm, the greater proportion of it the farmer is likely to have under improved fallows.

The reasons some farmers gave for not continuing to plant improved fallows included lack of labour, land, seed and technical assistance.

These factors point out that it is therefore important to conduct additional on-farm research and disseminate more information on mixing species, seasons and timing of planting in establishing the crops. It is also important to study farmer adaptations of this technology and the underlying reasons that farmers have for making them. Farmers' reasons for not following research recommendations are usually sound.

## 3 Establishing and managing the fallow

### 3.1 Seeds

#### ***Producing seed on farm***

Demand for seed is likely to increase as the number of farmers testing and adopting improved fallows increases. Farmers who already have seed can maintain their seed supply by doing the following as appropriate for their situation:

#### PRIVATE SEED STAND

- Establish a private seed stand, which should have a minimum of 20 plants. Space plants 0.5 x 0.5 m for *Crotalaria grahamiana*, 1 x 1 m for *Tephrosia vogelii*, 1.5 x 1.5 m for *Tephrosia candida*, and 2 x 2 m for *Sesbania sesban*.

#### BOUNDARY PLANTING

- Plant fallow species along farm boundaries and along contour lines to conserve the soil. Space as indicated and ensure that at least 20 plants are established.

#### TREES LEFT IN FIELD

- When harvesting the fallow, leave trees standing scattered on the farm; 30 to 50 trees are ideal, but to reduce genetic loss 20 should be the absolute minimum.

#### OTHER RECOMMENDATIONS

- If space is limited, arrange with neighbours to combine tree plantings and bulk seeds.
- To ensure good flowering and seed production, it may be necessary in some cases to weed and even fertilize the seed stands, such as with farmyard manure.
- Before collecting the seeds, check to be sure most of the trees are flowering, and thus are contributing to pollination.
- When the seed is ready, collect an equal amount from each plant and bulk it. If collecting from fewer than 20 trees, combine seeds

with those of neighbours. This will maintain a diverse and strong genetic base of seed for the future.

### ***Harvesting seed***

Harvest seed only when it is mature, because the viability of immature seeds is low and the storage life short. The seed of most species is mature when it can no longer be crushed between thumb and forefinger. Often, the colour of both fruit and seed changes on maturation—for example, from green to brown, black or grey. Collect seeds from several trees in the seed stands as described above to assure genetic mix.

Individual trees produce mature seed at different times in a season, and even on a single tree, seed maturity may vary through the crown. To obtain seed that is mature and of good quality, the seed in a stand must be collected several times. The interval chosen depends on the dispersal mechanism of the species; it may be as little as one week, as for *Crotalaria grahamiana*, or as long as one month in *Sesbania sesban*. Do not collect the very first seed or the very last to ripen, as these seeds may be of lower quality.

### ***Storing seed***

Seeds of all the species recommended for improved fallows can be stored for long periods if they are stored under conditions that maintain their viability. Storage temperature and moisture content should be kept low—moisture at about 5 to 8%. The dried seed should be kept in a cool and dark place in airtight containers such as plastic or glass jars with screw-tight lids. Mature and properly dried seed can be stored in airtight containers even at room temperature for at least one year. Label all seed properly before storing it. An unidentified seed lot is almost worthless. Label the seed container with the following information: species name, original collection source, collection location, collection date, viability and producer's name.

If in doubt about the viability of the seed, test a small sample by putting the seeds on moist paper in a plastic box. Keep the paper wet at all times and check if the seeds swell and germinate, which they should do in 1 to 2 weeks. If an acceptable percentage does so, the seed can be used.

### ***Buying seed***

Farmers who would like to get starter seeds of improved fallow species may try from the following possible sources:

- Farmers in Yala Division of Siaya District, and in Luanda and Emuhaya Divisions of Vihiga District
- Anyiko, Nyaminia or Sauri sublocational committees in Yala Division, Siaya District
- Office of the Ministry of Agriculture and Rural Development in your location in western Kenya

Other sources:

- Maseno Regional Agroforestry Research Centre, PO Box, 5199, Kisumu; tel (035) 51163/4. The centre is situated between Luanda market and Maseno University along the Kisumu–Busia road. The contact address is given on the back cover of this guide.
- World Agroforestry Centre (ICRAF), PO Box 30677, GPO 00100, Nairobi
- Kenya Forestry Research Centre (KEFRI) Seed Centre, PO Box 20412, Nairobi
- Sustainable Community-Oriented Development Programme (SCODP), PO Box 5, Sega; tel: (0334) 34253; fax: (0334) 34253, or any SCODP shop in Siaya and Vihiga Districts.

## **3.2 Planting the fallow**

### ***Erosion control***

The benefits of improved fallows can be increased by minimizing soil erosion on sloping land. This can be done by establishing soil erosion structures such as 'fanya juu' along the contour lines or by planting live hedges of calliandra, Napier grass and tithonia along contour lines across the slope. The soil conservation branch of the Ministry of Agriculture and Rural Development can assist in marking contour lines in the field. On slopes of more than 3 or 4%, it is advisable to practise minimum tillage. (See page 28.)

### ***Time of planting***

Western Kenya has two main types of agroecological zones: the 'highlands' (1200–1600 mm rainfall) and, particularly around Lake Victoria, the drylands (800–1200 mm rainfall). In the highlands, in a system with maize only it is advisable to plant the improved fallow species after the first weeding. In a system with maize and bean intercrop, planting should be after the second weeding, as by the second weeding, the bean crop is usually ready for harvesting, thus giving room for the trees. In the drier lake zone, where rainfall is less assured, improved fallows are best planted at the onset of the rains, either in sole stands or in intercrops such as maize or sorghum. In this zone, it is preferable to use perennial species such as *Gliricidia sepium*, which regrow when cut back, rather than annuals, which must be replanted each season.

### ***Seed pretreatment***

Seeds of some fallow species do not germinate quickly or germinate poorly. One such species is *Sesbania sesban*. This is because sesbania seeds have a very hard seed coat that requires softening before the seed can germinate. It is recommended that seeds of such species be soaked in hot water at 65° C for 10 to 15 minutes. Do this by leaving boiling water to cool for 15 to 20 minutes before fully immersing the seed in it in a cloth bag. Dry the seed in the sun for 15 to 20 minutes before planting it. Seeds of other plants listed in this guideline germinate easily without pretreatment.

### ***Plant density***

Spacing depends on the size of the seed. The spacing recommended in table 2 should give high biomass yield and good canopy cover within 6 to 8 months. The narrow in-row spacing of *Crotalaria paulina* and *Crotalaria striata* is because they are short plants when mature. This seed rate can also be used for herbaceous legume cover crops such as mucuna.

**Table 2.** Recommendations for establishing 1 hectare of various fallow species

Species	Seeds per kg	Spacing (cm)	Seed rate (kg/ha)	Seed rate (g/plot) <sup>a</sup>
<i>Cajanus cajan</i>	7,000	75 x 30	18.2	1638
<i>Crotalaria grahamiana</i>	18,000	75 x 30	7.0	630
<i>Crotalaria paulina</i>	64,000	75 x 10	2.0	180
<i>Crotalaria striata</i>	110,000	75 x 10	1.2	108
<i>Sesbania sesban</i>	100,000	75 x 30	0.3	27
<i>Tephrosia candida</i>	18,000	75 x 30	7.0	630
<i>Tephrosia vogelii</i>	18,000	75 x 30	7.0	630

Amounts calculated on seeds being planted 2 per hole; planting 4 seeds per hole doubles the seed rate. The germination rate for all seeds is 80%, except for *Sesbania sesban*, which has a rate of 70%.

<sup>a</sup>Seed rate for plots 30 x 30 m, the typical size of plots that smallholder farmers in western Kenya put to improved fallows.

### **Establishment**

For improved fallow species to benefit crops, they must have enough time in the field to grow and accumulate large quantities of biomass and nutrients. Several methods can be used to establish improved fallows:

- **Broadcast the seed in fields among existing crops**, for example, with maize after either the first or the second weeding. If intercropping bean with maize, harvest the bean then sow seeds of the fallow plants. This technique is best suited for species with large seeds such as mucuna. An advantage of this practice is that crop husbandry practices such as applying fertilizer and weeding also help the trees to grow better.

- **Plant in rows.** Sow seeds of improved fallow trees, shrubs and herbaceous legumes directly between the rows of the food crop after the first weeding or as soon as the food crop has germinated, and cover the seeds with soil. With maize, for example, plant in the furrows between the rows after either the first or the second weeding.
- **Plant the improved fallow trees into existing natural fallows.** One way to do this is to dig holes in the natural fallows and sow seeds directly or plant seedlings. If the weeds in the fallow are dense and inhibit digging the holes, first slash them.

*Crotalaria grahamiana* and *Tephrosia vogelii* can be planted directly into natural fallows. For species like *Sesbania sesban* that have small seeds or do not grow easily from seed, raise seedlings and plant them either in an existing crop or in natural fallow lands.

### **3.3 Pests**

Like any plant, fallow species can be attacked by a variety of pests and diseases. When the fallow species share these with the crops to be planted after the fallow, the problem is even more serious and the beneficial effect of the fallow on soil fertility may be lost completely because of a soil-borne pest or disease. It is therefore important to identify important pests and diseases and to take appropriate measures to control them.

#### ***Plant nematodes***

Nematodes are very small, transparent, parasitic worms that may enter and live inside the roots of some of the plants used for improved fallows, such as *Sesbania sesban*, *Tephrosia vogelii* and *Tephrosia candida*. The nematodes also parasitize many other plants, including bean, carrot, cowpea, eggplant, tobacco and tomato. The roots of infested plants swell with galls, sometimes called elephantiasis of the root. The leaves may also show signs similar to those of plant nutrient deficiency. Roots of healthy plants of *sesbania* and *tephrosia* also have swellings called nodules. Inside these nodules, bacteria live that help to convert free atmospheric nitrogen into a form that plants can use for growth. A

### *Improved fallows for western Kenya*

difference between galls and nodules that is easy to determine is that galls are strongly attached to the roots and are not easily removed when rubbed; nodules are easily removed by rubbing and are reddish-brown on the inside.

The nematodes that attack sesbania and tephrosia do not attack maize, sorghum, finger millet or groundnut, nor do they attack crotalaria or senna (*Senna siamea*). But they do attack bean and tomato. It is therefore recommended not to plant bean or tomato after sesbania or tephrosia fallow until the second season. Instead of bean in the first season following the fallow, plant groundnut. However, bean may be planted in the season following the fallow if the fallow was a mixed one, such as sesbania or tephrosia with crotalaria. The incidence of root-knot nematodes is significantly less in mixed fallows than in single-species ones. The following suggested crops can immediately follow fallows to minimize nematode damage.

<u>Improved fallow species</u>	<u>Crops recommended to follow fallow</u>
sesbania, tephrosia	maize, sorghum, finger millet, groundnut
crotalaria	maize, bean, vegetables
sesbania–crotalaria mixed	maize, bean, sorghum, finger millet, groundnut
tephrosia–crotalaria mixed	maize, bean, sorghum, finger millet, groundnut

### ***Insect pests***

In western Kenya, insects that have been recorded on improved fallow plants include beetles on sesbania and caterpillars on crotalaria. The beetles are a problem only on young sesbania, whose tender leaves they eat. As the tree becomes established, the damage is less. On crotalaria, caterpillars of the butterfly *Amphicallia pactolicus* prefer feeding on flowers, but they may also feed on the leaves. They are not likely to cause much loss of biomass. Over 70% of the amount of leaves eaten are returned to the soil in the form of faecal pellets or manure. The

Insects have not been found to damage food crops. Other insect pests recently recorded include an unidentified leafhopper and the groundnut hopper, *Hilda patruelis*, which can also cause severe damage to *Crotalaria grahamiana*. It sucks sap from the stem just below ground level. Severe damage can cause the crotalaria to wilt and lodge. The pest can feed on several other hosts such as bean, maize, cashew and potato, and it can survive on common weeds such as *Conyza sumatrensis*, *Bidens pilosa* and *Tagetes minuta*.

The insect pests can be controlled by practising traditional methods such as planting fallows of mixed species, and planting the food crops early enough to escape attack by the insects.

The insect pests mentioned here are indigenous species. Scouting and monitoring will continue in the field as more farmers adopt the practice of improved fallows, to establish economic injury levels of the insects and new methods of control.

### **3.4 Managing and harvesting the fallow**

After harvesting the food crop, leave the fallow trees in the field to grow. In 6 to 8 months, they form a closed canopy and cast a dense shade on the ground, which helps to suppress weed growth. With fast-growing species such as crotalaria and tephrosia, it is not necessary to weed the fallow.

To achieve good weed control with slow-growing improved fallow species like sesbania, sow the tree seeds along with herbaceous legumes such as mucuna, siratro (*Macroptilium atropurpureum*) or even with food crops such as sweet potato and groundnut.

At the end of the fallow period (8 to 9 months or longer after planting), cut down the fallow trees and chop off the leaves, twigs and soft branches. Spread them evenly over the field, and then incorporate them into the soil while preparing the land for planting the next crop. Use a jembe or an ox-drawn plough.

Remove the woody parts of fallow plants from the field and use them for fuelwood or for stakes for crops such as climbing bean and tomato.

### *Improved fallows for western Kenya*

Then plant crops at the beginning of the next season. At this stage, it is best to add phosphorus fertilizer, especially in phosphorus-deficient soils. Most of the soils of western Kenya lack sufficient phosphorus. Place the phosphorus fertilizer in the planting hole or broadcast it and work it into the soil. The amount of phosphorus applied will depend on the crop to be planted after the fallow period.

## **4 For more help . . .**

For more information, seeds or seedlings, contact the following:

National Agroforestry Research Centre

PO Box 5199

Otonglo, Kisumu

tel: (035) 51163, 51164, 21918 and 21234

email:

[icrafksm@africaonline.co.ke](mailto:icrafksm@africaonline.co.ke) and [kefrimas@africaonline.co.ke](mailto:kefrimas@africaonline.co.ke)

or

World Agroforestry Centre (ICRAF)

PO Box 30677, GPO 00100

Nairobi

tel: (02) 524230

email: [b.jama@cgiar.org](mailto:b.jama@cgiar.org)

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