Agrodok 16

Agroforestry

Ed Verheij

This publication is sponsored by: KERKINACTIE.
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First edition: 1994
Third, completely revised, edition: 2003

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Printed by: STOAS Digigrafi, Wageningen, the Netherlands

ISBN: 90-72746--92-9

NUGI: 835

Foreword

Each year, Agromisa receives many enquiries on agroforestry from persons and institutions in the South. There is thus clearly a need for practical information on the subject. It is in this context that this Agrodok is presented. It describes the essential elements of agroforestry, from some basic principles to their practical application; looking at the benefits but also paying attention to the difficulties and constraints. The aim is to offer options for improved land-use in the tropics. Extension issues are also addressed, because recommendations by scientists or extension workers to introduce certain agroforestry systems can only be successful if village people are convinced that the proposed change in their land-use is beneficial.
Certain aspects of agroforestry systems are also covered in other Agromisa publications:

- AgroBrief no. 1 (Van Tol, 2002: *Fodder trees*)
- Agrodok no. 5 (*Fruit growing in the tropics*)
- Agrodok no. 11 (*Erosion control in the tropics*)
- Agrodok no. 19 (Schreppers et al., 1998: *Propagating and planting trees*)

Acknowledgement
This third edition of Agrodok 16, Agroforestry, has been completely rewritten to incorporate new insights in agroforestry. I gratefully acknowledge the text contributions and reviews of specific subjects by Robert Peter Heijer, Rick Thijssen and Nick Pasieczik (HDRA) and the editorial work of Orisa Julius Ainyia, Jan Joost Kessler, Paul Kiepe and Marg Leijdens. I am particularly grateful to Dr M. Wessel, emeritus professor of Tropical Crop Science, Wageningen University, for inspiring discussions, suggestions for further reading, and comments on the manuscript. However, I accept full responsibility for the contents, including any imperfections or errors.

Ed Verheij, September 2003

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1 Introduction

1.1 Annual crops and trees in agricultural development

Farmers in large parts of the tropics have no tradition of aiming at maximum production per hectare; their main concern was to reduce the risk of crop failure. The principal reason is that - except in the main population centres - there were no convenient markets for food surpluses. The traditional farming systems were integrated, based on self-sufficiency and hence on internal supplies and services between different farm components: mixed cropping with a legume supplying nitrogen to a cereal, field crops supplying fodder for livestock in exchange for manure, etc.

However, in the last century these systems proved to be not sufficiently productive to feed the rapidly growing population. That is not surprising, because these traditional systems were not touched by agricultural science, which was the driving force for ever-increasing yield levels in the temperate zones of the world. Agronomists neglected the traditional mixed farming systems for two reasons:

- the prevailing notion that the market economy demands specialization;
- the lack of suitable research methods to study the intricately interwoven farm components.

The second reason of course follows from the first; modern agricultural science, in spite of its roots in systems research, gradually became very much preoccupied with the improvement of single crops. When called upon to combat hunger in tropical regions, agronomists knew no better than to concentrate on raising yield of the principal annual staple food crops, such as rice and wheat. These crops were already grown as mono-crops for the market and lent themselves to the approach which had been so successful in the temperate zones. Agronomists indeed succeeded with these crops, as for instance shown by the ‘green revolution’ in Asia.

Unfortunately this approach failed to alleviate hunger, in particular in tropical regions with rainfed farming systems and underdeveloped markets for food crops. In those regions the situation continued to deteriorate, also because the prices of non-food commodities (e.g. cotton, coffee, spices, fibres) kept falling worldwide, strapping smallholders of cash income and reducing them to subsistence levels of farming. Mounting population pressure resulted in ever-smaller farm size and the need to sacrifice 'unproductive' trees in favour of planting food crops. Moreover, the inability to raise yield levels forced the growing population to bring more land (often marginal land) under cultivation at the expense of the natural vegetation.

Before long these trends led to alarming reports about deteriorating land use systems: expanding 'dust bowls' and deserts (because of wind erosion), degraded land following loss of topsoil and silting up of irrigation systems (all because of water erosion), declining soil fertility and yield levels (because of inadequate inputs of manure and fertilizer and the opening up of marginal lands), etc. And then it was realized that these precarious situations had something in common: trees were vanishing from the landscape. Deforestation to open more arable fields, trees and shrubs killed by overgrazing, cutting of trees for fuelwood, etc., all add up to a landscape being denuded of its permanent vegetation (mainly forests and grazing land for cattle).

Thus it became clear that trees not only yield useful products but also play a vital role as more permanent elements in the landscape, sustaining the capacity of the land to feed people. This brought trees onto the agenda of agricultural development. Although trees are the largest perennial plants and they best exhibit the qualities which are important in sustaining the productive capacity of the land, the most important factor is that permanent vegetation covers the land, whether it consists of trees, shrubs, vines or perennial herbs (such as grasses, banana/plantain, yams). Therefore, where the term 'trees' is used in this booklet, it usually stands for all woody plants (and large perennials such as banana as well). In Chapter 2 the benefits and limitations of trees are discussed in more detail.

Unfortunately the benefits of a permanent vegetation cover of trees and other perennials only become obvious when the land has been denuded under excessive population pressure, overgrazing and deforestation. Then it is too late; once the elements have free play over the bare land 're-greening' becomes very difficult, because only the hardiest of plants can reclaim the area, and these tend to produce little in the way of food for man and beast. It is therefore of the utmost importance to reverse this overexploitation process before land degradation has impoverished the people who live in the area.

Figure 1: Wood being carried home to be burnt; but will the loss be compensated by new growth?

Annual crops cannot provide permanent cover and in dryland farming the fields lie a large part of the year unprotected. The realization that these crops should benefit from suitable combinations with tree crops in mixed cropping systems gave rise to AGROFORESTRY as a distinct discipline in agricultural science in the 1970s. Further consideration of the role of trees, shrubs and vines in mixed cropping systems resulted in the inclusion of crop mixtures of woody plants as well as cropping systems combining woody plants and animal husbandry.

Meanwhile agricultural science had rediscovered its origins - dating back to the early 19th century - in farming systems research, and was developing methods to study the mixed farming systems in the tropics. Crop science had already extended its reach from single crops to the study of mixed crops. This research confirmed the farmers' claim that mixed cropping reduces the risk of crop failure, but it also dampens the response to crop care. To demonstrate that a simple crop mixture of e.g. maize and beans outyields two plots of maize and beans grown separately requires many years of painstaking research and the outcome is not spectacular at all: the mixture yields only slightly more than the sum of the two crops on their own, mainly because the total yield of the mixture is more stable from year to year. The difference is larger - but the yields are much lower - at low input levels (no fertilizer, imperfect crop protection, etc.).

Compared to the interactions between maize and beans in mixed cropping, the interactions in agroforestry systems are a good deal more complex. Moreover, trees require years before they reach an effective size. During these years their interactions with companion crops and/or livestock keep changing. Thus the results will not be achieved quickly, nor will they be spectacular (if they were, farmers would have discovered this long before agronomists became involved). The hoped-for result of agroforestry technology is the reversal of a downward trend in land use into an upward trend, putting land-use back on a sustainable basis.

In fact the main benefit of agroforestry so far has been descriptive: studying the role of trees in traditional farming systems in various parts of the tropics and sounding the alarm over the dramatic losses of trees in the vegetation in many regions. The information collected regarding the many auxiliary woody plants and their uses in farming systems and descriptions of traditional forms of agroforestry provide the basis for experimental work. It took about a dozen years before the first agroforestry field experiment was laid out in 1984. Up till now the only system that has been tried well enough for a provisional evaluation of its usefulness is alley cropping, described in Section 4.5. In recent years the focus of attention has shifted to improved fallows, described in Section 4.6. This promising agroforestry system also requires long-term research work, but the complexity of the interactions is greatly reduced because the woody plants and the crops are not grown side by side, but one after the other.

1.2 The scope of agroforestry and of this Agrodok

Agroforestry is concerned with the role of woody plants in farming systems; it deals in particular with mixed cropping systems on the farm which comprise:

- several woody plants, e.g. coconut casting shade over cocoa or a windscreen of trees along an orchard of fruit trees;
- woody plants and herbaceous (usually annual) plants, e.g. improved fallows of fast-growing trees which restore soil fertility for the field crops grown after the fallow period;
- woody plants and livestock, e.g. scattered trees in parklands, which provide shade for cattle and lopped branches for fodder in periods of scarcity.

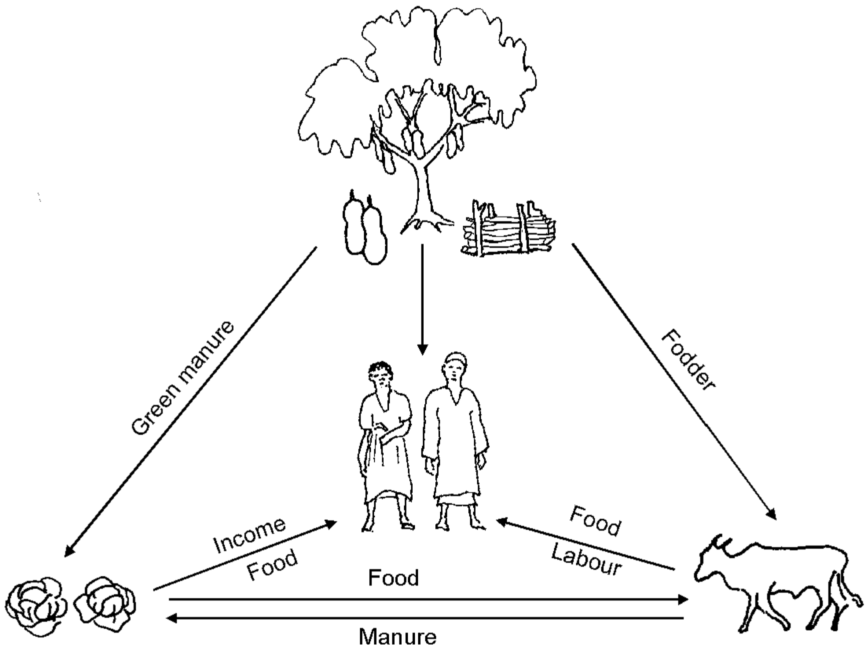

Figure 2: Interactions between trees, field crops, animals and people

This Agrodok does not give recipes for agroforestry plantings. That would be impossible in view of the diversity of the tropical environments, and of the large numbers of woody plants deserving consideration. Rather it is hoped that the reader gains insight in the scope and limitations of trees (Chapter 2) and in their possible roles within the farm (Chapter 3), in order to be able to choose practical applications of agroforestry (Chapter 4) which suit the local conditions. In Chapter 4 conditions under which an agroforestry approach is applicable are spelled out and examples of woody plants used for that application are given. Moreover, important characteristics of these plants are listed in Appendix 1; on the basis of these characteristics locally available plants may be selected which have similar properties. In other words: it is hoped that this Agrodok will foster understanding of the issues, so that the reader can adapt a specific agroforestry application to his or her local conditions, making good use of trees which have proven their usefulness locally, perhaps supplemented by some of the trees mentioned in Chapter 4.

To end this introduction the scope of agroforestry is briefly considered in relation to other disciplines in agriculture and forestry dealing with trees. Taking a historical perspective, public concern for the development of tropical tree crops emerged during the colonial era. This era started off with sea voyages from Portugal around Africa to give Europe direct access to the oriental spices, in particular black pepper and clove (borne on a vine and a tree resp.). Soon other tree crops were moved across the oceans, to set up large-scale production of what came to be known as plantation crops: coffee, tea, cocoa, coconut, oil palm, rubber, etc. These are still the best-researched tropical tree crops; they cover vast areas, now mainly in the hands of small farmers.

Likewise the tropical rain forests were a welcome source of timber for the colonial powers. They logged the valuable hardwoods and initiated plantation forestry - e.g. teak plantations - to supply the mother countries (with lasting consequences for the organization of forestry in the former colonies).

The tremendous variety of tropical fruits also aroused attention in the colonial period. Because transporting fresh fruit to the mother country was not feasible, the study of these trees was largely left to botanists; agronomically the tropical fruits remain ill-understood tree crops.

This episode in agricultural development is related here because it marked the beginning of new disciplines in agricultural science: tropical forestry, plantation tree crops, and tropical fruit growing. Is there really a need for agroforestry to supplement these older disciplines? Yes, there is. For one thing the other disciplines operate mainly in the humid tropics and in the tropical highlands; their impact in drier regions is quite small. Sisal, for instance, is practically the only plantation tree crop in low-rainfall areas.

Secondly, these other disciplines stand on their own; unfortunately the study of tropical trees is largely fragmented. There is little exchange of information, which weakens the impact of science on tree crops. Agroforestry, by cutting across these barriers, can play a unifying role: fostering the understanding of how trees function in order to give them their due place in the tropical environment.

Thirdly, the formal disciplines leave a large category of so-called auxiliary woody plants unattended. These auxiliary plants produce no marketable product; they play a supportive role in cropping systems, by providing shade or shelter, serving as a hedge or live stake (to support a trellis for climbers), providing fodder, etc. The supportive role on the farm implies that we must not only get to know these plants themselves; we also must study <u>how the woody plants interact with the crops or animals on the farm</u> which they shade, shelter, support, feed, etc. That is the scope of agroforestry.

2 Benefits and limitations of trees

2.1 Favourable impact of trees on the environment and on farming

What are the qualities of 'trees' which annual crop plants lack? As perennial plants trees cover the soil throughout the year, protecting it against the hot sun, high winds and heavy rain. But not only the soil: trees cast their shade over man and beast and companion crops (particularly shade-loving plants) and reduce the stress caused by drying winds or storms. Sheltered against the wind and shaded for part of the day the companion crop consumes less moisture, an important factor in ensuring good yields in dry areas. The trees themselves consume moisture which they transpire to cool the leaves; this helps to raise humidity and to lower daytime temperatures (see box 1).

Moreover, rooting to a much greater depth than annual crops, woody plants take up nutrients from these deeper strata and deposit most of them on the soil surface when they shed their leaves. In this way nutrients which have been leached from the topsoil are recycled and made available to the annual field crops: trees act as 'nutrient pumps'.

Let us list the beneficial effects of trees on the environment, including crop plants and animals. Trees:

- ameliorate the (micro)climate, breaking the wind, moderating temperatures and raising humidity;
- protect the soil against erosion by wind and water, at the same time improving water infiltration;
- support companion crops and animals by their effect on the climate and the soil, but also directly through providing shade and shelter or protection (live fences, hedges) and acting as nutrient pumps (see figure 3);
- diversify the landscape and enrich the environment: where would the birds nest without trees?

Box 1: Vegetation affects the environment

All plants transpire water to prevent overheating in the full sun. Transpiration cools the leaves and these act like air-conditioning, cooling the surrounding air. That is how a lush vegetation can lower the daytime temperature. At night the earth radiates heat and cools down, along with the ambient air. A dense vegetation acts as insulation; the soil cannot emit its heat freely and the temperature drops less than above bare soil.

During the second half of the last century Singapore developed rapidly into a large metropolis. However, at the same time every effort was made to strengthen its image as a 'garden city'. Trees were raised on a massive scale to plant avenues, parks and recreational areas. Remarkably, considering the heat expelled by all the air-conditioners on new buildings, by all the cars now clogging the roads and by the increased industrial activity, the maximum temperatures in the city dropped during that period. It has been claimed that this is a result of the 're-greening' of the city. Such a claim is hard to prove, but it has been convincingly shown that trees along busy Singapore highways reduce air pollution and tree barriers planted between industrial and residential areas have cut air pollution by about 25%.

A more extreme example of vegetation moderating extremes of temperature is Metahara Sugar Estate in Ethiopia. Driving from the capital Addis Abeba to Metahara one descends into the Great African Rift; it is like entering an oven. However, turning off the main road to Metahara, the oppression of the heat vanishes almost at once, and entering the estate 4 km down the access road, one feels quite refreshed. The estate takes in 5 m^3 of water from the Awash river per second to irrigate 6000 ha of sugarcane and most of this water is transpired to cool the cane and the air!
Before the cane was planted frosts occurred in the area. Weather records of the estate show that the average minimum temperature during December - the month with the coldest nights - has risen to nearly 12°C. The increase in minimum temperature is not only due to the cane acting as a blanket against heat loss; the wet (irrigated) soil also does not cool down as quickly as the dry soil did, because the heat capacity of wet soil is much larger.

All woody plants have these beneficial effects on their environment, including on companion crops and animals, although the impact of a large tree is of course greater than that of a shrub. Auxiliary woody plants are primarily grown for these benefits and/or for the fodder or fuelwood they provide. Tree crops are primarily grown for their marketable product: e.g. fruit, spice, oil, stimulant, timber; the benefits listed above are valuable but of secondary importance to the grower.

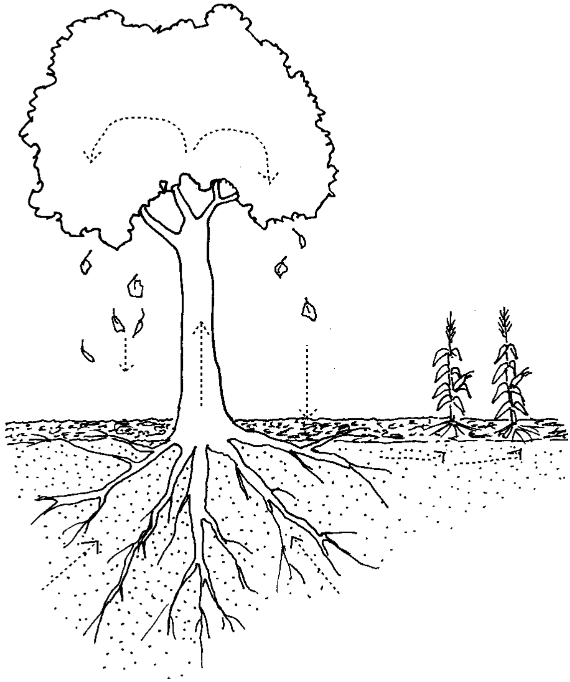

Figure 3: Trees act as nutrient pumps

Box 2: Multi-purpose trees

In the early days of agroforestry, when agronomists realized that certain woody plants are useful in more than one respect, the cultivation of these species as multi-purpose trees was promoted. A well-known example is *Leucaena leucocephala*: the twigs serve as a high-quality green manure or as fodder, the woody parts as fuelwood, and the main stems are used as poles. However, as discussed in this chapter, practically every tree or shrub can serve multiple purposes. On the other hand it is clear that not all these functions can be combined effectively. If a farmer regularly cuts branches off a tree for fodder, he will not expect that tree to produce much fruit or provide good shade for cattle; moreover its growth will be set back so that in the end it will yield less wood.
Thus it is important to treat each tree in accordance with the main purpose for which it is grown and to accept that as a consequence the other benefits are reduced.

Figure 4: Trees provide shade to people and livestock

2.2 Limitations of trees

Given all these benefits, why do we still need agroforestry to promote the use of trees? The answer lies in the consideration of time and space. Trees take a long time to reach the required size. If a hedge would be goat-proof the moment it is planted, there would be far more hedges! And trees grow to a large size. If land is scarce, how will farmers agree to allocate a strip of land sufficiently wide to plant a shelter belt (which will take several years to reduce the wind noticeably)? This consideration also implies that we should think twice before cutting existing trees; once they are gone it takes a lot of time and effort to get them back.

The other important limitation of trees is that they may compete with the companion crop. A shade-loving crop such as cocoa fits more easily in a mixed cropping system with trees than a sun-loving crop like maize. Eucalyptus trees use large quantities of water and in a dry climate the roots extend sideways almost as far as the tree is high; no ideal characteristics for a windbreak! Moreover, in that situation it pumps nutrients mainly for its own benefit.

Scattered trees in arable fields interfere with cultivation (e.g. ploughing) and lead to an uneven stand of the crop: poor growth under the trees, improved growth near the drip line of the tree canopy. This is why farmers usually prefer to have trees on the edge of a field (where they also may serve to mark the boundary of land owned by the farmer).

Trees compete with companion crops - whether field crops or pastures - for light, water and nutrients. Light need not be a limiting factor if trees are well spaced and trees with dense canopies are avoided. Pruning for fodder, for green manure or for puddling material can further reduce shade during the cropping season (although farmers prefer to prune for fodder during the dry season when other feedstuffs are scarce).

Competition for water is the largest problem in the drier parts of the tropics, not only because rainfall is lower, but also because it is more erratic from year to year. Thus, even where the average rainfall during the wet season is enough to grow sorghum, there is a real chance that the rainfall in any one particular year may not be enough. In that case the yield of sorghum will be further depressed if soil moisture has to be shared with trees.

Shortage of nutrients is common; it becomes serious where mounting population pressure leads to more or less continuous cropping and farming on land with low natural fertility. Deep-rooted plants such as trees act as nutrient pumps. However, a tree can only pump up nutrients it finds in the soil. On poor soil few nutrients are brought to the topsoil, especially because the trees themselves tend to grow poorly on such soils. The one exception, where trees not only pump up nutrients but increase soil fertility, is fixation of nitrogen by leguminous trees and a few others. This is very important because nitrogen is practically always in short supply for vigorous plant growth. (See box 3 for a brief explanation of nutrient shortages in tropical Africa and remedial measures.)

Box 3: Agroforestry on impoverished soils in Africa

In large parts of tropical Africa soil fertility and crop yields have declined over the last 30 years because the loss of nutrients through leaching, erosion and harvesting has not been made good by natural processes and manuring. This has led to a gradual decline in yields per hectare; maize yields on smallholder farms typically have dropped to about 1 ton per ha. In combination with the declining farm size due to rapid population growth this is an alarming trend.

Yields are in particular reduced by lack of nitrogen (N) and phosphorus (P). Legumes can convert inert N from the air into plant N with the help of bacteria living in the roots. That is why legumes are preferred for green manuring and in mixed cropping. However, crops such as bean, soybean and peanut have only a short growing season during which they can fix N, and most of the N is removed with the harvested pods, so that little remains for the non-leguminous companion crop. Leguminous trees have the great advantage that they fix N throughout the year. Moreover N is quite easily leached and only deep-rooting plants such as trees can pump up this N which has leached beyond the reach of annual field crops. That is why leguminous trees, if used properly in agroforestry systems, have such a favourable effect on nitrogen levels in the topsoil.

Phosphorus is not leached from the soil; it is mainly lost through erosion (which, if it ends up in ponds or lakes, pollutes the water) and harvested products. Even if crop remains and manure are efficiently returned to the soil, these contain only about half the amount of P which is removed with the next crop. Thus, in spite of perfect erosion control and husbandry, continuous cropping inevitably leads to a shortage of P in the soil; after a number of years this affects crop yields even more than N deficiency.

The only way to raise P levels in the farm is through fertilizer application. On most impoverished soils a single heavy dressing of 1 – 2 ton rock phosphate per ha (mined in different parts of Africa) can support, in combination with improved N levels, a several-fold increase in yields for 5 - 10 years. A further benefit is that N-fixation by legumes is much higher at adequate P levels.

Interestingly, it has been found that some plants extract far more P than others. *Tithonia diversifolia* accumulates twice as much P per kg dry material as legumes. In an experiment in western Kenya prunings of a *Tithonia diversifolia* hedge were supplied to a nearby arable field in which P had been replenished by rock phosphate. The results indicate that the high yield level following P replenishment can be maintained by annual green manuring with these prunings.

Source: Sanchez, P.A. et al., 1997

Up till now agroforestry has mainly promoted fast-growing trees, because these promised quick results with respect to tree size or good yields in terms of green manure or fodder. However, in many cases the results were disappointing because fast-growing trees proved to be fierce competitors. Apparently they mainly compete with the companion crop for soil moisture, fast growth being associated with extensive rooting in the topsoil. Thus agroforestry systems designed to let the trees supply nutrients to the companion crop, such as alley cropping (see Section 4.5), can only be successful where rainfall during the cropping season is adequate. If it is not, crop yield will be depressed by drought rather than being increased by improved availability of nutrients! It is mainly for this reason that agroforestry research aimed at improving soil fertility for the field crops is shifting attention from alley cropping to improving the fallow vegetation (see Section 4.6). By planting fast-growing trees during the fallow period competition between trees and field crops is avoided altogether.

In dry areas deep-rooting trees deserve more attention. In arid regions trees are mainly found in depressions, near river beds and in other places where their roots can reach the ground water table. Trees that are adapted to such conditions generally grow slowly; during the seedling and sapling stages they survive by sending roots down and restricting aerial growth to limit transpiration. Once the roots tap ground water the tree top can grow more vigorously. Trees with this habit of growth do not compete strongly for water with a rain-fed companion crop.

Certain shrubs, when introduced into a new region, proved to be such fierce competitors that they became rampant, smothering other vegetation and making it extremely difficult to reclaim the land for grazing or field crops. This happened for instance with *Prosopis juliflora* on the Deccan plateau in India; for the same reason it is legally forbidden to grow *Lantana camara*, a common ornamental shrub much used as a hedge, in the Solomon Islands. Another well-known example of an unfavourable relationship between trees and animals is that cattle may be killed by browsing poisonous shrubs.

Hence the benefits of trees for companion crops and animals cannot be taken for granted. On the other hand, better insight into their mutual relationships should result in even more successful mixed cropping systems. In Chapter 4 the role of woody plants in several agroforestry systems is discussed in more detail. But let us first consider why in so many areas in the tropics trees are losing ground, in spite of their benefits, which can be summarized as follows:

Box 4: Within the farming system woody plants:

Protect

- the environment *)
- companion crops and/or livestock

Produce

- green manure**), fodder, fuelwood***), stakes for on-farm use or the local market
- yield of cropped trees: fruit, fibre, timber, etc. for home consumption or to be marketed

*) the principal benefit in farming is soil conservation
**) improved fallow vegetations offer the best scope for sustaining soil fertility
***) fuelwood is the main product of auxiliary trees in rural areas

2.3 Why trees disappear

In many parts of the tropics trees are disappearing. To reverse this trend it is important to understand why this is happening. If we do not know what motivates rural people to cut trees, it will be impossible to convince them to plant trees instead.

Traditionally rural people are very much aware of the benefits of trees and they know everything about subsidiary products and services rendered by each species. This is evident from the local customs governing the ownership and use of trees. These rules are often very intricate. People distinguish trees which have grown spontaneously from trees which have been planted deliberately. Trees which have grown spontaneously - ‘wild’ trees - are generally owned collectively, especially if they grow on non-cultivated land. Every type of tree is known by name and has its approved uses, for certain purposes in name and has its approved uses, for certain purposes in certain seasons. Destructive use, e.g. for fuelwood, is strictly regulated, and limited to named species.

Planted trees are usually owned by the planter and he may be entitled to use the tree, even if it is not standing on his own land. It is believed that violation of trees planted in burial grounds would incur the wrath of the spirits of the dead. Trees under which elders meet to discuss village affairs are held in high esteem, and if they do not thrive this is seen as a bad omen.

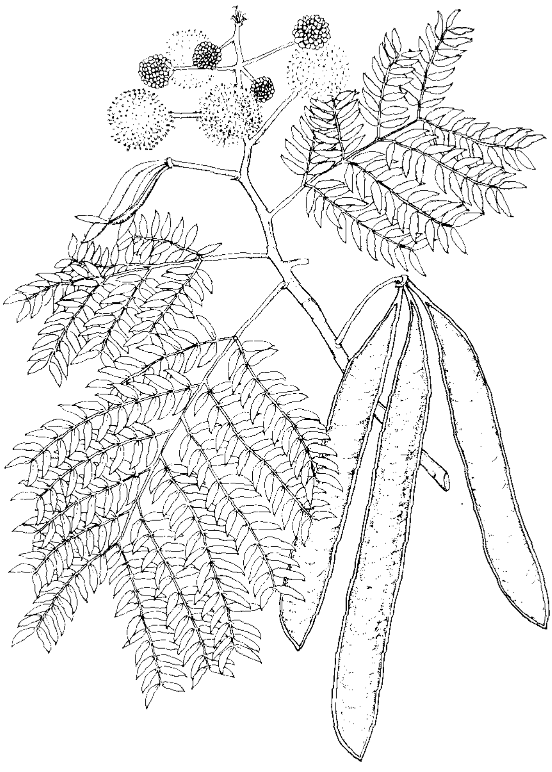

Figure 5: Leucaena leucocephala

Much more could be said about traditional customs governing the ownership and use of trees, but it is clear that people will not lightly cut down trees. So if trees are disappearing, there must be compelling reasons, such as scarcity of land or migration. The rapid increase in population makes land more scarce virtually everywhere. To feed more mouths the areas under food crops have to be increased and land used for grazing or collection of fuelwood is renamed ‘waste land’ and converted into arable fields.

Often the highlands with their more congenial climate have the highest population density, therefore one sees that people are forced to migrate to the nearby lowlands. These settlers have yet to develop their customs regarding dealing with trees in the new environment. Most likely, they have settled on land which was already used by pastoral people; in that case it is easy to imagine that the trees will suffer under this conflict of interest. All over Africa and in many other parts of the world people are on the move, as in the above example, or because the spreading desert drives them away, or because they hope for a better life in the towns. Thus the population becomes more and more mixed, comprising people with different notions about dealing with trees. Consequently there is no longer consensus regarding the traditional customs and their enforcement in the village; again the trees suffer.

Sometimes even government regulations forbid certain desirable uses of trees. In Kenya for instance, ill-advised government policy does not allow farmers to interplant coffee with bananas; just across the border in Tanzania it is shown that this mixture is very advantageous....

Anyone who wishes to strengthen the role of trees should first become thoroughly familiar with the traditional customs regarding trees and the reasons why trees are losing ground before proposing a tree planting project.

3 Agroforestry in the farming system

3.1 Trees in different parts of the farm

To get a better idea of the practical applications of agroforestry, we must look at the farming system. It is not possible to deal with all the different farming systems, but in large parts of the tropics the farming system basically consists of the following major components:

1. farmstead with one or more building, farmyard and - ideally - home garden,
2. arable fields for staple foods and cash crops and
3. the 'natural' vegetation: non-cultivated communal areas, where the farm animals of the entire village are herded and firewood is collected; if forested areas are included these supply timber and a range of forest by-products.

Farmers largely depend on the field crops for their livelihood. Usually only a few food and cash crops are grown in a village, all farmers growing the same crops at the same time. After the growing season animals can graze the stubble. Although in certain farming systems the arable fields are dotted with scattered trees - the 'parklands' described in Section 4.4 - farmers usually consider trees a nuisance in those fields because they interfere with cultivation and lead to uneven growth of the crops. Trees are more commonly grown along field borders, where they may also serve as wind breaks (see Section 4.3). On sloping land hedgerow barriers, planted along the contours, greatly reduce erosion and in the long run lead to formation of terraces (see Section 4.2). Thus, although the major cropping system on the farm, the arable fields, is least suited to combinations with trees, it nevertheless offers scope for distinct forms of agroforestry.

A farmyard in the tropics is not complete unless there are a few trees. Many people also do their best to grow some garden plants near the house. In the home garden fruits, vegetables, pot herbs, spices (and ornamental plants) may be grown to supplement the staples and animal products. In contrast with the arable fields, each family grows the garden crops it prefers, and the aim is year-round supplies of small quantities of a range of products. That is why the garden needs to be protected against goats and school children by a hedge or fence. (See Section 4.1; the original meaning of ‘garden’ and ‘hortis’ is enclosure!) Notice that whatever cannot be bought in the market with the cash earned from cash crops and the sale of animal products has to come either from the home garden or from the non-cultivated common lands to which the villagers have access. So the home garden may also be the source of medicines, fibres, fodder for livestock, bamboo, construction wood, live stakes, etc.

Trees give the garden its permanent character; they also provide shade in the farmyard for outdoor activities of the family. Thus the home garden, discussed in Section 4.7, is a form of agroforestry in the true sense of the word, because it is a mixed cropping system with a strong component of woody plants.

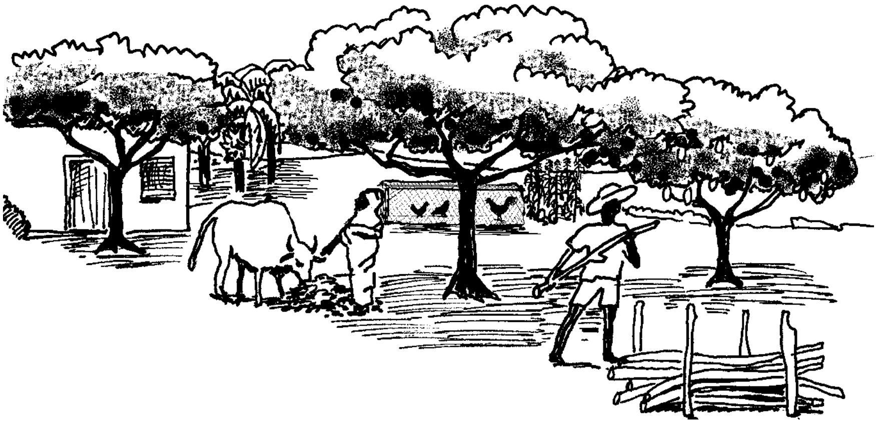

Figure 6: Trees in the farmyard/ home garden

Beyond the arable fields lies the non-cultivated land, which is often mainly used to let the cattle graze and to collect fuelwood. It may be marsh, grassland, scrubland or forest. In most cases it is common land, i.e. collectively used by all villagers. Its use may be controlled by the village council or by a state agency, e.g. the Forestry Department. Increasing population pressure often leads to rapid deterioration through deforestation, excessive fuelwood requirements or overgrazing; in regions with favourable growing conditions for field crops the non-cultivated land has all but disappeared.

Apart from fuelwood and timber, other tree products found in these communal areas such as wild fruits and nuts, honey, gums, resins, fibres, etc., may be important resources. There is much scope for agroforestry to improve the mix of animal husbandry and woody plants. However, consensus between the users and the controlling agency is essential and this tends to complicate agroforestry interventions.

Although based on a simplified model farming system, the above discussion shows that woody plants can interact in many ways with herbaceous crops and animal husbandry. It also shows that the term ‘mixed cropping system’ is not restrictive: agroforestry deals with the thorny hedge used to set up a cattle pen and a shelterbelt on the windward side of a village as well as with true mixtures of woody plants and herbs in home gardens, parklands or alley cropping.

3.2 Climate, farming system and agroforestry

Trees become more prominent in the vegetation when one moves from high latitudes towards the equator. This is caused by climatic differences, in particular the absence of cold winters in the tropics. Within the tropical region rainfall is the main climatic influence; it affects the vegetation and - as a consequence - also the farming system. The changes in farming systems and the position of woody plants in the vegetation when going from wet to increasingly dry tropical climates are presented schematically in Figure 7.

In the humid tropics trees dominate the vegetation; that is why we use the term tropical RAIN forest. In the farming system this is reflected in the dominant position of perennial crops, in particular tree crops (e.g. tracts of coconut palms in many coastal areas). The open fields may be largely limited to wet rice. The garden crops tend to merge with the field crops. Non-cultivated land is limited to inaccessible slopes, wetlands, and the like. There are few farm animals apart from poultry and fish; if there are larger animals (e.g. buffaloes) they are usually stable-fed or tethered, not herded. The favourable growing conditions allow a high population density and small farm size.

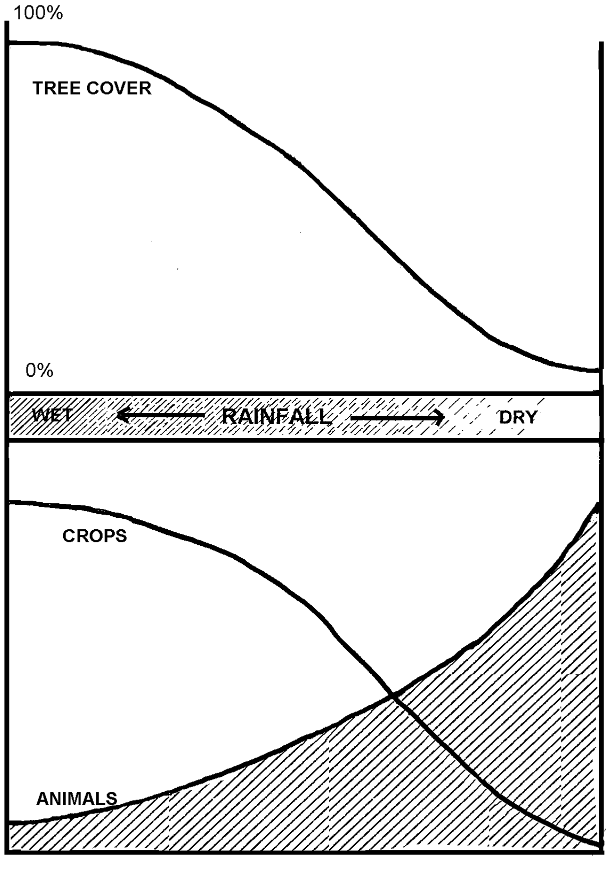

Figure 7: Climate, tree cover and farming system

Going from the humid tropics to areas with an ever longer dry season, culminating in semi-arid conditions, the natural vegetation changes from tropical rain forest to seasonal forest in monsoon areas and finally to gradually more open savannah with scattered trees and grass. In the farming system this is reflected by a diminishing role of crops in favour of animal husbandry. In semi-arid areas farms need to be large because of the low yield levels and extensive grazing areas under the harsh semi-arid conditions; these areas can only support a sparse population.

Figure 7 is greatly simplified but it serves to show that the need to strengthen the role of trees is greatest where natural conditions for tree growth are less favourable. But even in the humid tropics where trees, including a wide variety of tree crops, do so well, they are losing ground to annual crops. And if annual crops become dominant, land degradation ensues very rapidly through erosion and leaching of nutrients by the heavy rains. Thus from the humid to the arid tropics the first agroforestry rule is: think twice before cutting down a tree.

4 Practical applications of agroforestry

Introductory remarks

In this chapter seven agroforestry technologies are described. The systems can be classified as:

- traditional (evolved through the experience accumulated by generations of farmers), such as the home gardens, parkland trees, and live fences,
- modern (evolved with the help of agricultural science), such as shelterbelts and hedgerow barriers, or
- recent (evolved with the help of research in agroforestry): alley cropping and improved fallows.

These systems have been chosen because they represent farming in a sustainable way; moreover in most cases the woody plants yield by-products, in particular fuelwood and fodder. The technologies generally have their origins in tropical countries. The agroforestry solutions presented in this chapter are largely concerned with cropping systems in sub-humid to semi-arid conditions, ranging from monsoon climates with a long enough growing season to plant a second crop, to semi-arid conditions where only short-season, drought-tolerant field crops - such as sorghum or millet - can be grown.

The technologies can be adopted by individual farmers, but shelterbelts require a communal effort, because they have to be quite long to be effective; likewise hedgerow barriers cannot protect a field on a slope for long, if neighbouring fields are left unprotected. This last effect applies more generally: if more farmers in a village plant trees this has a strong cumulative effect on the environment. Therefore it is usually worthwhile to mobilize the villagers for agroforestry projects, in order to ensure that many farmers participate. If this is the case it is also easier to organize the procurement of seeds and - if it can be agreed upon - to raise planting material in a single nursery, supplying all the participants. Where land degradation has already undermined the carrying capacity of the land, resulting in poverty, agroforestry solutions require external assistance; people battling to survive cannot implement long-term investments unaided.

The descriptions of the technologies are rather tentative; there are no firm recommendations, leave alone clear-cut recipes for success. Hence the seven forms of agroforestry discussed below are not the last word on agroforestry in the tropics. In fact the reader is strongly advised to consider which technology might be useful in his or her situation, and to modify it to suit the local environment. This process of adaptation is very important: do not copy the examples below rashly, but consider to what extent local conditions differ from the situation in the example. If a technology is to be copied, first consider whether local trees and shrubs might fit in that technology (perhaps by comparing them with the trees or shrubs mentioned in the example) and use those. Appendix 1 gives some characteristics of the trees and shrubs mentioned in the examples; if some of these species appear to suit your requirements, you may obtain further information and - possibly - seeds or cuttings for a trial planting from the addresses listed in 'Useful Addresses'.

Many auxiliary plants have no common English name, or the common names that are in use cause much confusion. That is why botanical names have been used in this booklet for all the auxiliary plants. In Appendix 1 the common names in English, French and Spanish - as far as they could be gleaned from various sources - are given alongside the botanical names.

4.1 Live fences

Live fences are used to keep farm animals in an enclosed area (e.g. a pen where cattle pass the night) or to keep them out of a cropped area (e.g. a home garden). There are two types of live fences:

- live stakes serving as fencing posts and connected by a lattice of slit bamboo, raffia, or by barbed wire;
- hedges.

Fences supported by live stakes

Some woody plants can be propagated by very large cuttings; if poles the size of fencing posts are cut and planted they strike root and leaf out. Different kinds of coral trees (*Erythrina* spp.), for instance, are planted as stakes about 2 m long and with a diameter of 5 - 10 cm. Once they are growing they can support barbed wire or a lattice made from local materials, such as slit bamboo. For a cattle pen the large stakes may be set so close that they form a stockade without any further material; in the highlands of East Africa *Commiphora* spp. (e.g. *C. africana*) are used in this way.

Figure 8: Live fence: lattice supported by trees
Source: Dupriez & de Leener, 1993

Live stakes also have other uses, mainly to support climbing crop plants such as black pepper, betel, vanilla and yams. Both stakes of coral trees and *Gliricidia sepium* are used in this way. The stakes may also be linked by bamboo cross bars and wires to form a trellis, e.g. for snake gourds, chayote or ornamental climbers in the home garden. In South East Asia *Lannea coromandelica* is preferred for trellising, because it forms a beautifully straight pole.

Desirable properties of species used as live stakes are:

- easy to propagate from large cuttings;

- able to survive regular lopping of new branches at the top ('pollarding');
- not attractive to termites.

By lopping the branches the shade cast by the stakes can be limited. This will also limit moisture consumption and help the stakes survive during the dry season. Lopped coral tree branches make good fodder or green manure.

Suitable coral trees exist for lowlands as well as highlands; most species are adapted to a wide range of altitudes, but water requirements are generally 1000 mm per year or more. Gliricidia thrives in similar conditions and the stakes are much thinner. *Commiphora* spp. are suited to dry, some even to arid, conditions; they are leafless for about 9 months. Many *Euphorbia* spp. propagate easily through stakes and these may be suitable as live stakes under fairly dry conditions. Physic nut, *Jatropha curcas*, is a poisonous shrub, also suited as a live fence in hot and dry conditions.

Hedges

A great variety of hedges is found in the tropics. In some areas they dominate the scene in the villages: wherever one goes, one always walks between two hedges, often made up of a mixture of plants. In these villages garden crops are mixed in the fields, and these fields are out of bounds for cattle throughout the year. Such farming systems are only possible in a fairly wet climate with a limited dry season. Although hedges are commonly only 1 - 2 m high, they nevertheless provide useful shelter against the wind in exposed situations.

The following species are all thorny or poisonous and suited to areas with moderate to low rainfall. The region where it is commonly used is given between brackets. *Pithecellobium dulce* (Central America, South-East Asia) can be planted from sea level to medium elevations; it has medium vigour and is not very thorny (the pods and young shoots are used as fodder!). *Parkinsonia aculeata* (Mexico, widely distributed) is a fast-growing thorny shrub that makes a good barrier hedge. *Dichrostachys cinerea* (Africa) is used in agroforestry systems in Africa and India, and also as a thorny hedge. *Carissa carandas* (India, South-East Asia) is a small thorny tree with edible fruit. In the highlands *Dovyalis caffra* (S. Africa, wide-spread) is a small sturdy fruit tree with long thorns. It grows slowly but makes an excellent hedge (very common on coffee estates in East Africa) in areas where rainfall is 1000 mm or more. *Caesalpinia decapetala* (Asia) is a straggling fast-growing shrub which requires frequent pruning when used as a hedge; the bark supplies tannin. *Jatropha curcas* (throughout the drier tropics) is a fast-growing poisonous shrub. *Euphorbia tirucalli* (Africa, Sri Lanka) is known by its English name, milk-hedge, for its poisonous sap; it is fast-growing, but slower in semi-arid regions. In dry regions other *Euphorbia* species, cacti, agave and yucca species are also used as hedging plants.

Figure 9: Goat-proof hedge made by closely planted live stakes (Source: Dupriez & de Leener, 1993)

Planting and maintenance

When a hedge is sown or planted the farmer wants it to grow fast, but when it reaches the desired size fast growth means that the hedge needs to be cut 3 - 4 times each year. Trimming hedges is a lot of work, which somehow must always be done when there is plenty of other work to be done on the farm. Thus it is very important to weigh the one-time advantage of fast establishment against the recurring advantage of easy maintenance! A slow-growing hedge requires little pruning during the first year or two, apart from topping the plants to induce leafing out of side shoots, which will make the hedge sufficiently dense right from the ground. Regular pruning suppresses flowering; so if hedges of *Carissa* or *Dovyalis* bear a lot of fruit this indicates inadequate trimming!

It always pays to prepare properly for planting, by digging up a sufficiently wide strip (50 cm) and incorporating manure and - if possible - some phosphate fertilizer. When seed is sown on the spot it is usually dibbled in double rows. Plant or sow timely - early in the rainy season - and protect the young plants as much as possible, e.g. by a cover of thorny branches. Collect seeds during the fruiting season and store the seeds properly. If seedlings have to be raised for planting out, start the nursery in time and make sure that there is sufficient water, even if only waste water from the kitchen, to raise the plants. Attention to field preparation and planting helps a great deal to speed up growth during the first year, shortening the establishment period even if a slow-growing species is chosen.

4.2 Hedgerow barriers

Hedgerow barriers are rows of trees or shrubs closely planted along the contours of sloping land and pruned to form hedges. They are also known as contour hedgerows, and are planted to reduce erosion by run-off of water. By preventing the loss of topsoil the hedgerows help to maintain soil fertility. The hedgerow barriers work in two ways.

- First, the hedge is a physical, but permeable, obstruction to runoff, slowing down the flow of water, so that it drops most of its soil particles.
- Secondly, the litter fall and the extensive root system tend to improve soil structure close to the hedge. This results in a much higher rate of infiltration of the run-off water near the hedge and the soil particles stay behind.

The overall effect is that at the bottom of the slope not only far less soil accumulates, but also less water than one would expect. Improved water retention on the slope through slowing down of the flow and high infiltration near the hedges is an important bonus where low soil moisture limits crop growth (Kiepe, 1996).

Erosion control is an important subject in both civil and agricultural engineering. Hedgerow barriers should be considered in relation to the wide array of engineering technologies available to control erosion, e.g. check dams, diversion canals, soil traps. On stony land, for instance, the stones are often gathered into barriers along the contours. In some cases the hedgerows may be combined with check dams, diversion channels or soil traps. As an agroforestry technology, hedgerow barriers may serve multiple purposes: large hedges may be cut back for fuelwood and smaller hedges can still provide fodder during the dry season or green manure during the planting season.

Figure 10: Hedgerow barriers dividing the slope in strips of cropped land along the contours

Design and management

Control of erosion is considered effective when less than 10 tons of soil per ha per year is lost. (Without conservation measures losses often are in the order of 100 - 200 ton per ha per year.) This level of control can easily be achieved with contour hedgerows on slopes up to 20%; on steeper slopes the results are more variable and slopes of 60% and more should not be cultivated at all.

Hedgerows should be planted on contours situated 2 m or less below one another, i.e. a vertical drop in height of no more than 2 m. On a 10% slope this corresponds to a distance of about 20 m between rows. On a 20% slope the distance should be about 10 m. These figures are just based on a rule-of-thumb. The actual spacing may be less depending on the occurrence of rainstorms and on how erodable the soil is. Farmers do not like closely spaced hedgerows, for obvious reasons: loss of cropped area, more work to maintain the hedges, and increasing competition between hedges and crops. The distance between hedgerows can vary considerably on irregular slopes, where the contours do not run parallel. Consequently the width of the cropped strip varies, a complication for ploughing and planting.

Seeds, seedlings or cuttings are planted in a single row or double row, 3 to 4 plants per m. They are allowed to grow undisturbed till they are well-established; thereafter they can be pruned to reduce interference with the crop. The height of the hedges is not important for erosion control, so they are usually cut back drastically to 30 - 50 cm. The prunings can be used to reinforce the barrier, as mulch or green manure for the crop, or as fodder for livestock. The strips of land beween the hedges are ploughed along the contour; if the field crop is planted on ridges these are also aligned along the contour.

Erosion and - even more so - ploughing or hoeing move soil from the high side of the cropped strip towards the hedgerow below. Within two or three years this displacement of soil leads to the formation of terraces with a clear drop in height behind the hedge; the end result after a longer period of time is horizontal terraces separated by steep banks (see Figure 11). The loss of topsoil just below the hedge and the deposition of this soil above the next hedge also results in large differences in soil quality across each cropped strip and this is clearly shown by much better crop stand above the hedge than below the bank. This problem can be largely overcome by applying most of the green manure just below the banks where crops grow poorly.

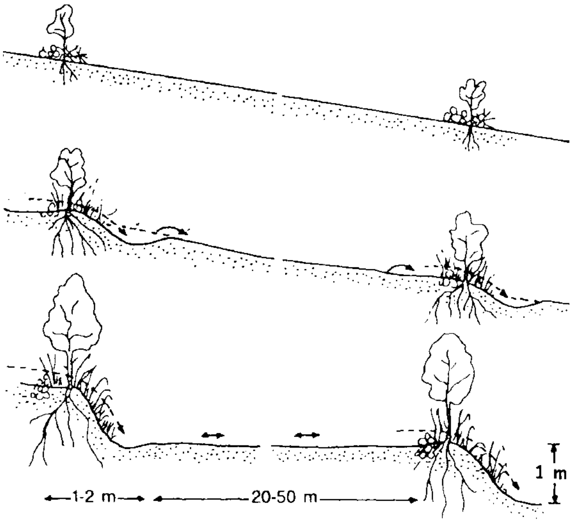

Figure 11: Hedgerows leading to terrace formation
Source: Agrodok 13: Water harvesting and soil moisture retention

Choice of species

If the only aim is to control erosion the choice of species is not critical. This was shown by farmers in Mindanao, the Philippines. In a badly eroding upland area (half the fields are on slopes of over 15%, and annual rainfall is 2200 mm) they were advised to plant hedges of *Gliricidia sepium* in combination with Napier grass (*Pennisetum purpureum*). Finding that Napier grass competed fiercely with gliricidia as well as with the maize crop and that gliricidia cuttings suffered from termites, they tried a variety of other grasses and shrubs. In the end they simply marked the contour lines for the barriers and skipped them during ploughing, resulting in weedy strips of 0.5 m wide. The natural vegetation of grasses and weeds on these strips proved to be as effective a barrier as the hedgerows! It is now recognized as a distinct system, named ‘natural vegetative strips’ (Stark et al, 2001).

This course of events shows that woody species are chosen for their auxiliary benefits and these have to be weighed against yield loss through competition with the hedgerow and the labour required to establish and maintain the hedgerows. The natural vegetative strips used by the farmers in Mindanao do not compete with the maize and require hardly any labour (just slashing before the weeds form seed, to limit infestation of the cropped strips of land). Gliricidia had been recommended for green manuring of the maize strips. But farmers prefer to restore soil fertility by using more fertilizer or by resorting to improved fallows on the terraces. Obviously, minimizing labour requirements is the main consideration in their situation.

In most farming systems fodder is the principal auxiliary use of hedgerows. This is the case in the Machakos area in Kenya (elevation 1600 m, rainfall 800 mm but very variable, erosion-prone soil). Farmers use hedges of *Leucaena leucocephala,* which are pruned to give the cattle their daily fodder rations. Experiments with *Senna spectabilis* demonstrated that this plant hardly competes with the maize and cowpea crops in the area - probably mainly because it has few spreading roots - and provides a good mulch. But farmers know that good mulch means poor fodder and they therefore continue to plant leucaena.

Species that have shown their usefulness in other parts of the world include the legumes *Calliandra calothyrsus, Flemingia macrophylla* and *Leucaena diversifolia*; *Inga edulis* is used in Peru. Generally speaking a high production of fodder, mulch or green manure requires a fast-growing species, but such species also consume much water and nutrients and therefore are likely to be fierce competitors. In drier areas slow-growing species may have a long-term advantage. These considerations suggest that the fast-growing *Senna spectabilis* is an exception in showing so few signs of competition in Machakos.

4.3 Windbreaks and shelterbelts

Detrimental effects of strong winds

The wind takes up moisture from the soil (through evaporation) and from plants and animals (through transpiration); over the sea and large lakes wind takes up so much water vapour that the air becomes moist, resulting in increased rainfall. In the drier parts of the world moisture losses limit the choice of crops and crop yields and in this situation windbreaks may be useful or necessary. Laundry on the clothes line dries more quickly if the air is drier and warmer, and if the wind blows harder. These three factors: dry air, warm air, and air moving fast, also sharply increase moisture loss by plants and soil. Large parts of the tropics suffer from seasonal hot winds, coming from a particular direction, making windbreaks useful. If such winds are strong they scorch the earth and windbreaks become essential for successful farming.

Wind - even if not particularly strong - may also physically damage susceptible crop plants, e.g. shred the leaves of some banana varieties. Stronger winds can tear the leaves and shoots off plants. In areas with sparse vegetation where the wind has free play, it can blow away the litter on the ground and fine soil particulars (resulting in dust storms). Even heavy particles, such as grains of sand, may hop along, chased by the wind, giving rise to shifting sand dunes.

How to break the wind

A windbreak is usually defined as a row of trees or tall shrubs planted across the direction of the prevailing wind. A shelterbelt is a strip of trees and shrubs planted to shelter communities and their land from strong winds. Shelterbelts usually consist of at least three parallel rows of trees, shrubs and/or grasses. The trees and shrubs used are evergreens or species that do not shed all their leaves during the windy season. Grasses and other plants are sometimes planted to prevent the wind from blowing the soil away from around the base of the trees and shrubs.

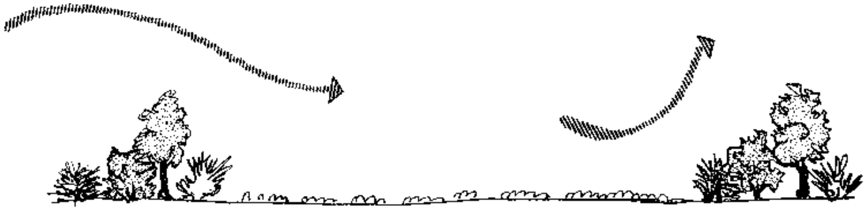

Figure 12: Shelterbelts protecting farmland

Windbreaks are planted and maintained by individual farmers. If the surroundings of the village are exposed to the wind, farmers with land on the windward side face an uphill battle to raise and maintain their windbreaks, whereas most of the benefits accrue to the farmers with land on the leeward side. In this situation a communal effort is called for to raise a shelterbelt on the windward side which gives some protection to the entire village and makes the windbreaks behind it more effective. Clear agreements need to be reached about the exact site of the shelterbelt, the ownership and use of the trees and the land, the allocation of costs, responsibilities and benefits. When introducing shelterbelts, it is important to ensure that they do not offend local customs or block traditional thoroughfares.

Because the strip of land intended of a shelterbelt is 10 - 25 m wide, shelterbelts can accommodate large trees; for windbreaks slender trees are preferred, although often such trees are alternated with more spreading trees which bear a crop, e.g. cashew. A shelterbelt has to confront the full force of the wind, so its design is more critical than that of a windbreak, although the same considerations apply. Shelterbelts and windbreaks should be permeable; the wind should not be deflected as in case of a solid wall, its force must be broken. If the wind is blocked completely it will cause much greater stress on the trees and may even blow the trees over. Moreover, behind an impregnable obstacle turbulent downdraughts will undo most advantages; the turbulence may even damage the crops (see Figure 13).

Figure 13: When the shelterbelt blocks the wind completely, turbulence will occur behind the trees and damage the crops.
Source: Rocheleau D. et al., 1988

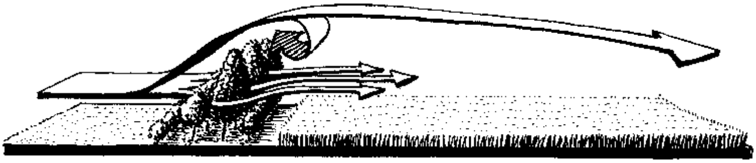

Figure 14: The shelterbelt should allow some wind to pass through, to reduce turbulence. Note that there is also turbulence behind a permeable windbreak, but that it stays above the trees. Lower down the wind speed is greatly reduced and the crops are protected.

Ideally, the permeability of belts and windbreaks should increase with height; air should certainly not be funnelled underneath the tree canopies, as would be the case for a single row of trees with tall, unbranched trunks. In a shelterbelt the rows of shrubs on the windward side gradually deflect the wind upwards, so that it does not hit the tree rows in the shelterbelt at full blast; the rows of shrubs also ensure low permeability at ground level.

The wind is deflected over and along the sides of an obstacle; as a consequence the wind speed tends to be increased along both ends of the belt. That is why a single long belt is much better than several short lengths, leaving draughty gaps between them through which the wind is funnelled with even greater force. For the same reason a belt must be properly maintained, with special attention to spots where a gap might develop.

On the sheltered side of the trees the speed of the wind at ground level is appreciably reduced over a distance equal to about 10 times the height of a permeable barrier. If there are more windbreaks downwind, the protection may extend up to 20 times the height of the breaks, because stagnant air in front of the next windbreak prevents the main flow of wind from dipping down to near ground level. Thus repeated windbreaks at properly chosen intervals have a strong cumulative effect. In many areas it is the custom to plant trees on the edges of the fields; this traditional practice can be a great help in limiting wind damage.

Whilst shelterbelts can be found all over the world and under any climatic conditions, the reasons for establishing shelterbelts will differ from place to place. They may be used to shelter livestock and their range land as well as field crops. They are also planted to stabilize sand dunes and prevent further wind erosion, which threatens dry and poorly structured soils.

In the temperate zones of the world there is a fair body of information on improvements in yield and quality resulting from sheltering crops against wind. A windbreak to protect an orchard, for instance, allows the bees to pollinate the flowers in spring; following fruit set the shelter mainly leads to improved fruit quality (e.g. fruits do not rub against branches). Unfortunately there still is a lack of such information for tropical crops. On the other hand the improvement in crop stand when shelter is provided in exposed sites is quite obvious. Crops benefit from the reduced loss of moisture through evaporation and transpiration. This not only results in better growth, but also extends the growing season, which to some extent widens the choice of crops, e.g. the farmer will be able to grow maize instead of sorghum or millet. The fact that less dust is blown about not only benefits the crops but also people and livestock. But the main point – which will come as no surprise to anyone who has witnessed the deterioration of land exposed to strong wind - is that if shelter is provided the productivity of the land can be sustained.

Planting and maintenance

The shelterbelt itself should not be wider than necessary. To achieve sufficient density and strength, it is important that several rows of shrubs and trees are planted. For most woody plants the spacing is 3 - 4 m between the rows and 1.5 - 3 m in the row. Including fast-growing trees and/or shrubs helps to ensure mutual shelter for the plants in the belt, which may be very important during the first years. Fast growers usually consume more moisture, so it may be wise to plan the spacing with a view to thinning these species as soon as the slow-growing, more hardy shrubs and trees mature. Protecting a long narrow strip of woody plants against browsing animals is not a simple matter, so unpalatable species are preferred. A path should cross a shelterbelt diagonally so that the wind will not be funnelled through it.

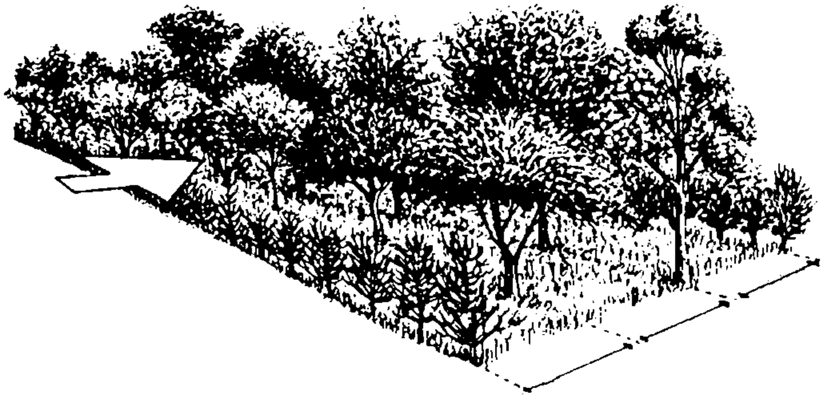

Figure 15: Detail of a shelterbelt; arrow shows wind direction. (Source: Weber & Stoney, 1988)

Shelterbelts can be established by direct seeding. It is best however to use seedlings or cuttings whenever possible, at least for the taller trees. Shelterbelts have to cope with the full force of the wind. Therefore hardiness is the main consideration in choosing species: look for drought-resistant, deep-rooting species with leaves - preferably fine foliage - that persist through the season with fierce winds.

The requirements are less stringent for windbreaks. The trees should not compete too strongly with the crops; in general slender trees with an upright habit of growth are preferred. Farmers often like to include trees that yield useful products, such as jackfruit or cashew. That is alright, but fruit-producing trees are vulnerable and therefore not very suitable to form part of a windbreak. Whilst shelterbelt trees can supply a wide range of secondary products, management priority must be given to keeping the trees in good condition, to ensure that the shelterbelt serves its main purpose of wind protection.

Following planting, shelterbelts and windbreaks need weeding around the young trees and gapping up. In later years the fast-growing species in shelterbelts may have to be thinned and some pruning may be desirable to maintain the vitality of the shrubs and to remove overhanging branches of the trees. Some species respond well to coppicing: if they are cut close to the ground, several vigorous upright shoots emerge that grow into poles, which may be useful on the farm when the stubbs are coppiced again. The trees in windbreaks may require heading back to keep the lower branches alive (otherwise the same thing happens as in a hedge which is allowed to grow ever higher; soon gaps develop near ground level).

Ideally the shelterbelt and windbreaks should yield secondary products which pay for the maintenance. However, this is only possible if the growing conditions - apart from the season during which wind is the main adverse factor - are favourable. In that case far more species can be considered than the ones mentioned below, which are mainly meant for dry and hot conditions during a large part of the year. In these harsh conditions even the production of firewood and poles will be quite modest; windbreaks can provide some forage when other food is scarce.

Choice of species

Fast-growing species have the advantage that they create an effective barrier as quickly as possible. *Casuarina* species, *Azadirachta indica*, *Leucaena* and *Senna* species and *Prosopis juliflora* are often planted for this reason. Other possible species are *Acacia auriculiformis, Albizia procera, Erythrina variegata, Eucalyptus camaldulensis, E. tereticornis, Moringa oleifera, Pongamia pinnata, Schinus molle, Thespesia populnea,* and *Vigna vexillata.*

To stabilize shifting sands in the Sahara and adjacent areas, the following species are recommended: *Calligonum* sp., *Tamarix* sp., *Salvadora persica*, *Capparis decidua, Leptadenia pyrotechnica, Calotropis procera, Parkinsonia* sp., *Casuarina equisetifolia, Euphorbia balsamifera*.

4.4 Parklands (scattered trees)

Parklands are characterized by well-grown scattered trees on cultivated and recently fallowed land. These parklands develop when crop cultivation on a piece of land becomes more permanent. Canopy cover of the trees in parklands averages from 5 to 10%, with variations mainly due to farmer attitudes toward trees in cultivated fields. As crop cultivation intensifies, there are usually fewer trees (e.g. on cotton fields). Parklands are best developed near the villages, as here they can be well protected and managed.

Parklands are a very common type of agroforestry system in the tropics. Yet, for a long time they were overlooked by agronomists and hence not recognized as an agroforestry system. To date, there is relatively limited knowledge about how parklands are managed. Only recently it was noticed that farmers also plant trees to rejuvenate their parklands. They also prune the trees to reduce shading of crops, and use the prunings for fodder. On the Deccan plateau in India, farmers allow buffaloes to trample the prunings into wet rice fields to improve water retention of the soil. So it is strongly advised to observe and try to understand how farmers manage their parklands, before proposing any improvements or alternative techniques.

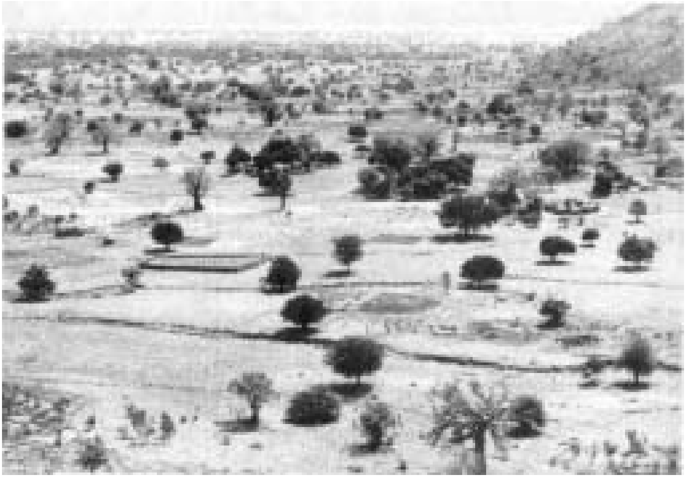

Figure 16: Parklands, with various types of trees scattered in the landscape (Source: Dupriez & de Leener, 1993)

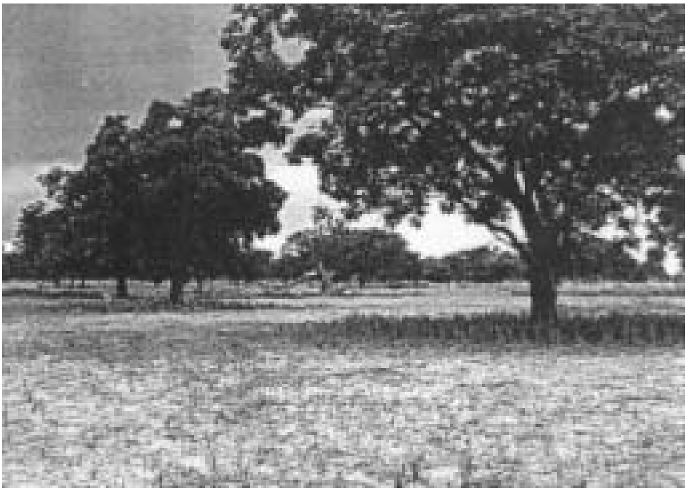

Figure 17: Parklands, pattern of light and shade (Source: Dupriez & de Leener, 1993)

Advantages and disadvantages

In this agroforestry system, useful trees from the original vegetation remain and are encouraged to grow in the arable fields and pastures. Trees that are not useful have been removed. The trees are chosen for their general usefulness, providing multiple products such as fodder, fruit, timber, fuelwood, medicinal products, etc. In addition, there are important long-term ecological benefits: the trees reduce erosion, help maintain soil fertility, and improve the microclimate for crops, reducing the incidence of wind and providing shade. The trees are scattered far apart, so that they do not compete with their neighbours.

Farmers refer to trees as 'hunger crops'. Trees offer stability in dry periods, as they are less vulnerable to drought. In pastures trees are a stable component, providing forage in the dry season when fodder is scarce. There are many examples, especially from semi-arid areas, of crop yields being depressed in the vicinity of trees, through competition for water, soil nutrients and light. Nevertheless the farmers preserve their parklands, because they consider the benefits of the trees to outweigh the reduction in crop yields under the tree canopies.

The key to good management of parklands is to strengthen the advantages offered by the trees, while reducing the disadvantages. This can be done through various management techniques, including selection of tree species with desirable properties, proper tree spacing (scattered, in line, in blocks), tree management (pruning, lopping, controlled harvesting, etc.), selection of associated crops and livestock management.

Choice of species

Parklands consist of indigenous trees; for North-West Africa the following species have been recorded: *Vitellaria paradoxa, Parkia biglobosa, Adansonia digitata, Tamarindus indica, Borassus aethiopium, Saba senegalensis* and *Combretum glutinosum*. All these species yield useful products as well. *Faidherbia albida* (formerly known as *Acacia albida*) is an interesting tree, because it sheds its leaves during the rainy season. Therefore it does not compete strongly with the companion crop, which is reflected in good yields, even under the tree canopy. Moreover, *Faidherbia albida* is a leguminous, nitrogen-fixing tree. In addition, it provides shade and very nutritious fodder in the dry season, which is good for livestock. The main limitation is that the tree does not grow well on poor soils and requires access to ground water to survive in dry climates.

As far as possible parkland trees should have the following characteristics. They should:

- be deep rooting, preferably reaching the ground water table
- grow tall, and have an evergreen habit
- be slow-growing and have a long life span
- have the capacity to fix nitrogen
- produce litter that decomposes well to add as much as possible to soil organic matter.

In their early stages trees must be protected against browsing by farm animals, for instance by having thorny branches. This applies both to naturally regenerated and to planted seedlings.

4.5 Alley cropping

Alley cropping is a system in which strips (or ‘alleys’) of annual crops are grown between rows of trees or shrubs, resembling hedges. For this reason it is also known as ‘hedgerow intercropping’. The concept of alley cropping was proposed by agroforestry research workers. Seeing that land scarcity leads to shorter fallow periods and declining soil fertility, it was thought that instead of growing the field crops after too short a fallow period, it might be easier to maintain soil fertility by growing woody plants permanently between the field crops. Lining up the woody plants in hedges should ensure that there is little interference with cultivation of the field. Moreover, the crops would also benefit from the effects of woody plants on the environment, such as reduction of erosion by wind (hedges lined up to break the wind) or water (hedges planted along the contours). Thus as an agroforestry technology, alley cropping stands somewhere between improved fallows, parklands and hedgerow barriers:

- Shifting cultivators grow crops after the tree or bush fallow, whereas alley cropping combines field crops and woody plants.
- I parklands the trees are large and scattered, whereas in alley cropping they are lined up and managed to reap the benefits and minimize competition with crop plants.
- Hedgerow barriers are planted primarily to reduce erosion, wheras the main purpose of alley cropping is to maintain soil fertility.

Figure 18: Alley cropping; hedges of leucaena being pruned

In the alley-cropping system, fast-growing small trees and shrubs are used which can be pruned regularly and which supply large amounts of twigs and branches to serve as mulch and green manure for the crops in the alleys. Alternatively the cuttings can supply significant amounts of fodder for livestock, e.g. during the dry season, the manure being returned to the field.

Planting and maintenance

Hedgerows are generally spaced 4 to 8 m apart; and in the row spacing is 30 to 100 cm. They are planted along the contours, so as to break the wind when it is strongest, or parallel to the longest side of the field. The hedges can be established by direct sowing, or by using cuttings or seedlings. They must be protected from browsing animals, trampling, and pests. The young trees should be treated like a crop and will benefit from weeding, manuring etc. If given a good start in life they will require less attention later on.

In a humid climate allowing year-round cropping of the field, the hedges should be pruned regularly, at least each time a new crop or a relay crop is planted. However, even the fastest-growing trees, such as leucaena, should be allowed to grow 6 to 12 months before the first cutting, so that they have time to establish good roots.

In a monsoon climate the hedges are pruned drastically at planting time early in the wet season. The height of the hedges may vary from 30 cm where the expected rainfall during the growing season is fairly low, to 60 cm where generous rains are the rule. If the growing season is long the hedges may need another light cut before the harvest to limit competition for water and reduce shading of the field crop. During the dry season the trees are allowed to grow out or they may be lopped for fodder. If they grow unrestricted and the dry season is not severe, the trees may have reached an impressive size when they are to be pruned again during the planting season. In that situation hedging takes the form of coppicing and the wood may serve as firewood or stakes.

Choice of species

Calliandra calothyrsus, Gliricidia sepium, Etrythrina subumbrans, Flemingia macrophylla, Sesbania species and *Leucaena* species have been tested in various experiments; other species which deserve consideration - in addition to local shrubs or treelets - are *Pithecellobium dulce, Paraserianthes falcataria* and *Cajanus cajan*. The characteristics to look for are:

- fast growth, to ensure a high production of prunings and litter;
- a light open crown (e.g. feathery leaves), which lets the sunlight pass through;
- a root system which extends downwards rather than sidewards;
- legume or other species which fixes nitrogen;
- good response to frequent pruning (sprouting easily and quickly on old wood);
- leaf litter which decomposes quickly to release nutrients or slowly to provide a more persistent mulch;
- adaptation to the site (saline or acid soil, flooding, wind, tolerant of pests, etc.).

Although in experiments each hedgerow consists of a single species (using mixtures would greatly complicate the interpretation of the results), farmers may prefer to mix species (or to plant different species in alternate rows) to make the system more robust (e.g. a reduced risk of pests) and versatile (e.g. to get both good mulch and good green manure and a more varied fodder).

Evaluation

When alley cropping was first launched in the 1980s expectations were high. The system received more attention from research workers than any other agroforestry technology. Nevertheless the results have not matched the expectations and disappointingly few farmers have adopted alley cropping. Evaluation of the method suggests that the main limitations are:

- competition for water; it is now estimated that alley cropping requires at least 800 mm rainfall during the growing season;
- high labour requirement for establishment and pruning;
- drastic modification of the cropping system, requiring a number of years to establish a 'steady stage' that can be routinely managed by the farmer;
- in conjunction with the above point: the need to adapt management to conditions on the farm, e.g. mixing species in hedges and working out suitable pruning recipes (e.g. shearing, coppicing, replacement pruning) depending on the season and the use of the prunings.

Because of these constraints alley cropping is now recommended mainly on sloping land, where the hedges serve at the same time as hedgerow barriers against erosion.

4.6 Improved fallows

Shifting cultivation: fallow periods to restore soil fertility
Before fertilizers came into use, farmers needed fallow periods because with each harvest nutrients are removed; after a series of crops soil fertility drops to a level that makes further cropping unprofitable. (The only alternative to maintain soil fertility is animal husbandry: herding the animals over a large area and bringing the manure to the cropped field.) Hence the principal role of a fallow period is to restore soil fertility, so that the land can again be profitably cropped. In the wet tropics, growing conditions are so favourable for the natural vegetation, that in the course of time farmers abandon cultivated fields not only because the soil is exhausted, but also because they can no longer cope with weeding and slashing the forest regrowth.

In traditional shifting cultivation fallow periods used to be as long as 20 years; each year the oldest fallow would be slashed and burnt to be cropped for a few years, until the natural vegetation took over again. By burning the vegetation the organic matter (which holds the nitrogen!) is largely lost, but mineral nutrients accumulated during the fallow period end up in the ash. Soil fertility is increased but because the organic matter is burnt instead of being allowed to decay slowly, nutrients are easily lost through leaching, and within a few years the field has to be fallowed again. In this system a farm consists of a few cropped fields, of say 1, 2, 3, and 4 years old and 20 fallow fields, ranging from 1 to 20 years of age, adding up to a large area.

With increasing populations land becomes scarce and fallow periods have to be shortened. In due course slashing and burning is replaced by clearing and saving the wood (to be used as fuelwood, posts or construction wood); the thinner branches are left to enrich the field with organic matter. However, in many rural areas fallow periods have become too short - only 1 to 3 years - for the natural fallow vegetation to restore soil fertility. This was the reason to experiment with alley cropping. But when it became clear that in most situations alley cropping was not the answer, attention was shifted towards improving the fallow vegetation, which was what farmers were already trying to do.

Figure 19: Sesbania sesban in an improved fallow woodland

Example: improved sesbania fallow in Zambia

An 'improved' fallow involves growing specially chosen trees, shrubs or herbaceous plants in the fallowed field, e.g. fast-growing leguminous species which tie up nitrogen. Work at Chipata, eastern Zambia, is related here as an example of the experiments and the results obtained with improved fallows. The natural vegetation in the region (elevation about 1000 m, annual rainfall in the order of 1000 mm) is Miombo woodland, the main crop is maize, grown with 1 - 5 year grass fallows; the grass is burnt when maize is to be planted.

Some of the fallow plants used in the trials in Zambia are listed in Tables 1 and 2. The tables show that *Sesbania sesban* was the best fallow plant. The best maize yields were produced after a 2-year *Sesbania sesban* fallow (see table 1 and 2). Maize following a 1-year *Sesbania sesban* fallow yielded more than in any other rotation and almost as much as fertilized continuously cropped maize (table 1). *Sesbania sesban* also controlled striga very well (see table 2; Striga is a parasitic weed that tends to get the upper hand on poor soils.) The results of improved fallows on farms were so convincing, and *Sesbania sesban* was so superior to the other plants, that farmers are now rapidly adopting sesbania fallows. They are positive about the effects of sesbania fallows, but also notice some negative points (see box). The farmers' positive appraisal is not surprising in view of the increased yields, as shown in Figure 20. Yields after a sesbania fallow on the 5 farms in the trials were close to those of fertilized maize and far superior to continuous cropping of maize without fertilizer.

Table 1: Yields of maize at Msekera, Zambia, in response to fertilizer and different fallows (Kwesiga & Beniest, 1998)

Treatment	**Maize yield (ton/ha)**
maize with fertilizer	3.96
2-year *Sesbania sesban* fallow	5.36
1-year *Sesbania sesban* fallow	3.43
2-year *Tephrosia vogelii* fallow	3.18
2-year *Sesbania macrantha* fallow	2.97
1-year *Tephrosia vogelii* fallow	2.80
2-year *Cajanus cajan* fallow	2.78
1-year *Cajanus cajan* fallow	2.40
1-year *Sesbania macrantha* fallow	2.07
groundnut - maize rotation	1.87
grass fallow	1.84
maize without fertilizer	1.09

Research findings showed that *Sesbania sesban* produces about 10 ton of fuel wood at the end of a 2-year fallow; what remains behind is the litterfall during the 2 years, and - when the field is cleared - the twigs, leaves and roots. Together these plant parts enrich the soil with about 120 kg N per ha per year (equivalent to 250 kg of urea) plus mineral nutrients. Imagine the work load if all the organic matter - which contains these nutrients - would have to be transported from elsewhere and distributed in the field; the fact that it is all produced on the spot is a great advantage of improved fallows!

Table 2: Effects of fallow plants and nitrogen on maize yield (ton/ha) and striga growth (plants/plot) (Kwesiga & Beniest, 1998)

Treatment	Maize yield	Striga
Sesbania sesban	5.6	0
Gliricidia sepium	3.8	712
Leucaena leucocephala	3.7	0
Flemingia macrophylla	3.5	448
Calliandra calothyrsus	2.6	44
Senna siamea	2.1	0
grass fallow	2.2	130
groundnut - maize rotation	3.1	130
continuous maize, no fertilizer	2.0	1532
continuous maize + 112 kg N/ha	4.1	157

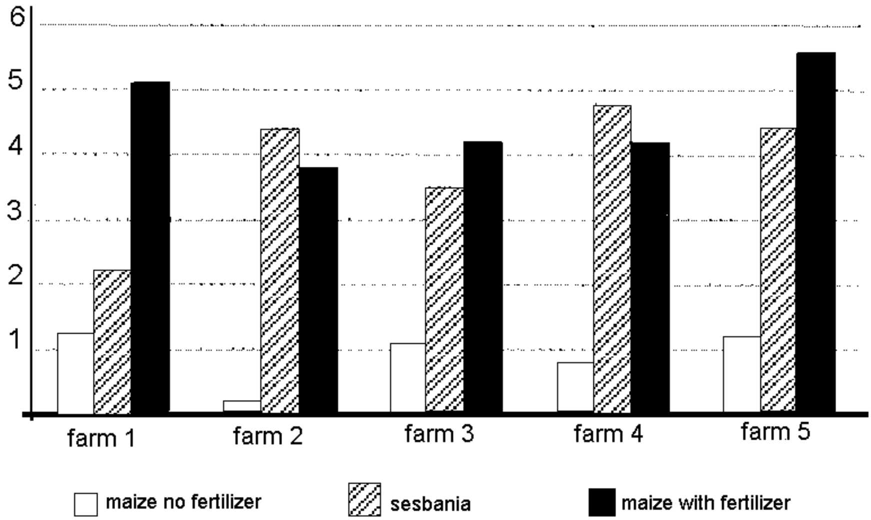

Figure 20: Maize yields in tons per ha on 5 farms over a 3-year period (1993 -96), with or without fertilizer, and following a 2-year sesbania fallow. Fertilizer treatment: 112 kg N, 40 kg P_2O_5, 20 kg K_2O per ha. (Source: Kwesiga & Beniest, 1998)

Box 5: Farmer perceptions of pros and cons of *Sesbania sesban* fallows

Perceived effects in the field:

- improved soil fertility, soil structure and rain infiltration
- reduced erosion
- improved water retention
- better maize seedlings and yields
- much better control of striga
- serves as windbreak

Impact on the farm and in the household:

- increased food supply
- more firewood available
- more cash available
- improved standard of living and nutrition
- poles can be used to construct storage bins and fences
- more maize stover for cattle available
- control of beetles in *Sesbania* is difficult
- affects the workload in the course of the year; nursery work and planting come at a busy time
- takes a long time - 2 to 3 years - to achieve results

Consquences for the village:

- increased food security
- diminished pressure on forests, trees and wildlife because much fuelwood is produced on the farms
- reduction of the on-farm grazing areas
- makes it necessary to regulate grazing and fires in order to protect the fal-lows
- group nurseries are efficient, but pose organisational problems

Source: Kwesiga, F. & Beniest, J., 1998.

Management

In eastern Zambia 3 - 5 ha is a common farm size and labour tends to be more scarce than land. Raising sesbania seedlings, cultivating and ridging the field for planting and weeding (mainly grasses, because that is the natural fallow vegetation) require much labour during the busiest time of the year (the crop planting season). This is the main handicap for farmers wishing to adopt improved fallows. About 125 man-days per ha are required for these activities, compaired to 75 man-days for land preparation, sowing and weeding 1 ha of maize. On the other hand, fallow clearance requires only 5 man-days. The remaining stubs and roots decay easily; they do not seriously hinder land preparation for maize.

Sesbania seedlings are raised in a nursery. 150 - 300 g seed should suffice to obtain 10,000 good seedlings, enough to plant 1 ha at a spacing of 1 x 1 m. Direct sowing is inferior to raising bare-rooted seedlings in a nursery, because it extends the fallow period, gives an uneven stand and requires much more labour for weeding till sesbania covers the land. Seeds germinate within 2 weeks and seedlings can be planted out 6 - 10 weeks after sowing. Because the start of the rainy season cannot be predicted it is advisable to sow twice at an interval of 2 weeks. Inoculation of the nursery soil with the nitrogen-fixing bacteria may be necessary. The seedlings are planted out on ridges early in the rainy season, when they are about 20 cm high. Seedlings which do not take are replaced by spare plants. Weeding is necessary till the end of the rainy season.

After 2 years, before the start of the rains, the sesbania is cleared by cutting the trees close to the ground. The trees are left in the field for 1 - 2 weeks, to allow the leaves to drop. Thereafter they are further partitioned into stems and branches for fuelwood and smaller twigs. The soil is scraped off the old ridges to form the new ridges for the maize crop on top of the sesbania litter.

Sesbania is not a hardy crop; it is susceptible to nematodes, pests and diseases. In eastern Zambia beetles are the main problem, in the nursery as well as in the fallow field. Chemical control is too costly (except in the nursery), so that hygiene, crop rotation and catching insects by hand in the early stages of infestation are the practical control measures. Sesbania is not very palatable but protection against browsing livestock is nevertheless important. Fire is another hazard, because Sesbania fallows are often located dangerously close to traditional grass fallows, which are burnt when the field is to be cropped. As more farmers adopt improved fallows the prevention of damage by browsing and fires becomes a community concern.

Conclusion

The successful introduction of sesbania fallows in eastern Zambia is an encouraging example. So it is not surprising that improved fallows are being tried elsewhere, particularly in Africa. Depending on the growing conditions, modifications will be necessary. In western Kenya sesbania fallows are also being tried, in spite of an average farm size of only 0.5 ha. The soils there are naturally fertile, but they have been impoverished by very inadequate natural fallows and continuous cropping. On these soils phosphate fertilizer has to be added as was mentioned before (see box: *Agroforestry on impoverished soils in Africa* in section 2.2). At low P-levels sesbania does not grow well, nor do the roots nodulate properly, so far less nitrogen is fixed.

Box 6: Enriched fallows in the humid tropics

The tropical rain forest is converted to agricultural use through ‘slash and burn’ clearance of forest. Quickly the cleared plot is planted with food crops - including large herbs such as cassava and plantain - to take advantage of the nutrients in the ash. Often trees which yield valuable products within a relatively short time are planted along with the food crops. Within a few years the resurging forest vegetation smothers the food crops which cannot compete because the nutrient levels drop and the farmer cannot keep up the weeding. The plot is left fallow to restore soil fertility, and the planted trees - e.g. pejibaye palm and Amazon tree grape, common fruit trees in Colombia - bear their fruit crops during the fallow period. Hence the purpose of these ‘enriched fallows’ differs from that of the ‘improved fallows’.

Natural fallows consist of a variety of plants. *Sesbania sesban* is a fairly vulnerable plant; in many situations the risk of failure may be so high that other plants or mixtures with other plants may be advisable. In Zambia *Tephrosia vogelii* and pigeon pea were second-best in experiments with improved fallows, and in western Kenya *Crotalaria grahamiana* also shows promise. In fact a much wider range of plants should be considered, with emphasis on indigenous plants.

The high labour requirement during the planting season may be reduced by minimal land preparation; in Zambia farmers have achieved a good stand of sesbania with zero tillage.

Thus there appears to be much scope for further experiments with improved fallows, to break the alarming trend towards declining soil fertility and declining crop yields. The fuelwood produced during the fallow is an added bonus.

4.7 Home gardens

As noted in Chapter 3 a home garden is generally a hedged or fenced area near the house where garden crops are grown to supplement the staple food supplied by the field crops (see box). In a good home garden trees and other perennials are grown, to ensure that there is still something to be picked during the dry season when there are no seasonal garden crops available to make the meals more tasty and nutritious. Hardy perennials are easy to grow and give the garden a permanent character. If the garden cannot be tended for some time because of pressing other work, one can still pick some leaves, young shoots, pods or other fruit, etc., to add variety to the meals, while the framework of the garden remains intact.

Annual vegetables are mainly grown in the wet season. At that time women also gather leaves from field crops (e.g. cowpea, beans, gourds) and weeds. These supplies all tend to run out simultaneously in the dry season. Thereafter people depend on tubers and stored produce (cassava, sweet potato, onion, gourds, pulses). Hence it is fortunate that everywhere in the tropics people have learnt to use leaves and young shoots of perennial plants, including trees and shrubs, which can also be gathered during the off-season. Examples include *Moringa oleifera, Parkia speciosa, Sesbania* spp. (all trees), *Telfairia occidentalis* (woody climber), *Basella alba* (trailing herb), and cassava. Perennial vegetables are often grown as hedges, which are pruned by harvesting the young shoots, e.g. *Sauropus androgynus.*

Box 7: Home gardens and nutrition of the family

Nutritionists recommend an average daily consumption of 150 - 200 g vegetables (preferably including a good portion of dark-green leaves) and 50 - 100 g of fruit for each member of the family. Vegetables and fruit are protective foods that provide mainly protein, vitamins and minerals. Together with the staple food and perhaps some animal products (eggs, milk, meat) this constitutes a balanced diet. A mother of three children therefore would have to prepare about 1 kg of fresh fruit and vegetables in the kitchen every day to serve balanced meals. Obviously a large majority of rural households in the tropics fall far short of this recommended quantity. In fact nutrition studies indicate that in many regions malnutrition caused by lack of protective food is more serious than undernourishment (people going hungry).

The common short-duration-fruit crops (banana, papaya and pineapple) and most palm species produce fruit throughout the year. Most other fruit crops have a short harvest period. In a monsoon climate the majority of the fruits can be picked towards the end of the dry season or early in the wet season, a period during which protective food is scarce. The availability of some fruit throughout the year and others during a critical period makes fruit an even more important source of protective food.

In Chapter 1 it was also explained that a range of auxiliary woody plants is often grown in the home garden to supply traditional medicines, fibres, fodder for livestock, bamboo, poles, timber for domestic use, live stakes, etc. Traditionally these products came mainly from the non-cultivated areas near the village. If this source is inadequate or inconvenient, the products have to come from the home garden (or from agroforestry activities in and around the arable fields).

Home gardens flourish in the wet tropics. In drier climates it requires a bit more planning and effort to establish a home garden. However, its contribution to the diet of the family is even greater, because compared to farming in the wet tropics there are usually few other sources of protective food, apart from animal products. Many women have hardly any herbs or spices to make the staple food tasty and more nutritious, particularly during the dry season. And fruit is either not available or too expensive, unless one can grow one's own.

Lay-out and maintenance

A home garden is usually adjacent to the house. This facilitates supervision, use of household waste water to water a few plants, and the picking of produce for the next meal. The trees in the home garden also enable the family to do various tasks and enjoy leisure time in the shade. Ideally the house, the farm yard, and the garden should be enclosed by a hedge to form a compound. The hedge is essential where farm animals are not kept in a stable but move around every day with a herdsman. (Sometimes chickens or pigs are allowed to roam freely in the garden, but it is much better to fence off an area for these animals, because they do interfere with gardening; in any case growing seasonal garden crops becomes impossible if poultry or pigs run about freely.)

Planting the hedge determines the size of the garden (or the farmstead compound). In general home gardens are smaller in drier climates, but the size of a garden does not matter much. What matters is that gardening does not take up too much time and that the gardener is richly rewarded for his or her efforts. After all the garden is only a sideline; farmers generally depend primarily on the field crops and animal husbandry for the livelihood of their families.

If rainfall is so low and unpredictable that only short-duration field crops are grown, such as millet, there is hardly scope for seasonal garden crops. The emphasis should be on perennial vegetables and a few hardy fruit trees, e.g. guava, sugar apple, lime, lemon, cashew and tamarind. In addition auxiliary woody plants may be grown, in positions where their shelter or shade is most effective. In such a situation 50 - 100 m^2 is a fair size for a garden. Of course a garden this small cannot produce enough protective food to provide a family with balanced meals throughout the year. Where the dry season is long this would require irrigation or a large garden. However, the intake of protective food is now often so low, that every improvement is very worthwhile.

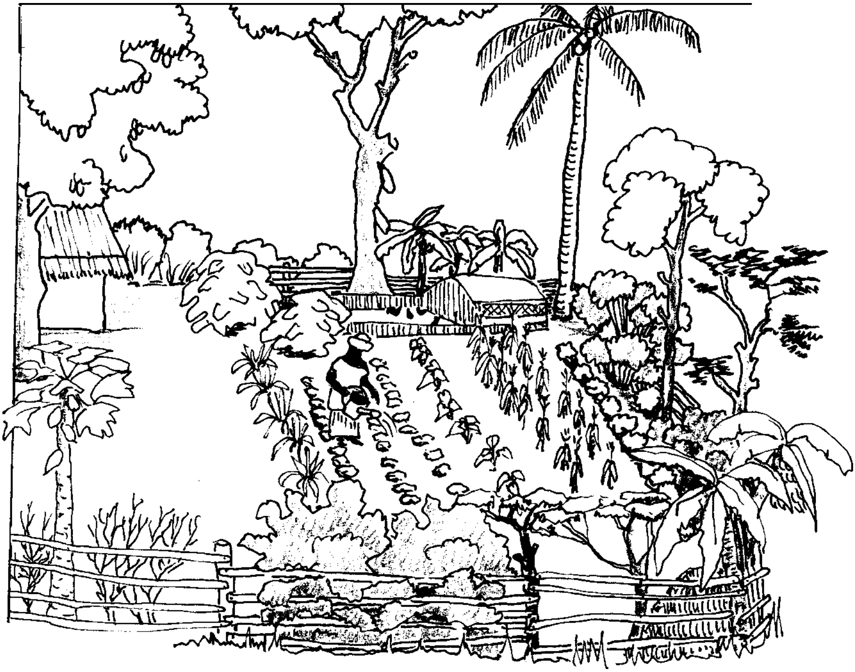

Figure 21: Woman at work in a home garden

With increasing rainfall the choice of crops widens rapidly and a much larger garden can be maintained, say 200 - 2000 m^2. This leaves room for seasonal vegetables, e.g. a few rows of eggplants or gourds, successive sowings of a bed of greens. However, perennial vegetables, fruit trees and woody auxiliaries still deserve much space, to ensure continuity of supplies through the dry season.

Maintenance of the home garden differs from care extended to field crops. Many methods of hand watering, mulching, composting, and plant protection mentioned in agricultural textbooks are hardly practiced on a field scale but they are very relevant in the home garden.

Examples of plant protection techniques are the use of wood ash on seed beds to keep the ants away (and to fertilize the seed bed) and surrounding the trunk of a fruit tree with thorny branches or a metal collar to prevent rats and other vermin getting at the fruit. A great advantage of planting mainly woody perennials is that as a rule they are hardy and require little care. Moreover, the work is often done when products are needed: pruning is carried out when livestock requires fodder, a tree is felled when the timber can be used in construction, etc.

5 Postscript

Plant a tree

In my first post as an extension worker in the south of the Netherlands I was introduced to an old tradition: a farmer would always plant a walnut tree in the farmyard when his first son was born. The walnut grows well but slowly in that area. As the boy grew up he would notice the peculiar smell of the walnut leaves, which repels flies (making them less of a nuisance in the house and stable). By the time he married he would have learnt to enjoy the nuts, which are eaten by the fireplace at Christmas and used in a variety of confectioneries. And in his old age, when his time was running out – and hopefully new trees had been planted for his son and grandson – his own tree would be ready to yield its valuable timber....

This old tradition honours the walnut as a multi-purpose tree, a tree moreover with a characteristic silhouette that lends dignity to the farmstead. Above all, the tradition is an expression of faith in the future. That is the essence of planting a tree: it is a token of trust. I do hope that you, respected reader, in spite of the concern expressed in this booklet about overexploited land, impoverished soils and declining yields, can face the future with enough confidence to plant trees. Because I also hope that the preceding chapters have strengthened your conviction that if the right tree is planted in the right place it will not betray your trust.

June 2003, Ed Verheij

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Useful addresses

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ICRAF is engaged in research and development activities leading to more sustainable and productive land use. It focuses on agroforestry systems that restore soil fertility, lift rural poor out of poverty and enhance the environment. They also focus on capacity building for agroforestry research and development. For Southern Africa there is the:
SADC-ICRAF Regional Agroforestry Programme:
C/o CIMMYT, P.O. Box 163, Mount Pleasant, Harare, Zimbabwe
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Kenya Forestry Research Institute (KEFRI)
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Tel: (+254) 0154-32009, 32891, 32892, 32893
E-mail: kefri@arcc.or.ke or sofem@kefri.org
Fax: (+254) 0154-32844 or 32009
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The objectives of KEFRI are to generate technologies for farm forestry, natural forests, drylands forestry and forest plantations, to strengthen research capacity and to document and disseminate scientific information.

International Institute for Tropical Agriculture (IITA)
P.O.Box 5320, Ibadan, Oyo State, NIGERIA
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IITA conducts research, training, and information exchange activities. The research agenda addresses crop improvement, plant health, and resource and crop management within a food systems framework. Research focuses on smallholder cropping and post-harvest systems and on several food crops.

Joint Energy and Environment Projects (JEEP)
P.O. Box 4264, Kampala, UGANDA
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Fax: (+256) 041-530765
Jeep's aim is to combat environmental destruction and conserve natural resources in Uganda. Activities concentrate on community training (in energy and soil conservation, and forestry), as well as networking and advocacy work.

ASIA:

International Crops Research Institute for Semi-Arid Tropics (ICRISAT)
Head Quarters502 324, Andhra Pradesh, INDIA
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Fax: (+91) 08455-40283 / 43064
Web: www.icrisat.org: (+91) 040-3241239 / 3296182
ICRISAT's mission is to help the poor of the semi-arid tropics through 'Science with a Human Face' and partnership-based research and to increase agricultural productivity and food security, reduce poverty, and protect the environment in SAT production systems.

Center for International Forestry Research (CIFOR)
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Web: www.cgiar.org/cifor
CIFOR contributes to the sustained well-being of people in developing countries, particularly in the tropics, through collaborative strategic and applied research in forest systems and forestry, and by promoting the transfer of appropriate new technologies and the adoption of new methods of social organization for national development.

Regional Community Forestry Training Center for Asia and the Pacific (RECOFTC)
P.O. Box 1111, Kasetsart University,
Bangkok 10903, THAILAND
Tel: (+66) 02-9405700
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RECOFTC's objectives are guided by the potential of community forestry management regimes to contribute both to sustainable forest management and to the needs of more than a billion rural people in Asia who depend on forest resources for their livelihoods. They do training and capacity development to enable rural people to manage their forest resources.

EUROPE:
ILEIA (Centre for Information on Low External Input Agriculture)
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ILEIA publishes information on low external input and sustainable agricultural practices. It also publishes the international quarterly LEISA Magazine, which is freely available to readers and organisations in the South.

Glossary

Arid: a climate in which potential evaporation exceeds rainfall in all months of the year. A condition that makes cropping possible only with the support of water harvesting or irrigation. Refers here to an area with an average of less than about 200 mm annual rainfall.

Browsing: the feeding on buds, shoots and leaves of woody plants by livestock or wild animals. Browse is the material consumed.

Contour line: an imaginary line on a field, joining all points which are at the same height above sea level.

Crown: the canopy of a tree or other woody plant, which rises above the trunk or stem.

Deciduous tree: a tree which stands virtually leafless for a while after shedding its leaves and before a new flush leaves out. By contrast an evergreen tree changes its leaves gradually.

Desertification: process of continuous decline in the biological productivity of arid or semi-arid land. Resulting in a skeletal soil that is difficult to revitalize (a form of land degradation).

Erosion: the process of wearing away soil by wind and/ or rain. Soil erosion is harmful because of the loss of fertile top soil. Where this soil is deposited it may also cause problems, e.g. silting up of waterways.

Evaporation: transition of water to vapour. Usually the water evaporates from the soil or vegetation; as a result the soil gradually dries out.

Fallow: land resting from cropping, which may be grazed or left unused; often colonized by natural vegetation.

Foliage: the mass of leaves on plants.

Green manure: green plant material used as fertilizer. See Agrodok 28, *Green manuring and other forms of soil improvement*.

Humid: a climate in which rainfall exceeds potential evaporation during at least 9 months of the year. Refers here to tropical areas that receive more than about 1500 mm annual rainfall.

Infiltration rate: the rate at which water can move through a soil.

Leaching: the process by which nutrients in the soil are washed down through rain or irrigation water to a depth at which plant roots can no longer reach them. After leaching, the nutrients may be carried away by ground water movement.

Leeward: the side of an object and its surrounding area that is sheltered from the wind.

Legume: member of a large family of trees, shrubs and herbs (e.g. beans and peas), the Leguminosae. On the roots of these plants there are small nodules which contain bacteria. These bacteria convert inert nitrogen from the air into a form which the bacteria and plants can use for their growth.

Litter: organic material on the soil surface, including leaves, twigs and flowers, freshly fallen or slightly decomposed.

Lopping: a form of pruning, in which some of the branches of a tree are removed. Usually the lower branches are cut, while the upper part of the crown is allowed to continue to grow. Lopping should lead to the sprouting of new shoots near the cuts.

Micro-climate: the temperature, sunlight, humidity, and other climatic conditions in a small localized area, e.g. in a field, under a tree or in the topsoil.

Mulch: protective covering of the soil surface by various substances, such as green or dry matter, sand or stones, applied to prevent evaporation of moisture, moderate soil temperature and control weeds.

Nitrogen fixation: the processing of inert nitrogen in the air into a form that can be used by plants. The process is performed by organisms that live in association with the roots of certain plants, e.g. legumes.

Nutrients: mineral substances and nitrogen, which are absorbed by the roots to enable plants to grow.

Orchard: a field planted with fruit trees.

Perennials: plants that (usually) live for longer than one or two years.

Permeability: the capacity to allow air, water or other material to pass through. A desirable property of soils.

Pollarding: removing all the branches, including the top of the tree, leaving only the trunk. Shoots are allowed to sprout to form a new crown.

Pruning: the cutting of parts of a woody plant, often to stimulate better-placed new growth.

Range lands: an extensive area of land on which livestock can graze.

Root collar: the point near ground level where the root system merges with the stem.

Rotation: cultivation of a succession of crops, possibly including a fallow period, on the same land. One rotation cycle usually takes several years to complete.

Run-off: rain or other water that flows over the soil surface and does not infiltrate into the soil.

Sapling: a young tree, no longer a seedling, but not yet big enough to be used as a pole. Usually a few metres high and at most 2.5 cm in diameter at breast height.

Semi-arid: a climate with an average annual rainfall of about 200-900 mm and large variations from year to year.

Splash erosion: raindrops that fall on soil aggregates, causing small soil particles to splash in all directions.

Stake: here refers to a wooden pole used to support climbers (e.g. yam, pumpkin); live stakes strike roots easily and are in fact very large cuttings.

Sub-humid: in the tropics, a climate with an average annual rainfall of roughly 900-1500 mm

Sustainability: here refers to management of resources in agriculture to satisfy changing human needs, while maintaining or enhancing the quality of the environment and productivity of the land.

Taproot: the first root to emerge from the seed; usually vigorous, persistent and growing down-wards.

Transpiration: loss of water in the form of vapour by living organisms to prevent overheating.

Turbulence: whirling of wind after it has passed an object.

Wind-ward: the side of an object and its surrounding area that is exposed to the wind.

Appendix 1: List of auxiliary species in Agroforestry

Explanatory notes

The information in the following list has been gleaned from several published sources. Sometimes the information is incomplete, resulting in blank spaces in the list; in a few instances the information from various sources is contradictory. AGROMISA welcomes suggestions for corrections, supplementary information about species and additional species which deserve being listed.

Botanical name: The species are listed alphabetically by their botanical name. The botanical name of a species may change because of new insights in its relations with similar species. If the name has changed in recent years and the species is still better known by its former name, that name is given between brackets. An asterisk (*) behind the botanical name indicates that the species is able to convert inert nitrogen from the air into a form that can be taken up by the plant. All these N-fixing plants are legumes, except *Casuarina equisetifolia*.

Common names: Some species have no common English (E), French (F) or Spanish (S) name that is widely used; in that case the botanical name is used. Common names are not unique; they may differ in different parts of the world. That is why for some species several common names in one language are given.

Origin: The continent where the species is thought to have its origin is given, mainly because it may indicate that the chance of obtaining seed or planting material is best on that continent. However, many species have found their way across the tropical world and are readily available outside the continent of origin.

Habit: In this column the general appearance of the plant is given in a few words. The habit of species which occur over a wide range of ecological conditions may differ substantially at the extremes of the range.

Propagation: Propagation methods which have found practical application are given. If several propagation methods are used, the most common method is mentioned first. If one of the methods is recommended, this method is underlined.

Ecology: Available information about the growing conditions a plant requires is often fragmentary; and often given in very different terms in the various sources. Moreover, within many species several types are distinguished which differ in their ecological requirements, e.g. one type being much better adapted to dry conditions than the other type. In as far as it is available, information starts with the range of altitudes at which the plant is found within the tropics. The symbol < indicates ‘lower than’ , > indicates ‘higher than’; a plus sign (+) behind a figure means that the plant is generally found up to the altitude given, but in some instances in even higher locations. Rainfall requirements are given in similar terms; however, if plants have access to ground water, e.g. along river banks or in depressions, they may thrive with less rain water than indicated. Information about soil requirements is available for only very few species.

Uses: Both use of products yielded by the plant – e.g. fruit, fodder, fibre – and environmental uses of the tree – e.g. green manure, shade, shelter – are listed. The principal use is listed first, but this main use may differ in various regions, e.g. in relatively wet areas the plant may be mainly used for fodder, in dry areas for its fruit and fuelwood. The limited space does not permit listing uses extensively; in a few cases the most important uses are followed by ‘etc.’

Remarks: In this column information is presented that does not fit into other categories, but is of interest to the grower.

Nr	Botanical name	Common names	Origin	Habit
1	*Acacia auriculiformis**	northern black wattle, ear-pod wattle (E)	Australia	tall tree
2	*Acacia mearnsii**	black wattle (E); acacia noir (F)	Australia	small tree
3	*Acacia nilotica**	Egyptian thorn (E); acacia d'Arabie, gommier rouge, gonakié (F)	Africa	small thorny tree
4	*Acacia senegal**	gum arabic tree (E); gommier blanc (F)	Africa	small thorny tree or shrub
5	*Acacia sieberiana**	African laburnum, white thorn (E); acacia pelona (S)	Africa	spiny tree
6	*Acacia tortilis**	umbrella thorn (E); faux gommier (F)	Africa	tree
7	*Adansonia digitata*	baobab (E,F)	Africa	tree
8	*Albizia adianthifolia**	West African albizia (E)	Africa	large tree with flat crown
9	*Albizia lebbeck**	siris, koko (E); langue de femme (F)	Asia	tree
10	*Albizia procera**	white siris, tall albizia (E)	Asia	tall tree
11	*Annona senegalensis*	wild custard apple (E); pomme channelle du Sénégal (F)	Africa	small tree or shrub
12	*Azadirachta indica*	neem (E,F)	Asia	tree
13	*Basella alba*	Ceylon spinach, Indian spinach (E); baselle, brède de Malabar (F)	Asia	perennial twining herb
14	*Borassus aethiopum*	borassus palm, elephant palm, fan palm (E); rôtnier (F)	Africa	robust palm

Nr	Propagation	Ecology	Uses	Remarks
1	seed, cuttings	0 - 1000+ m; > 650 mm rain	fuelwood, pulp, timber, shade, land rehabilitation	grows on any type of soil
2	seed, cuttings	subhumid highlands	tannin (bark), fuel-wood, poles, wind-break, green ma-nure	rehabilitates degraded land
3	seed	0 - 1300 m; river banks; 400 - 2300 mm rain	tannin (bark, pod), gum, fodder, wood (fuel, constr.)	reclaims alkaline soil
4	seed	dry savanna (< 700 mm rain) on sandy soils	gum (bark), fodder, cordage, wood, medicine	only stressed trees yield gum
5	seed	coastal and inland savanna	gum, forage, con-struction wood, medicine, honey, etc.	retains leaves far into the dry season
6	seed	drought-tolerant; common in the Sahel	forage, sand-binder, shade tree, wood, fibre, medicine, etc.	deep-rooted
7	seed	in a belt N and S of the equator in Africa	food (leaf, fruit pulp, seed, root), fibre, salt (ash), etc.	trunk stores mois-ture which can be tapped
8	seed	common in moist savanna zone	shade tree, con-struction wood, fuelwood, medicine (bark, root)	
9	seed	semi-arid to sea-sonally dry tropics	forage, hardwood, honey	underutilized in agroforestry
10	seed, stake cuttings	0 - 1500 m; 500 - 3000 mm rain	fuelwood, timber , windbreak, shade, land rehabilitation	
11	root suckers, seed	at home in savanna	medicine, food (fruit, leaf), fodder	fire-resistant; sprouts from the stake
12	seed, layers, graft-ing	0 - 1500 m; 400 - 1400 mm rain	insecticide, oil, timber, fuel	protects and improves very poor soils
13	tip cuttings	0 - 500 + m	leaf vegetable, medicine	resistant to diseases and pests
14	seed	savanna palm of tropical Africa	fruit, sprouting seed, palm sap, cordage, logs, etc.	fan-shaped leaves, to 4 m long

Nr	Botanical name	Common names	Origin	Habit
15	*Byrsonima crassifolia*	nance, golden spoon (E); maurissi (F); manero, manteco, nancite (S)	C. + S. America	shrub or small tree
16	*Caesalpinia decapetala**	Mauritius thorn (E)	Asia	straggling spiny shrub
17	*Cajanus cajan**	pigeon pea (E); pois d'Angole, ambrévade (F)	Asia	short-lived shrub
18	*Calliandra calothyrsus**	(red) calliandra (E)	C. America	shrub or small tree
19	*Calligonum polygonoides* (*Calligonum comosum*)	-.-	Africa	shrub
20	*Calotropis procera*	auricula tree,Sodom apple (E); arbre à soie (F)	Africa	shrub
21	*Capparis decidua*	salt bush, siwak tree (E); caprier, caprier sans feuilles (F)	Africa	spiny bush, largely leafless
22	*Carissa carandas*	karanda, karaunda (E)	Asia	climbing shrub
23	*Casuarina equisetifolia**	coast she-oak, ironwood, casuarina (E); filao (F)	Austr. Malesia	large tree
24	*Combretum glutinosum*	ratt, bois d'élèphant (F)	Africa	small tree
25	*Combretum molle*	bush willow (E)	Africa	shrub or small tree
26	*Commiphora africana*	African bdellium (E); bdellium d'Afrique (F)	Africa	shrub or small tree
27	*Cordia alliodora*	cordia, salmwood, Spanish elm (E); bois soumis, chène caparo (F)	C. + S. America	large tree
28	*Crotalaria ochroleuca**	sunhemp (E)	Africa	shrubby annual herb
29	*Dactyladenia barteri*	monkey fruit (E)	Africa	scandent small tree

Nr	Propagation	Ecology	Uses	Remarks
15	seed	hot lowland monsoon climate; all soils	fruit, home garden	
16	seed	lowland (< 1000 m) monsoon climate	hedge, medicine, tannin	
17	seed	0 - 2000 m; 600 - 1000 mm rain	pulse or vegetable, nurse or shade crop, medicine	versatile plant in dry conditions
18	seed, cuttings	0 - 850 + m; >1000 mm, 2 - 6 dry months	fuelwood, forage, land rehabilitation, lac insect host	popular auxiliary shrub
19		sandy desert areas (Sahara)	sand binder, fodder (camels), charcoal	
20	suckers, seed	abundant in arid conditions	sand binder, medicine	indicates subsoil water
21		on edges of Sahara; drought-tolerant	spice, fodder, carpentry wood, medicine, sand binder	forms dense thickets
22	seed	full sun, not too humid conditions	hedge, fruit, medicine	mainly used for hedges
23	seed, cuttings	coast - 1200m; semi-arid to sub-humid	reclaims land, shelterbelts, fuel, charcoal	very fast early growth
24	seed	Sahel desert tree; drought-tolerant	medicine, hard wood (house posts), fodder, dye	survives where grass does not
25	seed	savanna forest tree	medicine, durable wood (house posts)	
26	stake cuttings	dry areas, such as Sahel savanna woodland	live fence/hedge, fodder, resin/gum, food (root)	
27	seed, cuttings	0 - 1000 (2000) m; 750 - 2000 mm rain	timber, shade	pioneer plant; good regeneration
28	seed	widely grown in moist situations	vegetable (leaf, flower, pod), green manure, fibre	
29	seed, stake cuttings	0 - 300 m; > 1200 mm rain	fallow crop, forage, poles	thrives on poor soils; popular in Nigeria

Nr	Botanical name	Common names	Origin	Habit
30	*Dalberghia melanoxylon**	African blackwood, Senegal ebony (E); ébènier du Senegal (F)	Africa	spiny shrub or small tree
31	*Dalberghia sissoo**	sissoo (E)	Asia	deciduous tall tree
32	*Daniellia oliveri**	African copaiba balsam, West African copal (E); satan (F)	Africa	tall tree
33	*Dichrostachys cinerea**	Chinese lantern tree, marabou thorn (E); mimosa clochette (F)	Africa	spiny shrub or small tree
34	*Diospyros mespiliformis*	West African ebony (E), ebenier de l'Afrique de l'Ouest (F)	Africa	tall tree
35	*Dovyalis caffra*	kei apple (E)	Africa	small tree
36	*Erythrina fusca**	purple coral-tree, coral bean (E); bois immortelle, immortelle blanc (F)	pantropical	tree
37	*Erythrina poeppigiana**	coral tree, mountain immortelle (E); bois immortelle (F); poró gigante (S)	S. America	tree
38	*Erythrina subumbrans**	December tree (E)	Asia	deciduous tree
39	*Erythrina variegata**	Indian coral tree, tiger's claw (E); arbreau corail (F)	Africa, Asia	deciduous tree
40	*Eucalyptus camaldulensis*	river red gum, Murray red gum (E)	Austr.	tree
41	*Eucalyptus tereticornis*	forest red gum, blue gum (E)	Austr.	large tree
42	*Euphorbia balsamifera*	balsam spurge (E); euphorbe de Cayor, euphorbe candélabre (F)	Africa	erect shrub
43	*Euphorbia tirucalli*	milk bush (E); arbre de Saint Sébastien (F)	Africa	shrub or small tree

Nr	Propagation	Ecology	Uses	Remarks
30	seed	dry savanna	hard wood for implements, fodder, medicine	wood resembles true ebony
31	seed	riverine situations	timber, shade, fodder	much cultivated in India
32	seed	savanna forest	gum, construction wood, medicine, fodder, chew-sticks	
33	suckers	thickets in savanna and on disturbed land	barrier hedge, construction wood, fibre, medicine, etc.	may spread like a weed
34	seed	in drier borders of rain forest	timber, fruit, parkland tree, fodder, medicine	
35	seed	highland monsoon climate	fruit, hedge	
36	seed, cuttings	0 - 2000 m; 1200 - 3000+ mm	shade tree, live stake, forage, ornamental	most widespread erythrina
37	seed, cuttings	500 - 1500+ m; >1200 mm rain	shade tree, live stake, forage, ornamental	
38	cuttings, seed	0 - 1500 m; < 4 months with < 100 mm rain	shade, live stake, fodder, medicine, wood for canoes	excellent live support for many crops
39	seed, cuttings	0 - 1200 m; >1200 mm rain	live stake, shade tree, vegetable, green manure, medicine	
40	seed, cuttings	very adaptable; copes with 0 - 8 dry months	wood, timber, charcoal, shade, honey	most common tree in dry tropical lands
41	seed, cuttings	0 - 1800 m; > 500 mm rain; deep light soils	wood, timber, charcoal, shelterbelts, eucalypt oil	comparable to *E. camaldulensis*
42	cuttings	southern edge of Sahara; deep sandy soil	(boundary) hedge, fodder (camels, goats), medicine	best hedge in dry (<900 mm rain) areas
43	cuttings	drought-tolerant	hedge, latex, fish poison, fuelwood, medicine	

Nr	Botanical name	Common names	Origin	Habit
44	*Faidherbia albida** (*Acacia albida*)	African winterthorn (E)	Africa	deciduous tree
45	*Flemingia macrophylla**	-.-	Asia	semi-woody shrub
46	*Gliricidia sepium**	gliricidia, mother of cocoa (E)	C. America	small tree
47	*Grevillea robusta*	silky oak, silver oak (E)	Australia	tree
48	*Inga edulis**	guamo (E); pois sucre (F); guaba, guama, guamo (S)	S. America	small tree
49	*Jatropha curcas*	physic nut, pig nut, fig nut (E)	C. America	tall shrub
50	*Lannea coromandelica* (*Lannea grandis*)	-.-		tree
51	*Lantana camara*	lantana, wild sage, curse of Barbados (E)	C. + S. America	low shrub
52	*Leptadenia pyrotechnica*	-.-	Africa	leafless shrub
53	*Leucaena diversifolia**	leucaena (E)	C. America	small tree
54	*Leucaena leucocephala**	leucaena (E), leucaene, faux mimosa (F)	C. America	small tree
55	*Maesopsis eminii*	umbrella tree, musizi (E), musizi (F)	Africa	tree
56	*Melia azedarach*	Chinaberry, Persian lilac, pride of India (E)	Asia	tree
57	*Moringa oleifera*	horseradish tree, drumstick tree (E); ben ailé (F)	Asia	small tree
58	*Paraserianthes falcataria** (*Albizia falcataria*)	paraserianthes (E)	Asia	tree

Nr	Propagation	Ecology	Uses	Remarks
44	seed	0 - 2500 m; dry climates	parkland tree, fodder, honey, fuelwood, timber, medicine	leafless in wet season; access to ground water
45	seed	0 - 2000 m; >1100 mm rain	hedge/alley crop, forage, cover crop, mulch, fallow crop	coppices very well
46	seed, cuttings	0 - 1500 m; > 900 mm rain; tolerates fire	multi-purpose auxiliary crop	2nd only to leucaena
47	seed, cuttings	100 - 2300 m; 700 - 1700 mm rain	shade tree, firewood, poles, timber, forage	very compatible with field crops
48	seed	hot, humid climate	hedge, fruit	flowers/fruits all year
49	cuttings, seed	drought-tolerant	hedge, live support, oil, medicine	
50	stake cuttings	fairly humid lowlands	live stake	
51	cuttings, seed	0 - 1500 m; does not need much moisture	hedge, ornamental	may become noxious weed
52		semi-desert and dry sandy Sahel	fodder, fuelwood, fibre, sand binder	twigs burn slowly
53	seed	700 - 2500 m; 600 - 2800 mm rain	fuelwood, poles, shade, fodder, reforestation	where psyllids attack *L. leucocephala*
54	seed	0 - 1000+ m; 650 - 1500+ mm	multi-purpose auxiliary crop, parts used as vegetable	most important agroforestry species
55	seed, cuttings	0 - 1500+ m; > 1200 mm rain; no waterlogging	shade, fodder, fuelwood, timber, avenue tree	open crown and long life -> good shade tree
56	seed, cuttings, suckers	lowlands - frost-prone highlands; > 600 mm rain	fuelwood, shade, pesticide, timber, medicine, ornamental	adaptable, versatile tree
57	cuttings, seed	0 - 1300 m; wet to fairly dry climates	vegetable, condiment (bark), live support, medicine	excellent home garden plant
58	seed, tissue culture	0 - 2300 m; wet climate: < 2 - 4 dry months	land reclamation, shade, fuel, woodwork, forage, ornamental	fast growing pioneer species

Nr	Botanical name	Common names	Origin	Habit
59	*Parkia biglobosa**	African locust bean (E); arbre à farine, mimosa pourpre, néré (F)	Africa	deciduous tree
60	*Parkia speciosa**	-.-	Asia	tall tree
61	*Parkinsonia aculeata**	Jerusalem thorn (E)	C. America	small thorny tree
62	*Pithecellobium dulce**	guayamochil, Manila tamarind, sweet inga (E)	C. America	small thorny tree
63	*Pongamia pinnata**	pongame oil tree, Indian beech (E); arbre de pongolote (F)	Asia	shrub/tree
64	*Prosopis juliflora**	mesquite (E); bayahonde (F); algarrobo (S)	C. + S. America	shrub/tree
65	*Saba senegalensis*	saba (E)	Africa	vigorous liana
66	*Salvadora persica*	salt bush, toothbrush tree (E); arbre brosse à dents (F)	Africa	treelet with trayling branches
67	*Sauropus androgynus*	star gooseberry (E)	Asia	shrub
68	*Schinus molle*	pepper tree (E); faux poivrier (F)	S. America	small tree
69	*Schleichera oleosa*	macassar oil tree, gum-lac tree (E); qennettier-rose, pongro (F)	Asia	tree
70	*Senna siamea** (*Cassia siamea*)	Siamese senna, kassod tree, Thailand shower (E)	Asia	spreading tree
71	*Senna spectabilis** (*Cassia spectabilis*)	yellow cassia (E)	C. + S. America	small tree
72	*Sesbania macrantha**	-.-	Africa	biennial small shrub

Nr	Propagation	Ecology	Uses	Remarks
59	seed	at home in savanna and transition woodland	food (leaf, pod, seed), fuelwood, medicine, parkland tree	very popular in northern Africa
60	seed, cuttings, budding	500 - 1000+ m; neither wet nor dry climates	seed vegetable, timber, shade, medicine	
61	seed	deciduous, does not need much moisture	hedge, charcoal, fibre, reforestation, ornamental	
62	seed, air layering	low - medium elevation; wet - dry areas; full sun	hedge, fodder (young shoots), medicine	shapely pruned small roadside tree
63	seed, cuttings	0 - 1200 m; > 500 mm rain, 2 - 6 dry months	fuelwood, woodwork, oil, forage, medicine, windbreak	very adaptable tree, reclaims poor land
64	seed, root cuttings	0 - 1500 m; tolerates drought (50+ mm rain) and saline soil	land reclamation, hedges, food/forage (pods), honey	colonizes dry, saline and alkaline lands
65	seed	tropics, fringe of forest zones	fruit, condiment (leaves), latex, medicine	fruit marketed in W. Africa
66	seed	0 - 1000+ m; favours dry locations	fruit, chew-stick, salt (wood), fodder, medicine, sand binder	
67	cuttings, seed	0 - 1300 m; light shade; fairly wet climate	leaf vegetable, hedge, medicine, dye (leaves)	easy to grow, productive, nutritious
68	seed, cuttings	high elevations; dry climate	roadside tree, windbreak, berries used as pepper	
69	seed, root suckers	0 - 900+ m; > 750 mm rain, needs dry season	firewood, charcoal, woodwork, oil, food/fodder, kusum lac	grows slowly, is fire-resistant
70	seed, tissue culture	0 - 1300 m; > 700 mm rain, 4 - 8 dry months	shade, windbreak, tanning, food/fodder, sandal wood host	much used in agroforestry systems
71	cuttings, seed		barrier hedge, firebreak, ornamental	
72	seed	monsoon climate	fuelwood, green manure	

Nr	Botanical name	Common names	Origin	Habit
73	*Sesbania sesban**	Egyptian sesban (E)	Africa, Asia	short-lived small tree
74	*Tamarindus indica**	tamarind, Indian tamarind (E); tamarinier (F)	Africa	large tree
75	*Tamarix articulata*	tlaie of Morocco (E)	Africa	tree
76	*Telfairia occidentalis*	oyster nut, fluted pumpkin (E)	Africa	vigorous liana
77	*Tephrosia candida**	white tephrosia, white hoary pea (E); indigo sauvage (F)	Asia	herb, shrub, or small tree
78	*Tephrosia vogelii**	Vogel's tephrosia, fish-poison bean (E)	Africa	herb or small tree
79	*Thespesia populnea*	milo, Pacific rosewood, portia tree (E)		tree
80	*Tithonia diversifolia*	Mexican sunflower (E)	C. America	perennial shrub
81	*Trema orientalis*	(Indian) charcoal tree (E)	Asia	shrub to large tree
82	*Vigna vexillata**	wild mung bean, zombi pea (E); pois zombi, pois poison (F)	Asia, Africa	perennial trailing herb
83	*Vitellaria paradoxa* (*Butyrospermum paradoxum*)	shea butter tree (E); arbre à beurre, karité (F)	Africa	small tree

Nr	Propagation	Ecology	Uses	Remarks
73	seed, cuttings	up to 2300 m; 500 - 2000 mm rain	fodder/food, green manure, live stake, shade, windbreak	other *Sesbania* spp. are used similarly
74	seed, cuttings, budding/grafting	0 - 1000+ m; needs dry season to flower	fruit, condiment (flowers, green fruit), windbreak, parkland tree	valuable agrofor-estry tree
75	seed	savanna tree, resis-tant to drought, heat, cold	windbreak, sand binder, wood for carpentry, turnery	
76	seed	on forest edges in W. Africa	food (shoot tip, seed), oil (seed)	
77	seed	0 - 1600 m; > 700 mm rain, acid soil	green manure, fuelwood, shade, contour hedges	replaces leucaena on acid soils
78	seed	up to 2100 m; > 850 mm rain	green manure, windbreak, hedge, shade, fish poison	taller than *Tephro-sia candida*
79	seed, cuttings	0 - 1000 m; prefers light sandy soil	construction wood, carpentry, medicine	sacred tree in the Pacific
80	seed ?	200 - 1500 m;	green manure, barrier hedge, fire-break, ornamental	tolerates frequent pruning
81	seed, cuttings	0 - 2000+ m; 1000 - 2000 mm rain	fallow species, firewood, charcoal, shade, silage	pioneer tree, colo-nizes denuded areas
82	seed, cuttings	highlands; with-stands long wet and dry seasons	food (tubers, leaves, seed), green manure cover crop	excellent pioneer for poor land
83	seed	tree of the open, dry savanna	vegetable oil, con-struction wood, fuelwood, fodder	fire-resistant; fruit important in sa-vanna