Hedges and wildlife management

Hedges offer a wide range of ecological niches. The nature and extent of niches depends on a variety of environmental factors, such as the proportion of trees, hedge length, width, and height, the existence and density of vegetation to mention only a few (93). When conservation practices are applied to the land, the habitat in the area is improved for birds and animals. Planting hedges and revegetation will increase wildlife in the process

Apart from the general consensus that it is possible to attract and increase wildlife in hedges, there are hardly any scientific guidelines in the tropics, particularly for the specific context of the poor.

In temperate zones sufficient knowledge exists on attracting and keeping several desired animals in the hedge. Bees are attracted by plants growing in the rim of a hedge, when there is always something flowering (32). In apiculture a year-round supply of bee forage is essential for poor people; they cannot afford to buy syrup etc. to bridge the period without bee pasture. Specially designed natural hedges are one approach.

Wildlife conservation which is not translated into economic results may be unacceptable to poor land users. The role of hedges in butterfly farming has already been mentioned. Sound wildlife management can be important for the poor. Any starting point has to be the interest and need of the people. For instance in the North-East of Thailand, wild lizards are regarded as an attractive food source. School children are keen on hunting them. Hence a proposal has been made to give incentives for hedgegrowing on school grounds in which wild lizards can find a habitat. Efforts in this direction can evolve into a very valuable environmental education process with tangible results. Active and attractive management are the key to the acceptance of sound wildlife management.

3.11.6 Some problems that may occur when promoting hedges for nature conservation

The conservation of hedges frequently requires the reconciliation of conflicting viewpoints. Farmers tend to regard them as a liability, while conservationists are anxious to promote their survival as sanctuaries for wildlife and an amenity. The present state of knowledge and awareness among planners is very restricted and it is not an easy situation to remedy. Ecologists are more interested in ecosystem hedges while planners are not convinced of their positive impact.

The mainstream of agricultural development is oriented towards western farming models (planners and agronomists in developing countries see hedges as a sort of backwardness). Hedges can be a constraint on the operation of large agricultural machinery. The application of universal biocides can be a threat to hedgerow growing.

4. SOCIAL AND ECONOMIC ISSUES IN HEDGEROW GROWING

Hedges are not a panacea for problems of land use management and the needs of resource-poor people. An understanding of the social, economic, cultural, and historical context of hedgerow growing, particularly for resource-poor people, is an important prerequesite for evaluating the hedge-specific potential. The following discussion summarises important issues; some have been dealt with under specific uses in Chapter 3. Chapter 4.1 discusses social, cultural, and socio-economic, and Chapter 4.2. economic issues related to hedgerow growing. More research and development of hedgerow systems is required. Chapter 4.3. briefly deals with this issue.

4.1 Social dimension of hedgerow growing

4.1.1 Hedges and resource-poor land users - a summary

With increased privatisation of land, and fewer trees on common property the incentives and opportunities for using hedges and hedge trees to satisfy needs, and to use them as assets, have become increasingly important particularly for the poor people.

A close relationship seems to exist between resource-poor people and the opportunities provided by hedgerow growing (334). This is valid for the urban and rural poor and small-scale farmers. It is obvious that rich citizens can afford to take advantage of tree growing by investing in plantations (woodlot, tree crops, etc.); poor people's opportunities may be restricted to a hedge, several hedges and other trees.

In low external input land use management hedges offer various attractive economic and ecological benefits. Small-scale farmers attempt to obtain a sustainable level of production through yield diversification and risk avoidance.

Hedges fit in well with this overall strategy. The relative advantages of hedges for small-scale farmers become evident by a comparison with commercial farming in terms of affordable level of external inputs, vulnerability (wind, droughts, etc.), flow of income, food, storage, soil conservation, and of course fencing (see table 3). The role of live fences as an agro-ecosystem for small-scale farmers underlines the various potential uses for small-scale farmers (Figure 5).

4.1.2 What research and development activities exist?

Research: Knowledge of socio-economic aspects of hedgerow growing is limited, and general restricted to a few socio-economic factors. Information on the cultural context of hedgerow growing is very scarce. In studies (e.g. agroforestry) hedges are mentioned mainly peripherally, if at all. Reasons for this gap in our knowledge include:professionals usually lack the knowledge that matters to poor people; in the past social scientists were not concerned with forests and trees; anthropologists paid more attention to cultural aspects; researchers have emphasised the flows of fuel, fodder and other products rather than paying enough attention to the importance of hedges as assets to meet a contingency crisis and total impact on (poor) families;

In recent years there has been increased progress of farming systems research in related research methodologies. Apart from a better understanding of hedge in alley farming, due to various on-farm trials under the umbrella of farming system research, little effort has been devoted to the socio-economic context of hedgerow growing, particularly for the rural poor.

In the past, ITTA paid most attention to agronomic aspects of alley cropping. Today results of ILCA on-farm trials provide useful hints on how small-scale farmers perceive hedges, and that much research in the past has been outside the context of application of the small land users. CATIE's research program on living fences has included socio-economic issues (51).

On the cultural dimension of hedgerow growing some observations from Peru are available (83); a few detailed studies exist for Africa (e.g. 290, 179). Some of the studies with a more comprehensive view of the role of hedges for small-scale farmers have been compiled in case studies in Appendix 1.

Nutritional and other impacts of hedges particularly for the urban poor and landless have not been documented. Also historians and related professions have hardly thematized the history of hedges in the tropics.

Development: In development policy hedges are not seen or are taken for granted by all people concerned without receiving adequate recognition (22). Rural programs rarely allocate special funds and other resources to promotion of hedges for the poor (apart from alley cropping).

Project personal neglect hedgerows even when there is a great demand, instead they seem to resort to costly walls, fences or other solutions (22). Other projects promote a few well-known species, without bothering much on the socio-economic context. The potential role of hedges for the rural poor is rarely explicitly seen or articulated in development strategy (for a notable exception see 144).

4.1.3 Some stimuli for hedgerow growing

With the present underdeveloped state of knowledge on tropical hedges only hints of the evolution of hedgerow systems in the tropics and subtropics are available.

For several autochtonous social groups and societies hedges are a landscape constant and a way of life; they are a component of the heterogeneous, traditional mixed farm landscape. There is evidence that hedges already existed in the tropics in ancient times; for instance in Central America (167). *Erythrina spp.* was used by Aztecs in pre-Columbian times (214). In some parts of Africa, native people developed a sophisticated defence line consisting of impermeable hedgerows (272)

When European settlers migrated to the New World, they sometimes adapted hedgerow systems to the new tropical environment (182, 346). On the other hand there is enough evidence that hedgerow growing has been a vernacular effort by local people; it is not unlikely that these two traditions have influenced each other.

In semi-permanent and permanent land uses hedges have sometimes played a decisive role. Often hedges were originally pioneers in naturally open habitats. Such plants were preadapted to occupy agricultural clearings (318, 93).

Problems related to land management (fencing need, microclimate modification, erosion control, soil fertility maintenance, etc.) and decreasing free availability of forest products (fuel, fodder, fertiliser, etc.) seem to be the main reason for the evolution of hedges.

Deliberate retaining of vegetation strips - as practised in Mayan agriculture - may finally result in a hedge-like vegetation. In Peru frost and wind protection as well as need for fuel have been identified as a stimulus to hedgerow growing (34). In the hills of Nepal, land availability is very limited. Hence, farmers plant trees on the risers between successive terraces. If this is done very closely, a rather open hedgerow develops. In Pakistan and Nepal farmers and other people are strongly motivated to incorporate hedgerows in their farming systems; at least the most critical area, to have a protection against cattle and other animals (22).

When livestock was introduced by the Spanish and before the invention of barbed wire, cattle expansion in the 18th century was accompanied by live fence growing, like that reported in Cuba (77). Indeed some exotic trees like *Gliricidia sepium* were introduced into Caribbean countries for their excellent performance as live fences (131). Even in a situation of sufficient natural forest, hedges are planted because it was found convenient to have a food source near the dwelling; e.g. *Vernonia amygdalina* hedges (an excellent vegetable) are cultivated in Nigerian compounds for this purpose (403).

Whatever the specific history of hedges or hedge-related vegetation, it is important to investigate their genesis, to see if it is possible to build on existing traditions. This is a wiser policy than introducing something alien to a target group

4.1.4 Perspectives

Attitudes

In the same agro-ecological zone, some people may have a favourable attitude towards trees while others are apathetic.

In Peru live fences are not only regarded as a physical security hedge against man and animals but also against "magic spirits" ("seres malignos") (34). In Sonora/Mexico live fencerows were regarded by the farmers as a way to preserve, extend and fertilize their flood plains. As one farmer described: "The fencerow forms the land". This practice contrasts with the negative attitude of Anglo-Americans living in the same agro-ecological zone towards so-called phreatophyte plants.

Farmers also appreciate hedges because they harbour birds like Chajote (black birds), which eat insects and their larvae (251). Other people are discouraged from growing hedges because of the threat of pests and diseases being harboured by the hedges. In parts of Africa the method used to control tsetse flies has been to cut down the trees which harbour the insects.

Hedges may be seen as a symbol for backwardness (reinforced by modern agricultural education). In the UK, hedges have frequently been removed even when the farmers could not justify the action on economic grounds; e.g. hedgerows were sometimes removed not to facilitate mechanization or to effect changes in grazing management, but because they were viewed as a sign of backwardness (132).

Priorities

Table 25: Different perceptions of hedge uses between foresters and local people in the North East of Thailand

Issues	Villagers	Foresters
Problem perception	Food: priority need No fuelwood scarcity	Anticipated fuelwood shortage Need to reduce pressure on remaining natural forests
Role of hedges according to perceived priority	Vegetable	Fuelwood
Selection of variety	Local variety: exotic variety is refused in diet	Exotic variety for quick biomass for fuel
Synthesis of priorities	Local variety for vegetables at the front of the compound Exotic variety on the other borders of the compound for wood	

People who lived as forest "squatters" were persuaded to resettle in clusters in a forest reserve. Foresters selected giant Leucaena as the most suitable hedgeplant to produce fuel and wood rapidly around the houses, thus reducing pressure on the remaining natural forest. However, when the hedges grew to a harvestable age, local people were not satisfied. According to their view, the hedges were regarded primarily as a source of vegetables. Indeed, they called them edible hedges. They did not like the bitter taste of the newly-introduced exotic Leucaena (indeed, this can be related to the higher Mimosine content of Leucaena leucocephala). The outcome of a dialogue between foresters and villagers was a compromise par excellence between two different initial perspectives. Villagers agreed to planting vegetable hedges on the frontside of their homesteads and giant Leucaena on the other side (215).

The fact is often ignored that tree projects are more likely to succeed if the local priorities are taken into account, i.e. the local needs and ranking of these needs as seen by the people themselves. Resources are not simply physical facts, they must be identified and defined as resources by human beings. Bias in assessment includes identification of man's viewpoint, cash versus subsistence needs.

Only people sharing the same conceptual perception are able to define what is a need and what is a problem. This was experienced during the process of hedgerow promotion in a forestry project in the north-east of Thailand. Initially different perceptions of needs between foresters and villagers existed due to incorrect assumptions about the felt needs of villagers by foresters. Following up the local people's discontent with the variety chosen by the foresters finally resulted in a compromise par excellence.

Preferences

Various studies clearly demonstrate the preferences of local people for specific hedge plants, e.g. among small rangers. *Gliricidia sepium* is among the most popular in Central America as a living fence due to easy management and reproduction (291).

In Tabasco/Mexico farmers have preferences according to agro- ecological zones. *Gliricidia sepium Diphysa robinides* and *Tabebu sp.*are the prominent live fences (5).

In Burkina Faso people appreciate hedges as windbreaks, field borders, and barriers against livestock intrusion. They have welcomed the support of a development project for species like *Jatropha curcas*, due to their multipurpose economic value, but were not very enthusiastic about planting *Euphorbia balsamifera*, which, apart from fencing, does not have any significant value from their point of view (232).

The wide occurrence of very drought resistant *Jatropha curcas* is due to its drought and browse resistance (208). In Angola, it is sometimes cultivated as an enclosure plant because it is not attacked by termites (4).

Henna (*Lawsonia inermis*) is definitely a "women's" shrub. It is grown by women, e.g in East Africa, in the compounds (215a).

Knowledge

Rural people living a long time in the same ecological zone know their trees and soils; they are knowledgeable about and have preferences for different species according to the environmental conditions and purpose of hedgerows. There is ample evidence that skilled hedgers exist among rural people in developing countries, like among the Kikuyu in Kenya or Bamileke in Cameroon.

A worldwide survey on traditional microclimate management showed that farmers are aware of the microclimate effect of windbreaks (344).

Farmers in Costa Rica are frequently convinced of the importance of a waning ("meguante") moon in successful establishment of living fences of *Gliricidia sepium*. The idea of cutting with the moon phase has recently been confirmed, i.e. that if one has to leave the stakes for a period of 15 days, it is best to cut during the waning moon. However the results also indicate that the best technique is to plant immediately after cutting, independently of the moon phase (23). Farmers' preference for pruning in the dry seasons may be due to their practice of leaving cuttings for a period of time before planting, or due to the physiological state of the stakes (315).

4.1.5 Tenure

Marginal farmers who move on to steep slopes or logging areas are often there on an illegal or semi-legal basis, with a constant threat of expulsion (98). However, planting trees or border hedges is often regarded as a first step in requesting ownership; this is practised by squatters in the Philippines (274). In some Latin American urban shanty towns, people with no real security of tenure planting trees are almost performing a symbolic act of defence against an uncertain future (98). Sometimes landless people occupy small plots sufficient to allow a hedge and a few trees to be establishedan harvested quickly.

The apathy towards hedgerow planting in some parts of the West Indies was explained by the fact that there is not a felt need for barrier plants, because people think the law gives sufficient security (10). This is not a motive among the Bamileke in Cameroon because their user rights are clear to everybody (179).

In Western Kenya hedges are always judged by the location of the obligatory *Euphorbia tirucalli* hedge. To avoid boundary conflicts, one way is to plant trees that are as neutral as possible (little shade competition, etc.). The disadvantage is that only "useless trees" can be planted as in the case of the *Euphorbia tirucalli* hedge. This is a unique legal significance as boundary marker (303).

In some agricultural schemes, like the Gezira/Sudan, where no fixed tenancy exists and farmers have to rotate the plot each year, the growing of trees was prohibited by the agricultural administration. The tenants of the scheme use *Cajanus cajan* as an annual multipurpose windbreak. Outside the scheme farmers use *Cajanus cajan* for several years as a windbreak. This clearly shows that tenure influences the period of windbreak planting (215a).

Rights and cashability may be restricted with trees. People may be unwilling to plant a certain tree if it is on the list of officially protected species (381). This may be valid for hedges as well. On the other hand it may be the great advantage of hedges that often they are not perceived by planners (as trees or resources at all).

Although tree tenure is separable from land tenure, many obstacles prevent poor people without land from planting or owning trees. Proposals to permit landless poor people to grow trees on public and wastelands like roadsides, canal banks, and other common or government land faces bureaucratic and departmental problems like in India (68) or Nepal (122). If the trees are planted on a border between two farms, it has to be clear prior to planting whom the trees and the harvest rights belong to. This is true of communal land as well. In serial tenure, e.g control of land by an extended family or clan, user rights are individually given on a short term basis. The introduction of a hedge would be an affront (173)

4.1.6 Labour

Competitions: Hedge growing has to fit into the labour economy. In arid areas, tree planting often conflicts with regular farming activities. Often the planting season for both crops and trees lasts only a few weeks each year. Farmers choose to spend that critical period working on food crops rather than on trees (98).

Choosing species which can be planted in the dry season can solve the problem if no other work opportunities exist in the off-season. This has been attempted by a food-for-work program with cuttings from Jatropha curcas in Cape Verde (152).

Perceived costs: For the land users the perceived costs and benefits are the reference base, and not the strictly economic ones.

Division of labour: Understanding the division of labour by age and sex groups is important. In Nepal only men and in Pakistan men and women plant hedges (22). A conflict has been observed between men and women (subsistence versus cash crop trees).

In muslim countries fuel from and near the homestead is collected by women. Hedges which can produce fuel can reduce the burden of gathering for many hours. In some parts of Sudan women have their own garden next to the village. Often men are responsible for organising brushwood fences. When these sources cease free roaming animals impede the development of these gardens. One priority area in a farm forestry project is to support the development of fast-growing living fences (215a).

Labour economy: Often it is assumed that there is a surplus in labour in developing countries. However for small-scale farmers family labour may be a very scarce resource. Some hedgerow technologies like alley cropping may not be found attractive because they are too labour intensive.

In alley cropping one to three prunings may be needed per year; the labour input varies depending on pruning between 40 and 85 hours/ha per cutting (with a hedgerow spacing of 4 m). The implications can be:

- Adoption of the system where labour intensity is low will be difficult.
- Cost of production may increase considerably if the additional labour has to be hired or supplied from the family labour pool at peak labour times (169).

Pure economic arguments have to be interpreted in the specific context of small-scale farmers. A study of on-farm trials in alley cropping in the humid tropics found: labour is not a critical issue in the establishment of hedges. Clearing and land preparation have to be done whether or not trees are planted. Direct seeding of hedges is done after other operations. Thus there is a minimum of conflict with critical planting times. Weeding of hedges may be perceived as a labour problem because it falls outside the routine weeding calendar. Fortunately the demand is outside the peak period (351).

One problem in hedgerow research is that many studies start with agronomic aspects (e.g. how to increase the total biomass for soil fertility enhancement). The maximisation of biomass production from hedges may be meaningless for small-scale farmers. From a labour economy point of view higher total biomass produced from hedges has to be balanced with higher costs due to higher labour input for pruning. Species will be preferred which can yield the same amount of forage/mulch or fuel with less labour input or more for the same labour input.

Ease of management, particularly related to labour inputs for pruning and potential crop shading if pruning is delayed, are of primary concern for farmers. It is of little value to investigate various pruning regimes which attempt to maximize the amount of mulch produced, when under real farm conditions the time and frequency of pruning are determined rather rigidly by the need to minimize shading of the crop. Similarly the pruning height will more likely be determined by considerations of ease and speed than by pruning effects on regrowth and tree longevity (350). Given the low resource base of small-scale farmers and their priority interests, labour economy is of pivotal importance.

4.1.7 Contingencies

Poor people are very vulnerable to contingencies (unforeseen or foreseen). Trees may help to cope with contingency through direct uses (subsistence and consumption) and through their market value (sale or mortgage).

Hedges and hedge trees can be sources or recurrent flows of food, fodder, and other useful materials. When these flows are counter-seasonal they help households to get through the slack or lean months, e.g. *Ziziphus spp.* in India producing late in the dry season. This diminishes the danger of impoverishment through sale of assets food or through loss of livestock. After fire, flood, etc. there may also be a need for poles and timber for construction (68).

Planting and/or deliberately retaining trees is a common long term strategy for saving and security. In many countries people cut and sell trees for timber when money is required for weddings or a major cash outlay (129).

Farmers in north-east Thailand have incorporated cash trees like *Eucalyptus camaldulensis* into their hedges or allow a few *Leucaena leucocephala* to reach a size that allows it to be sold for poles, in case there is a contingency need (own observation).

As saving and security against contingencies for poor people, trees, and particular hedges have clear advantages over other types of assets due to their ecological and economic functions (summary see Table 26).

As a business, growing trees is cheap and has a trivial starting cost compared with jewellery, livestock or bank deposits. The cost of protection varies considerable and can be higher with hedges than other tree planting. One of the main advantages of hedges compared with other tree growing is that they may yield in a very short time.

High rates of interest combined with inflation often mean that savings deposits earn negative interest in real terms, where as most trees not only maintain or improve their value in inflation but also appreciate in value rapidly from a low starting investment cost. Hedge trees may fulfill this function for the poor. Hedges are unbeaten in regeneration due to their preferable harvesting technique: coppicing and pollarding.

Comparative disadvantages of trees concern property rights, cashability, marketing, and safety. Especially on state land property rights and cashability are restricted: Where hedges are not officially perceived as resources this may be less of a problem. No miracle can be expected from hedges on marginal sites, if the hedges are intensively exploited and all their products are exported from the site.

4.1.8 Social constraints

One major institutional obstacle is that hedges are either not seen by planners or that they are taken for granted by all people concerned without being given adequate recognition. Rural programs rarely allocate special funds and other resources. Project personnel have neglected hedgerows even when they are of critical importance (22).

Other constraints on hedgerow promotion are related to problems of land (availability, tenure). Negative attitudes towards trees can be based on traditional taboos and negative experiences. The disintegration of local institutions and the lack of efficient modern organizations makes it possible for wealthier individuals to exploit the common properties and hamper coordination of communal planting like windbreaks. At the same time resource-poor people may not be able to protect trees from animals. Labour considerations are closely related to this aspect. Hedgerow growing always implies an initial intensification of labour input. Scarcity of labour may be serious in areas of high temporary migration. In some arid regions, labour allocation for hedgeplants may conflict with the planting season.

Table 26: Some assets of the poor - a comparison of costs, risks, and benefits (60)

	Positive Values	Jewellery	Small stock	Land Deposit	Bank	Trees[a)]	Hedges
LOW COSTS	low unit starting costs	-	0	-/-	0	+	++
	low initial maintenance	+	-	-	++	+/-	+/=[b)]
	low permanent maintenance	+	-	-	++	+/-	+/[c)]
LOW RISKS	low vulnerability to disease accident damage drought	++	-	+	++	+/-	+/-
	theft	0	-	+	++	+/-	+/-
RIGHTS SECURE	Property rights and cashability assured	++	++	+	++	=/0[d)]	=/+[d)]
HIGH BENEFITS	Rises fast in value (appreciates, breeds, etc.)	0	+	+/0	.[e)]	++/0	++/0
	Stores well	++	-	+	++	++	++
	Easy to pledge, mortgage	++	0	+	()	+	+
	Provides flows of income, food, etc.	-	+	+	0	+	++[c)]
	Easy to transport	++	+	()	++	-/+[g)]	-/+[g)]
	Divisible/small units for sale	+/-	+	+/-	++	+	+
	Good price for small amount	0	+	0	++	+/-	+/-
	Steady price	+	+	+	(++)	+	+
	Avoids obvious distress sale	+	0	-	++	+	+
	Regenerates after disposal	-	-	-	+/-	++	++

++ strongly positive (good) - usually negative (bad) 0 more or less neutral
\+ usually positive (good) = strongly negative (bad)

Source: modified from (68)

a) refers to all trees including hedge trees;
b) may need more initial care compared with other tree planting;
c) this is highly variable, depending on type and intensity of uses, earlier and more freqent harvesting is a common feature of hedges;
d) complete freedom in cut and sell is exceptional where government regulations are involved. Hedges appears not to be perceived by government as trees;
e) it has been common that inflation exceeds the interest rates for savings bank accounts;
f) there are major differences between high rates of growth in the humid tropics, and slower rates in temperate climates and in the semi-arid and arid tropics;
g) depends on product (nuts, firewood, timber, etc.)

Furthermore, hedgerow growing often implies negotiations with neighbours on use and management. There may be several alternative approaches to resolving this question, but all parties involved should agree in advance as to how the situation will be handled (381).

These few examples are sufficient to demonstrate that it is very important to analyze socioeconomic potentials and constraints in a particular situation before growing hedgerows. What may be a constraint in one locality may be a potential promotion factor in another one.

Table 27: Checklist of sociological issues related to hedgerow promotion

Local equity:

- How can the poorer section be reached taking into account the concentration of power, resources, and biased delivery of government services in the hand of a minority?

Tenure:

- How does prevailing tenure (tree and land) affect hedgerow growing?
- Can medium and long term land and/or tree users' rights be assured; in particular for tenants and landless on state/communal lands?

Land use options:

- Are important land use options with and without hedges and the degree of problem solving according to ranking of priorities assessed from the point of view of target groups?

Labour:

- How does the division of labour (sex, age,etc.) influence hedge growing?
- A shortage of labour (competition for labour in more arid areas, off-farm needs etc.) hamper hedgerow growing?

Priorities:

- Does social perception differ among social groups?
- What are the priorities of target groups as seen by themselves and their ranking?

Decision making:

- How does the decision making process function at the local level with regard to land use planning, labour allocation?
- Who makes the actual decision with regard to expenditure at the household level (men/women/both)?

Individual v. communal strategies:

- What are the most appropriate forms of organisation of hedge growing (individuals, family, sex, peer groups, reciprocal/communal labour)?
- What are the pros and cons of communal or individual approach to hedgerow promotion in a specific local context?
- To what degree does common interest exist?
- Can the advantages of individual growing be combined with communal coordination and cooperation?

Local participation:

- How can the target groups be involved in the process of decision making with regard to identification of priorities and formulation of programs and their implementation in monitoring and evaluation?
- Are all planting materials promoted that are technically viable and wanted by local people?
- How much local knowledge is incorporated in hedgerow development?

Assessment of needs:

- Have essential needs (subsistence, cash assets and contingencies) and their ranking been assessed?
- How do hedges contribute to the solution of perceived problems?
- Can lower ranked priorites and needs (e.g. conservation) be incorporated as a by-product in high perceived aspirations and needs?

Organisation:

- Is there a need to restructure existing delivery systems in order to meet the institutional frame to reach the intended beneficiaries?
- Can non-Governmental organisations (NGOs) be involved in promotion of hedgerows?

Enforcement:

- How can local participation and plan formulation be assured for enforcement of those goals to promote appropriate hedgerow technolgies?
- What organisations are likely to be most capable of enforcing goals which are generally accepted?
- What is the local perception of costs (financial, time, labour, and other financial gains foregone and returns accrued by individual housholds or segments)?
- What distribution mechanisms can be explored to ensure that the benefits finally reach the target groups and remain with them?
- How efficient has this mechanism been in the past?

Cost, recovery, and welfare approach:

- Can a hedgerow activity be implemented if the resource-poor people are charged for material supplies etc; do they have the capacity to repay?

Government policy:

- What is government policy with regard to giving priority to basic need orient developement (land use policy, budget carry support, etc.).
- Do land use regulations (forestry laws etc.) allow freedom of cashability of hedges and trees for meeting contigencies?

Definition of success:

- For whom is hedgerow promotion succesful (project residents or a segment of them, nation, etc)?
- Who decides what is a success (target groups, project management, etc.)?
- What are pragmatic and relevant indicators of success (physical targets, allocation of resources to the poorer section, number of self-help schemes and finally hedgerows contribution to the capacity for self-sustainable development)?

Dissemination:

- How to disseminate the success of interesting hedgerow patterns?
- How document and share lessons learned from ongoing promotion schemes?
- Through what cummunications channels with what kind of media including traditional forms and channels of communication.

Research:

- How can local people, in particular those with relevant experience, best be incorporated in identification of research gaps, generation and valididation of hedgerow technologies?

4.2 Economics of hedgerow growing

This section deals with economic aspects in a more strict sense. Being aware of the difficulties of translating all benefits of hedges into economic quantificable data, it is nevertheless important to be able to perform comparative evaluations of land use with or without hedges.

4.2.1 State of knowledge

In large areas of developing countries the loss of trees is causing degradation of the natural resource base, posing severe problems for economic development. Today economists are attempting to translate the ecological effects of afforestation into economic terms. This is important to demonstrate how investments in the environment can benefit the economy as well.

Since hedges are not yet seen as a development potential by development planners (dominated by economists), little research and development activity has been devoted to economic aspects. Most "hard" economic data are available from analysis of alley cropping. Procedures for classical windbreaks and economic case studies are applicable to hedges as well (within their limits). Economic analysis of windbreaks appears to be very simple, because some linear correlation between wind protection and increase in agricultural and livestock activities can be observed (8). General problems related to evaluating ecological (long-term) effects are relevant to economic assessment of hedgerow growing as well.

4.2.2 A note on economic evaluation with regard to hedges

Within the limits of rigid economic evaluation a note on general considerations of economic evaluation of hedges is warranted. In an economic evaluation of hedgerow systems, the potential benefits and costs are quantified, valued and compared. For a proper economic assessment, each of the inputs, outputs, and residuals must be identified and valued. For some components, like the price of seedlings or labour, this is quite easy. For other aspects, valuation is more difficult (e.g., changed water run-off, soil erosion, or wildlife impact). Various techniques have been developed to evaluate this phenomenon and estimates are frequently used (372).

To understand better the variables and parameters and be able to make sensitive analysis, economic benefits of hedges can be broken down, e.g.:

- It has been suggested that the benefits of preventing decline in soil fertility be measured by comparing the net present value (NPV) of farming in the protected area with the NPV where decline in soil fertilty occurs.
- It as been suggested that the increase in soil fertility, e.g. as a result of improved moisture retention, nutrient recycling, be measured by the PV (present value) of the incremental effects of hedgerow growing on crop yield.
- The increase in the output of livestock products (as extra dry season fodder becomes available) is meassured by the PV of the incremental livestock production.
- The value of the tree products is estimated in the usual way by multiplying the volumes produced by the proceeds of the products and taking the PV.

The scope of the evaluation can reach from microlevel (farm field, single hedgerow) to regional (i.e., watershed). There are differences between economic and financial analysis; forestry (public tree planting) and farm forestry (private/local tree planting) (8).

The time scale is another important evaluation factor. Hedges have a great range of economic lifespan, from 1 year (if not properly managed) to more than 100 years, as observed in Cuba (77). The selection of the time scale is often an arbitrary decision.

For individual farms, local prices can be used; if the analysis is at the national level, either market prices or social (shadow) prices can be used (for more details see 339). Other costs do not have market prices. Costs and benefits may occur on- and off-site (sedimentation, erosion, etc.) (for techniques see 178).

To calculate the present value of the future monetary amount, discounting techniques are applied. The most common technique applied is the net-present-value (NPV). Long gestation periods make the present value of benefits very small in relation to capital costs. One problem with such calculation is that estimates of benefits are generally based on the current net value of outputs in agriculture and land (some inconsistencies are to discount the returns to such economically important activities (e.g. see 8). Sensitive analysis of critical parameters is also important.

In economic analysis it is often assumed that profits can be maximized in terms of land. However, the unit of success or failure is always the enterprise, not the field. It is of pivotal importance to examine the maximum return on the most limiting production factor. Various budget techniques (including multi budgeting) have been developed to compare diverse input/output ratios (e.g. 110). When labour is the limiting factor, returns on labour comprise the most important economic factor. For risk assessment, the portfolio theory has been suggested (36).

4.2.3 Hard economic data

Cost of hedges: The cost of hedgerow establishment has a great range depending on site, e.g. sloping, land preparation, cost of planting material ect. Direct seeding are many times cheaper then seedling esteblishment (one example see Table 28). For erosion control, living hedges were found to be 4.5 times cheaper than "diquettes" in Cape Verde (123).

Costs of barbed-wire fencing compared with live fences

For small-scale farmers barbed wire may not be affordable. Barbed-wire fences are on average around 400 % more expensive than live fences. The higher cost depends on many factors, e.g. cost of material, labour costs, etc. In Nepal barbed wire fencing was as much as 25 times of the costs of living fences (Table 29).

In browsing plantations, the cost of barbed fencing in Tunisia compared with a double-row, spiny cactus hedge is about 660 % higher. The drawback is the non-productive predevelopment period. Even taking this preinvestment period for living fences into account (2 years) a higher internal rate of return compared to barbed wire fencing was calculated for *Acacia senegal* plantations in Senegal.

Labour: One very important economic parameter is labour; it can be the limiting factor in introducing and expanding hedgerow systems. On the other hand in a situation of labour surplus small-scale farmers can avoid capital cost by investing labour in a hedge.

Labour input varies greatly depending on availability of planting materials (seeds, cuttings) reproduction methods applied, intra-row tree spacing, topography, soils, skills, etc. The small amount of data available indicates a range of 150-600 meters per man day; 100 meters of hedge may be established in between 1 hour and a full man day (compare Table 30).

In alley cropping the labour input can be very high (up to 320 hours) per hectare for establishment. Establishment and maintenance of live fences of *Gliricidia sepium* may be roughly 8 hours/year per 100 m, without weeding and one pruning.

In the management of alley cropping, labour utilization has important economic implications. The results of an experiment showed that pruning *Leucaena leucocephala* including chopping the stems (about 15,000 trees/ha) took 185 man hours (33.8 man days/ha).

Table 32 shows average labour inputs per seaon by treatment for the production of maize or cowpeas. Pruning of Leucaena in maize or cowpea cropping is considerable. Herbicide treatment, however reduced labour inputs by about 30 % per season (269).

Table 28: Comparison of establishment of 100 meters hedgerow by direct seeding and seedling in Thailand

	direct seedingd) in Baht	seedlingd) in Bath	cost increase f. seedling in percent
Labor	5.7a)	9.7a)	170
Material	4.0b)	500.0c)	12500
Total	9.7	509.7	5225

a) 4.5 Baht cost of labour/hour;
b) application of seeds; 10 Baht/kg seeds;
c) 250 seedlings; 2 Baht/seedling
d) 1 US $ = 22 Baht (1982)

Source: (215)

Table 29: Comparison of cost of living fences with barbed wire fencing per 100 meters+

Country	Barbed wire fence (BWF)		Live fence		Cost increase for BWF
1. Nepal+	L	250	L	10	2500 %
2. Tunisia*	US $	100	US $	15	660 %
3. Kurunegala/Sri Lanka+	Rs.	200	Rs.	50	400 %
4. Sudan/Senegal*	US $	112	US $	37	300 %
5. Somalia+	US $	60	US $	20	300 %
6. Timor/Indonesia+	US $	15	US $	7	214 %
7. Anuradhap./Sri Lanka+	Rs.	8000	Rs.	4000	200 %
8. Kenya+	US $	50	US $	30	167 %
Average cost increase for BWF[a)]					388 %

a) excluding Nepal, due to its exceptional increase

Source: * = (174); + = (329);

Table 30: Labour inputs for establishment of different hedges in workdays

Country/climate	Species	Range(average) per day (in m)		m/day	hour/ 100m	Source
SUPPORT WIRE*						
Cape Verde (arid)	Jatropha curcas	50-100 (75)	CU	150	4 h	(152)
Costa Rica (humid)	Gliricidia sepium	50-200(100)	CU	200	3 h	(20)
CLOSED HEDGE						
Haiti	div.spp.	two rows:300-900m	SE	600	1 h	
semihumid	div.spp.	one row: 600-900m	SE	750	0.8h	(406)
Mexico	Cordia dentada	125	SE	125	4.8h	(109)
Thailand (humid)	Leucaena leuc.	600	DS	600	1 h	(215)

*assuming 2 m intra-row spacing of hedge
CU= Cutting
SE= Seedling
DS= Direct seeding

Table 31: Establishment and maintenance costs of Gliricidia livepost-supported wire fence

Activities*	meters/day**	hours/100 m**
ESTABLISHMENT		
1. Preparation of stakes[a)]	300	2.0
2. digging holes/fixing wire[b)]	300	2.0
Subtotal	50	4.0
MAINTENANCE		
3. Pruning[c)]	150	4.0
4. (Weeding)[d)]	(400)	(1.5)
Subtotal without weeding		4.0
(Subtotal with weeding)		(5.5)
5. Total without weeding		8.0
6. (Total with weeding)		(9.5)

*the input of labour is very variable depending on density, skills, etc., following data are a rough estimation serving as a rule of thumb;
**33 trees per meter run;

a) range: 50-200 cuttings/day (20); average 100;
b) range: 50-200 cuttings/day (20); average 100;
c) 100-300 meters/day/pruning (20); average 150;
d) weeding done only by few agriculturists; range 300-500 meter/day (20); average 400;

Comparison of different methods of establishment

In certain situations, direct seeding is the cheapest and quickest way to start hedges. In Thailand it was found that seedling establishment is 52 times more expensive than direct seeding, when seedlings are purchased for a nominal sum from a nursery (215).

Direct seeding has to be weighed against the possibility of higher weeding costs. According to farmers, *Gliricidia sepium* living fences established from cuttings require little weeding. If there are strong arguments for establishing hedges with seedlings and transportation is a problem, stump cuttings or bareroot seedlings have to be considered as an alternative to container seedlings. A person can carry up to 700 stump cuttings and bareroot seedlings. Approximately twice as many stump cuttings can be planted per day as bareroot seedlings (267).

A transportation dilemma is often created by container seedlings commonly produced in heavy bags. An ordinary pick up truck can carry only 250 seedlings. Hence a project in Haiti decided to produce small container seedlings. A pick up can transport 20,000 seedlings. Furthermore, the peasant can carry over 500 transplantable seedlings as opposed to five or six seedlings in heavier containers per day (250).

Table 32: Average labour inputs per season by treatment for maize or cowpeas in alley cropping in Nigeria (269)

	Labour input for maize			*Labour input for cowpeas*		
	Man-hours/ha	*Increase over control*		*Man-hours/ha*	*Increase over control*	
		Man-hours/ha	*%*		*Man-hours/ha*	*%*
Control	492	—	—	442	—	—
Nitrogen	538	46	9·3	—	—	—
Herbicide	319	−173	−35	321	−121	−27
Herbicide–nitrogen	365	−127	−26	—	—	—
Leucaena	751	259	52	565	123	28
Leucaena–nitrogen	794	302	61	—	—	—
Leucaena–herbicide	644	152	31	505	63	14
Leucaena–nitrogen–herbicide	691	199	40	—	—	—

Table 33: The economic contribution of various treatments in agro-economic alley cropping experiments in Nigeria (269)

Treatment	*1981 maize–maize*			*1982 maize–cowpea*				
	Net returns US$/ha	*Marginal rate of return/ha*	*Benefit–cost ratio/ha*	*Net returns US$/ha*	*Marginal rate* of return/ha*		*Benefit–cost ratio/ha*	
					subsidized	*unsubsidized*	*subsidized*	*unsubsidized*
Control	−438	—	—	491	—	—	1·50	1·39
Nitrogen	−371	loss	0·79	669	8·60	1·69 (2·90)	1·72	1·49
Herbicide	480	—	1·18	650	2·23	2·60 (1·25)	1·65	1·51
Herbicide–nitrogen	146	—	1·1	992	10·0	3·90 (3·10)	2·04	1·76
Leucaena	496	2·33	1·32	396	−0·21	−0·21 (1·58)	1·31	1·23
Leucaena–nitrogen	130	1·56	1·05	302	−0·23	0·34 (1·16)	1·29	1·17
Leucaena–herbicide	139	1·97	1·07	765	0·43	0·63 (2·81)	1·49	1·44
Leucaena–nitrogen–herbicide	−58	loss	0·97	1 108	1·30	1·01 (2·80)	1·76	1·59

* Figures in parentheses represent marginal rate of return from 1982 first-season maize alone.
In 1981/82 farmers in Nigeria received 75 % subsidy on fertilizers and the price was 13·5 US$/50 kg of nitrogenous fertilizers.

The economic impact of hedges on mechanization

Hedgerows restrict the use of large machines: the advantages to the arable farmer of enlarging fields by removal of hedges have been studied at Cambridge. One of these concerns the problem of turning in tractor cultivation.

If two adjacent arable fields are separated by a hedge the number of turns needed to plough both of them is 28, but without hedges the figure is reduced to 20, which is a saving of 29 % in fuel costs and the tractor driver's time. The real situation can be more complex (93).

Generally poor farmers do not have access to tractors. On marginal and/or steep slopes mechanisation is limited. However in some regions like the north-east of Thailand even the very poor land users take the service of the tractor landlords. This indeed was identified as one constraint on hedgerow intercropping (215).

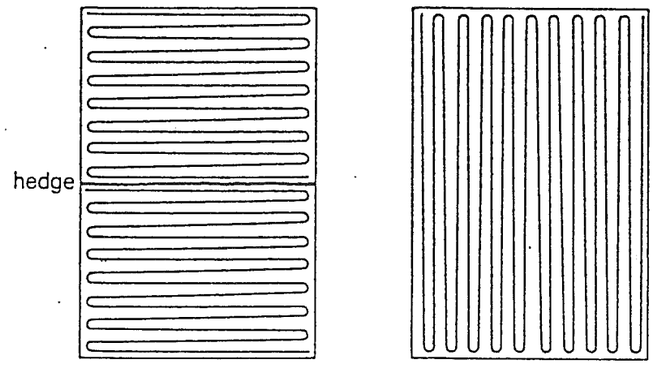


Figure 46: The effect of hedges on the number of tractor turns in cultivating a field (93)

Cost-benefit analysis

This kind of analysis can only simplify complex ecological and economic situations - most data is available from alley cropping and windbreak projects.

HOEKSTRA (170), comparing a maize/bean with a Leucaena alley cropping system, concluded that while the Leucaena alley system showed a negative balance in the first year, labour decreased and net revenue flow increased after the initial period. This reduction in labour is mainly caused by the great reduction in labour needs for field preparation and weeding, because only half of the area is cultivated. Furthermore, lopping of hedgerows, which requires additional labour, occurs during a period when demand on labour for other tasks is low. Hence, overall labour input and draught animals are used to greater benefit in the Leucaena hedgerow intercropping system than in the traditional cropping system.

Comparing direct seeding and seedling establishment in Thailand, it was found that only direct seeding has a favourable NPV (215) (see also Table 28). This clearly shows that in dense inter- and intra-hedgerows seedling spacing methods may not be economical. Consequently, in Rwanda it was not recommended (298).

An assessment of the economic impacts on labour utilization for the management of the Leucaena hedgerows, on crop yields and the overall benefits from alley cropping of Leucaena trees noted an increase in labour requirements by about 50 % and an attractive net income and marginal rate of return per unit costs. It has a reasonable benefit-cost ratio of 1.23 to 1.32 (269).

In all analyses Leucaena treatments gave the highest economic returns. This was followed by herbicide which has a higher net income than Leucaena-herbicides. In the second season all treatments suffered due to severe drought. But the Leucaena treatment suffered only 6 % loss. In the second season the Leucaena-nitrogen-herbicide treatment gave the highest net return in absolute terms, followed by the herbicide-nitrogen treatment, then the Leucaena-herbicide treatment. However, the herbicide-nitrogen treatments and treatment with herbicide alone have highest marginal rates of return.

Considering the benefit-cost ratio, the herbicide-nitrogen treatment again has the highest ratio, followed by that of Leucaena-nitrogen-herbicide. The Leucaena treatment gave a negative marginal rate of return per additional unit cost per hectare based on maize and cowpea crops. But for maize alone it yielded a relatively high marginal rate of return.

When costs of fertilizer are calculated at subsidised prices, the combination of herbicides-nitrogen gives the highest marginal rate of return. Generally the three economic indicators show that with a crop sequence of maize-maize, the Leucaena treatment gives the best economic return (269).

The results of this agro-economic experiments indicate:

- Maize-Leucaena alley cropping system can give high maize yields without nitrogenous fertilizer. The use of nitrogen fertilizer (at full rate) with Leucaena (even at subsidised prices) seems to be an economic waste.
- Although Leucaena stands occupy about 20 % of the land and the cutting and pruning of Leucaena increases labour costs by about 52 %, the economic contribution of Leucaena is greater than those of Leucaena-nitrogen, herbicide-nitrogen or herbicide (Tables 30 and 31).
- The highest level of technological input, Leucaena-nitrogen-herbicides, has on average the highest physical increase of 90 % on maize yields followed by Leucaena-herbicide and Leucaena (around 70 %). However its economic contributions are not necessarily better than those of herbicide-nitrogen or those of Leucaena-herbicide.
- With a crop sequence of maize-maize, Leucaena has the best economic return, followed by herbicide-nitrogen and Leucaena-herbicide. For the crop sequence of maize-cowpea, herbicide-nitrogen gave the best economic returns followed by Leucaena-herbicide (the depressing effect of Leucaena on cowpea yield needs further investigation).

In all cases the Leucaena treatment gave better economic contributions than Leucaena-nitrogen plots. Alley cropping, therefore, appears to be a good land conservation system. With the availability of subsidies on fertilizer and herbicides the system may be less attractive. (269). From a risk point of view, it can be argued that in areas where hedges are used for low-input, medium-output farming, the additional advantage is that high capital investment (i.e., loans for fertilizer) can be reduced. In the event of crop failure, which is common in rain-fed fields with erratic rainfall, the farmer does not fall into the debt trap so easily.

Micro-economic analyses are meaningless if they are outside the context of the land manager. This was also learned from an on-farm livestock trial. The management goal of herders was dry-seaon survival and not increasing the productivity of the most productive and valuable animals as assumed in the on-station trial. Hence the whole herd was supplemented with high-value dry-season animal feed from a fodder bank. Re-evaluation of this system showed that it gave the higher internal rate of return, despite lower eventual net income (260).

Hedgerow growing as an erosion control measure involves costs for establishment and often the loss of cropping area at least during the initial phase. Soil conservation measures which increase the farmers' income and reduce their risk by diversification have a great chance of adaption by farmers. In Thailand an economic cost-benefit analysis of a land-use system consisting of lac lice (*Laciser lacca*) raising on pigeon peas (*Cajanus cajan*) planted on contour bunds showed, that even evaluating only direct aspects (not reducing top soil), the loss of cropping area is more than compensated for the return from the new systems consisting of stick-lack and pigeon pea (348). Hedges can also play an interesting role in the generation of new employment opportunities. In the Philippines it was noted that selling forage for leaf meal during one of the two cropping seasons provided employment for 40 working days per year (365).

5 APPROPRIATE SPECIES

We have run into a snag: "Our mixture at present consists of a haphazard mix of Azadirachta indica, Cajanus cajan, Calliandra calothyrsus, Crotalaria juncea, Gliricidia sepium, Leucaena leucocephala, Sesbania roxburghii, Sesbania rostrata. In the future this makeup and ratio will be decided by the farmers themselves. We are presently asking them which species they prefer and would recommend for their area. ... We are presently learning the mistake of planting monospecific stands of Leucaena, because the psyllid insect (Heterophylla incisa) devasting Leucaena in Asia. ... Now is the time to diversify these benefits, but nutritional and economic benefits as well. Perhaps in the not-so-far future Thai farmers will walk their hedgerows for a handful of Leucaena for the pig, a spray of Gliricidia flowers to mix with a Cajanus stew to go with their sticky rice and a sprig of Azadirachta to keep the bugs out of his rice." (Taylor 353).

This statement above reflects well the state of knowledge on tropical hedges and the vision of future work. Species selection is not a "precise science"; it relies largely upon personal knowledge and judgement. The evaluation of species depends on the conceptual perception.

Chapter 5 focuses on selection and evaluation of trees and shrubs suitable for hedges. Some grasses are also mentioned. A summary of the state of knowledge on species including references and pros and cons of exotic species is made. Species selection, including methodology, general criteria for selection, hedge and hedge trees specifically are discussed. A note on elements in the design of hedgerows and simplified pathways in hedgerow species screening and testing is included as well.

5.1 State of knowledge on species

5.1.1 Hedges are not a research priority

No worldwide survey has been undertaken to define, identify, and characterise hedge plants that are currently widely used and indigenous species with potential as hedge and hedge trees. Some tentative work in this direction has been done by the author. A survey, and a literature and data bank search revealed that many trees and shrubs are actually used by local people or have a potential for hedgerow growing.

More than 1,000 woody species can be or are actually used as hedges (more details see 218 a). With the aid of checklists and data on suitable species, readers can start their own screening. With the progress in our present knowledge, a master list of the most important species can be made. Most of these species suitable for hedges have received little or no attention from research and development organisations in the past. Recent focus is on a limited number of species, planted mainly in monoculture.

There is sufficient information on hedge plants for temperate (see e.g. 44, 189, 337) and less for arid and semi-arid zones (see e.g. reference in 94). However, the state of knowledge is biased to the needs of industrialised countries, underlining either decorative qualities (94) or timber/fuel and recently conservation purposes (44, 189, 249).

There is a great lack of knowledge about production data and plant associations. In the long run it is not sufficient to say, for example, which is a fast-growing plant suitable for producing fuel, fodder, etc., although in the present underdeveloped state of knowledge hedgerow research is an important first step.

Progress with the database of biophysical features of plants poses fewer problems. For some genera like *Acacia spp., Parkia spp., Prosopis spp.* (64), and species like *Erythrina spp., Gliricidia sepium,* and some *Leucaena spp.* valuable information exists. Most research is available on living-fence supports for wire, some prominent alley cropping trees and shrubs, windbreak species and some well documented or researched multipurpose species, like *Calliandra callothyrsus,, Gliricidia sepium, Leucaena spp., Sesbania spp.*

Neglect: Lack of information is partially due to ignorance, neglect or underestimation of the potential role hedge plants play and can play for the poor in developed countries. The consequence is that hedges are not a research priority (e.g. ICRAF has not given top priority to hedges). Even in some otherwise very valuable references - e.g. 242, 366 - only a few hedge species are mentioned. There is a great discrepancy between stating the great importance of hedges, and consequences in species selection programs for rural development (an example see 366).

Species selection is not a "precise science"; it largely relies upon personal knowledge, judgement, and experience augmented by literature (38). Part of the dilemma is that foresters (with a biased qualification towards industry and natural sciences) dominate research. Gardeners and anthropologists are of equal importance.

5.1.2 Scattered information sources

References: One of the problems of describing lesser known species is that published information about their requirements and performances is scarce (366). References on hedges with regard to developing countries are widely scattered in literature and data banks. The role of hedges for a small farmer and other resource-poor people is virtually non-existent. Most complete surveys (e.g. 165, 166) are biased towards industrial countries' needs. HOWES' review (177) of barrier plants is still one of the more comprehensive references. Wickens (Royal Botanic Gardens, Kew/London) has started a small informal hedgerow survey (390).

Country surveys are rare. The only comprehensive survey has been completed for South Africa, which identified more than 400 barrier plants in use (165) and for southern Africa (166). On living fences older surveys exist for Costa Rica (318) and Cuba (77) and a tentative one for Mexico (316). A comprehensive list of genera of a family is lacking. An exception is one for the family Cactaceae suitable for hedges (160).

CATIE, leading authority on living fence posts supporting wire, has identified more than 90 species for this purpose (51). SEPASAT's data bank includes hedgerow entries, and is very useful for arid zones (328). The ICRAF multipurpose tree data bank (reference e.g. 64) may become a most important source for hedge plants (with some small amendments). Within agroforestry inventories by ICRAF some references are made to hedge plants. Other useful sources with a relevance for hedge information include scattered working papers and manuals; e.g. for Kenya (356), or Peru (34), or arid zones (381). On conventional windbreaks there is a wealth of information sources (see under 3.10).

5.1.3 Development projects promote a few well-known species

A global survey on tropical and subtropical hedgeplants (218a) revealed that there is an immense discrepancy between general interest in the promotion of hedges at project level and demand from field personal for exact database material for various species. Consequently only a few species are promoted, like *Gliricidia sepium* and *Leucaena leucocephala.*

Problems relating to this narrow species base are articulated by some project personnel (353). It seems that in rural areas where people are in closer contact with the indigenous flora (165), and a project has not successfully introduced exotic species, diverse local species are used.

Exotic species: A small number of exotic woody species are now a component of rural and urban ecosystems. More species may be introduced, but caution is needed to avoid failure and undesirable effects (238). The preference for exotic plants is not a surprise because there has been little serious investigation into the propagation, cultivation, and utilization of indigenous plants apart from the mostly shiny ornamental hedgeplants (165).

The great demand for fast growing and highly adaptable species in many development projects focuses the attention of development agencies mainly on the few well known (tried or assumed tested) exotic species. This reflects the need of experts to achieve physical results within the project period.

The best documented survey - conducted in South Africa - revealed that 60 % are exotic and 26 % of these exotics are invasive in some part of South Africa (165).

An increasing awareness of the potential of hedges among implementing organisations coupled with successful networking, can have the result that a few prominent species are quickly diffused (seed exchange, etc.). It is foreseeable that this trend will accelerate if drastic restrictions in fund allocation are not made immediately in favour of native vegetation.

5.1.4 Need for species diversification

Urgent need

Hedge plants are often fast growing pioneers with aggressive and invasive potential if not controlled. They may threaten the pasture, fields, and the indigenous flora (165).

Attention has to be drawn to potentially undesirable characteristics of some species. Fast growing aggressive woody perennials are often important where there is a serious fuelwood shortage or erosion problems. However, under some environmental conditions these species have the potential to be invasive and to spread into areas where they are not wanted (38).

Introduced hedges which are known as a pest in some countries include *Acacia armata, Acacia saligna, Lantana camara,* and *Opuntia spp.* to name a few (165). Other hedges are difficult to keep within bounds. Due to their habit of spreading spontaneously and thus of becoming a nuisance in some localities, the advantages have to be weighed prior to their introduction (94).

The recent problem of the attack on *Leucaena leucocephala* by psyllid insects (*Heterophylla inisca*) has demonstrated the great danger of focussing on a few exotic species. These problems seem to stimulate some projects to utilize other species but to avoid monoculture this time (353). This reorientation fits in well with the multiple use strategy of small-scale farmers and poor people.

Arguments for local species first

It is high time to broaden the range of native plants available for various uses in different parts of the developing countries. Priority should be given to them because

- this involves less risk (at least ecological);
- they have been shown to grow and yield under the prevailing (often harsh) site conditions (on a large scale and over longer periods than in any trial plots);
- planting material is readily available;
- and native plants maintain and improve the indigenous vegetation of the home region.

Above all the full use (or use potential) of many local plants is not yet sufficiently recorded. For example at present professional foresters in Central America concentrate only on *Leucaena leucocephala* largely through ignorance and convenience. It is well-known, published and promoted, and seed is readily available from national seed banks. Local Leucaena species such as *L. salvadorensis* are little known, often rare and with no seed available. In great contrast villagers distinguish these lesser-known species readily, know their qualities and the value of their products, often scorning cultivated *L. leucocephala* as inferior in wood quality (178a). It may well be that the replacement of today's weedy species by exotics will result in a great disaster for the survival of man and livestock in an area (238). Many hedge plants are weedy from an industrial point of view, but a valuable resource for the poor l

5.1.5 Summary-sheet

Highlights

- The problem of selecting tree species for non industrial uses in developing countries has been made more difficult because of the recent world awareness of the importance of trees and the pressure to achieve useful results quickly.
- Reliable information on many potential hedge species is still unavailable. There is a need to clarify the taxonomy with regard to species and related genera and expand research on reproductive biology.
- Typically, emphasis is still given to fast growing trees, but as more detailed knowledge becomes available it may be possible to trade-off species with rapid growth for those with slower growth but which have greater resistance to drought, pests, lesser water and nutrient requirements.
- The strong belief by some environmental groups that only native trees should be planted is understandable in the context that exotic trees planted for industrial purpose can be a threat for both people and the environment.

Lessons learned

Criticism of exotic trees may be justified when a poorly adapted species has been used for large scale planting. Tree history has taught that in many parts of the world the most important species were exotics (38). This has been based on long trial and error by local people. Promotion of untested (long-term) exotic species while ignoring the native vegetation may be fatal.

5.2 Evaluation of trees and shrubs suitable for hedges

5.2.1 Note on methodology for selection and evaluation of trees and shrubs

As noted before there is no precise science of species evaluation and selection. A resource does not exist per se, but has to be evaluated within a given context. Methodologies for evaluating tree resources are faced by the problem that decisions are made on the basis of assumed needs and benefits for the poor and the future. If the starting point for the screening of trees is dedicated to resource-poor people, the following steps may be considered (sophisticated methodologies exist, e.g. diagnosis and design, farming systems research, etc.).

Within a participatory action research the following procedure may be considered:

- identification of need/land management problems,
- evaluation criteria of species development and/or adjustment to specific context of specific target groups,
- screening of species (by local people and tree expert using preferably the same criteria),
- testing of species and evaluation of species.

One of the greatest challenges in a development project is how to identify quickly the perspective of the poor local people. Various quick appraisal methods exist; with regard to the perception and taxonomy of trees; the Repertory Grid has been applied (215). As long as the definition of problems and solutions is made on the basis of assumed needs and problems by an outsider, the risk of the solutions being of little value for the poor exists.

Once the problems are defined, the next logical question is how trees in general and hedges in particular can help to meet demand and solve problems. If this is likely, criteria have to be found on how to screen species.

At local level, existing hedgerow and related practices can be evaluated, while tree experts can evaluate the whole range of potential species.

It is now assumed that a tree species has been found that seems well adapted to thrive at the locality in question and within the particular ecological conditions. Further it can be expected that the species will yield one or more of the benefits which the small-scale land user will be wanting from a tree, and with a preferred form of management. How shall we now be able to evaluate the suitability and usefulness of such a tree, comparing it with other possible "candidates". Obviously it will not be enough to state, for example, that this is a fast growing tree producing excellent fuel and poles.

The preparation of a more comprehensive cost-benefit analysis will be required. As a kind of check list for such a calculation the balance sheet can be used indicating fundamental "credits" and "debits" which have to be taken into consideration (example see 292).Specific biophysical and sociological as well as species data sheets are given in this book. For developing and/or adjusting checklists the following more general list of criteria may be useful.

5.2.2 General criteria for selecting trees and shrubs

The selected hedge plants have to fulfill the functional requirements of the intended systems, i.e. specific productive and protective roles. It is the socio-economic and cultural context which ultimately determines the choice of species.

The value of a plant that is not accepted by the beneficiaries is zero. Hence, a qualified hedge plant is one that contributes to problem solving and/or enhancing the quality of life. Clearly stated objectives (as an outcome of a dialogue with local people) and understanding of socio-economic, staff and time-frame constraints have to be carefully analysed and documented.

A wide array of species, particularly multipurpose woody plants, are very suitable as hedges for poor land users. Only those trees and shrubs should be promoted which:

- contribute to solving problems (demand-oriented);
- are adapted to site conditions (climate, soils, etc.);
- can supply value products and/or protect the environment;
- will contribute to reducing risks in land use and do not cause new risks to themselves;
- can be managed with a technology which is affordable by the beneficiaries;
- are compatible with other land uses;
- are compatible with the socio-cultural tradition.

Special attention has to be given to extreme environments (e.g. poor farmers on difficult soils). Hence, priority should be given to plants capable of growing under extreme conditions including arid and humid tropical zones, infertile soils, heavy clays, saline, highly alkaline or waterlogged sites or exposed coastal situations.

Precedence should be given to native, culturally-known and accepted species. Both native trees and previously introduced exotic species should be carefully examined.

5.2.3 Hedge-specific criteria for choosing suitable trees and shrubs for hedges

A general feature of hedge plants is that they are easy to manipulate in shape. Selecting plants with desired biophysical features helps to achieve management goals. It is important to consider physical features like growth form (woody, shrubs, succulents, trees, climbers), morphology of stem, branches, foliage, armature, biological, and amenity features (next table provides a checklist of important biophysical features).

In addition to general criteria for selection trees and shrubs preferably used as hedges should possess the following features:

- easy and safe to establish by direct seeding or cuttings;
- planting material is available;
- have a long life span;
- have a tendency to make new growth near the ground, but not to sucker freely;
- withstand frequent prunings (trimming, coppicing, pollarding, loppping);
- be pest and disease free and non-invasive;
- do not adversely affect buildings, roads, and other land uses.

Particularly for small-scale farmers and small-scale gardeners the hedge species should also provide a quick/permanent and diversified yield; be usable to meet contingency needs. Most of the species do not possess all the qualifications. Nevertheless, they form useful hedges.

5.2.4 Which live form of a hedge plant?

Generally hedges are dominated by trees and shrubs and consequently this is the main theme of the book. However other plants, like grasses, are important as well. Graminacea used as hedge include *Adropogan spp., A. squarrosois, Arundo spp., A. donax L., A. gallica, Miscanthus fuscus (Roxb.)Benth., Pennisetum spp., Saccharum spontaneum var. aegyptiacum, Vetiveria zizanioides (L.)Nash* (151a, 280, 328). Bamboos are giant arborescent grasses which have a shrub-like or tree-like habit. They are part of the grass subfamily Bambusoidae (225a). In this book they are included under trees and shrubs.

Table 34: Checklist of biophysical features of plants suitable for hedge growing

PHYSICAL FEATURES	BIOLOGICAL FEATURES
Growth form	disease and pest free
woody shrub	non invasive/aggressive
succulents	(non) poisonous,(non) irritant
tree	wind/salt spray tolerant
climber	frost hardy
	fire resistant
Morphology	resistant to trampling/browsing
	attractive foliage, flowers
Stem	
single stemmed	*Reproduction*
multi-stemmed from the base	easy propagation
	responds well to cutting
Branches	easy regeneration when damaged
low-branching	little maintenance care required
sturdy	
dense branching	*Hedge plant association*
rigid or entangling branches	suitable
	limitations
Armature	
spines, prickles, thorns	*Interference with crops*
	resource sharing
Structure	tap root
framework	competition
tall/small filler	
entangler	*Biomass*
	quick growth
Height	longevity/permanence
minimum	high total biomass
low growing tree	degree of decomposition (C-N ratio)
spreading crown	N-fixation
homogeneous	
Foliage	*Hedge manipulation*
small sparsely distributed leaves	coppicing
(cast little shade)	pollarding/lopping
dense foliage	trimming
loosely arranged branchlets	
permeable/impermeable	

Tree or shrub?

The natural growth habit has to be understood when designing a hedgerow system. This is of paramount importance when only limited space is available and a more formal hedge is wanted. The growth form plays a significant role in hedgerow planting and shaping. It depends mainly of the branchsystem of the woody plant if and to what degree a tree or shrub is suited for a hedge.

A tree is not a hedge tree, but in a hedge it will become a hedge tree. What are the advantages of integrating a tree into a hedge? To answer this, a distinction is first of all made between trees and shrubs before the pros and cons of hedgerow trees are outlined (for illustration see Figures 47 and 48).

Shrubs are perennial plants which bear several woody stems near ground level. A mature shrub may be very small or as tall as 5-6 meters, depending on the variety. Most trees bear only one woody stem at the ground level. A mature tree may be small or tall.

The dividing line between trees and shrubs is not very clear-cut. Several shrubs may grow as small trees (168). Trees are characterised throug a so-called acrotone canopy structure, i.e. the crown develops from the terminal bud with only one or several life-long lasting trunks. These trees are only limited for nature hedges (apart from hedge trees), but good for formal hedges. Steadily pruning induces a rich branching and a shrub-like crown. This is valied only for those species which pocess without a fine and rich branching habit. Shrubs are basitone and mesotone during their whole life. Shrubs form a head of branches near the ground. There is however a considerable variation in the mode of growth among shrubs (see Figure 47) (281a).

The mature height is important when natural hedges are grown. Height can differ markly, e.g. Balanites aegyptiaca will reach a height of 7 to 8 m with 150 mm annual rainfall, and with 500 mm rainfall it can reach 20 m (153a). Irrespective of the life form, hedge trees when trimmed are not regarded as hedge trees.

The difference between climbers and shrubs is not simple. Some true climbers are often used as ground cover and some true shrubs are commonly grown up trellis work (168). Since some species can be both small trees (single stemmed) or shrubs (multistemmed near the ground) this has been noted whenever information was available (Table 50).

Many problems associated with hedgerow trees can be overcome by appropriate management and the right choice of species and location (see below). Species with a deep tap root cause fewer problems to agricultural crops. Root development can be controlled to a certain degree. The problem of shading can be minimised by limiting trees to two or three per hectare or by increasing field size (20 ha) (44).

For stockproof hedges only shrubs and low-growing trees should be considered. Excluding trees with a wide canopy is important, because under the umbrella of the leaves plant growth can be weak.

Hedgerow trees can be a very valuable timber source, as the trees grow more suitably for the purpose in isolation than in close company with their fellows. A solitary hedge tree needs regular management. Fuel and fodder obtained in this process are essential for poor land users.

5.2.5 Biophysical characteristics have to be matched to the main purpose(s) of the hedge

Biophysical characteristics have to be matched to the main purpose of the hedge (checklist see Table 35) (for more details see under specific uses, Chapter 3).

Categories

Garden hedges are often decorative plants to mark off garden areas. Plants should be woody shrubs or succulents with a multistem from the base or low branching; they should have a dense foliage and closely arranged branchlets. They should not be too thorny or difficult to clip, nor poisonous or irritant. Attractive foliage, flowers and fruits may be important to attract bees and butterflies (165).

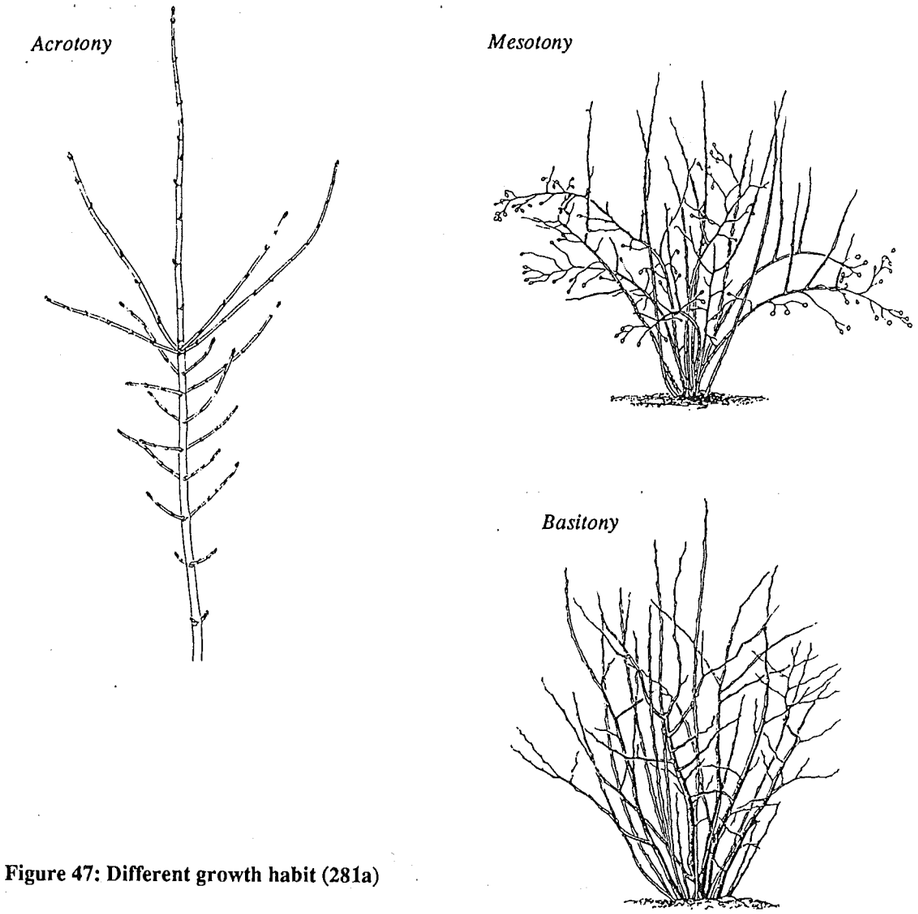


Figure 47: Different growth habit (281a)

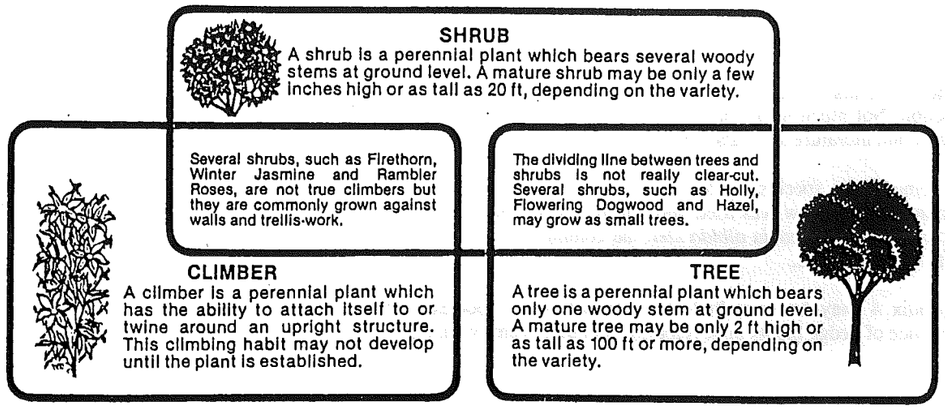


Figure 48 Differences between trees, shrubs, and climbers (168)

Wind (and frost) break: Windbreaks should be woody shrubs or trees with low branching and dense evergreen foliage. Their structure should be permeable and homogeneous with a certain minimum height. Barriers for frost protection, by contrast, have to be impermeable. Tolerance to wind and in coastal areas to salt spray is important as well.

Security hedges prevent the passage of man and/or animals. They should be woody or succulent shrubs or low growing trees which are sturdy, multi-stemmed from the base or low branching, dense-branching, with entangling branches or a spreading crown with spines prickles, thorns. They should be resistant to fire, trampling, and browsing. Security hedges should require little maintenance cost. Their capacity for regeneration of damaged hedges has to be possible. Irritant action in the form of stinging hairs, latex, etc. can reinforce the barrier function (165).

Others: Hedges with the main aim of providing fertiliser like alley cropping should withstand frequent cutting and have to be compatible with cropping systems (resource sharing and not competition). They should develop a deep tap root and not cast too much shade (for more details see under specific uses and summary under technical aspects).

Combination of functions

There is a need, particularly for poor people, to combine various functions. Multiple uses are essential for them. Generally, no single hedge plant can fulfill all the requirements. Mixed planting may be more limited where a homogeneous structure is needed (windbreaks). For security hedges and nature conservation there is no restriction. Any plant that contributes to the permanence and impermeability of the barrier is welcome in a security hedge (see also Table 10).

For security hedges the following types of plants can be distinguished:

- framework,
- fillers (short and tall),
- entanglers.

Framework is the trunk and the main branches of a tree and shrub with the basic structure that gives it its shape. Fillers: Short fillers close the gaps between the ground and the lowermost branches of the framework plants. They should have rigid main branches and be tolerant of shade. Tall fillers fill gaps in and add height to the barrier. They should have many branches but cast little shade. Entanglers are plants which will thicken up the barrier for a while and add to the difficulty of penetration; suitable plants are prickly climbers which do not cast much shade (165).

There are few ideal framework plants. To fill gaps in or to strengthen impenetrable barrier fillers and entanglers and irritants may have to be incorporated.

5.2.6 Explanatory comments on the use of Appendix 4 which may be consulted as an aid to hedge-plant selection

Some explanatory notes are given here on the use of the tables which may be consulted as an aid to hedge plant selection. Not much information that was comprehensive or fully applicable in all cases was obtained from a survey, and literature and databank searches.

For some of the species e.g for *Flemingia macrophylla (Willd.) Merr.* the accepted nomenclature by Royaal Botanic Gardens/Kew was used and not the widley used synonym *Flemingia contesta Roxb. ex Ait.f.* For other species, particular *Acacia albida Del.* the common known name, even now obsolete and not *Faidherbia albida (Del) A. chev.*is used.

Appendix 4 may be consulted for information on species. Table 46 indicates examples of geographical occurance of hedge plants in developing countries. Family names are listed in Table 47.

Table 35: Checklist of principal features for design of various hedgerow systems

Main purpose n ons	Wind- Soil break	Frost protect.	Garden hedge	Security hedge	Fertilisatio	c
Growth form:						
tree	x	x				
shrub	x	x	x	x		
climber				x		
Morphology:						
multi-stemmed from base	x	x				
or low branches	x	x				
sufficient height	x	x				
homogeneous height	x	x				
evergreen foliage	x	x				
impermeable		x		x		
permeable	x					
thorns,prickles				x		
Biology:						
irritant				x		
browse resistant				x		
Soil fertility maintenance					x	x
Management:						
easy regneration when damaged	x	x		x		
Harvest:						
Coppicing/pollard/lopping			x		x	
frequent harvest					x	
Plant Spacing:						
narrow intra row	x	x		x		x
medium intra row	x					
flexible intra row			x		x	
> 1 row preferable	x	x				x
Plant Elements:						
with hedgerow tree	x	x				
with fillers/entanglers		x		x		

x = necessary or very desirable

Table 49 provides added information for those users who are uncertain about the species to be planted. The table is offered as a first aid to species selection. This does not substitute trials and other references. It summarises site adaptability/tolerance (e.g. climate, soils).

With regard to climate class, the Koeppen system has been quoted whenever sufficient information was available (see Table 48).

Table 50 provides a checklist of important biopyhsical features which are essential for hedgerow planting, and information on reproduction and management. The height of the plant is that attained under natural conditions. Since some species can be both small trees (single stemmed) or shrubs (multistemmed near the ground) this has been noted whenever information was available.

Table 51 summarises important potential productive and service uses of plants. The use of various parts of species varies from one region and social group to another. Apart from the general protection (indirect) role of trees and shrubs, hedge specific ones are summarised according to some of the major barrier categories.

Table 56 summarises hedge plants according to agro-ecological zones. Species can be found in the ecological zone in which their occurrence is most common. However a variety of species has a wide range of ecological adaptability. More detailed information see Table 49. In addition, a data sheet (Table 57) on species used in the Andes is included. For these agro-ecological zones not much information with regard to hedge plants is available.

Recommended indigenous security hedge plants for trials in southern Africa are listed in Table 10. A list of woody plants suitable to fill gaps or strengthen an impenetrable barrier see Table 54.

In addition, lists of some trees and shrubs according to their specific high potential as food, animal feed, and timber (table 52), soil-improving functions (conservation, organic fertiliser, nitrogen fixation) and amenity value have been prepared (Table 53).

A list of a few species suitable for garden, windbreak, security hedges (general, stockproof), and living fence posts is given in Table 55.

5.3 Summary sheet

Highlights

- There is a need to clarify the taxonomy with regard to species and genera, since many hedge plants belong to lesser known species.
- When introducing new planting material support in seed orchard design and management etc. is required.
- Expanding the evaluation of germ plasm can be done best through networks concentrating on edaphic and management variables, with appropriate evaluation techniques (methodology, experimental design, data collection, etc.).
- Procedures in tree species selection and hedgerow systems are still biased owing to experts who by their tradition are used to dealing with industries and non-social issues.
- Taking the poor land user as the reference base in species selection, it becomes evident that there is a need to focus on species with quick and diverse output and which can be grown on adverse sites; easy establishment and management.
- There may be a conflict between the need for quick results (poor people and projects) and long term tested or locally available species.
- Under pressure to get quick results, development projects will continue promoting a few exotic hedge species.
- The real problem is not a conflict between exotic or native species, but the fact that untested species (time frame) are widely propagated.
- Many local species can survive under extreme conditions and be of great importance for the rural poor.
- Specialists in tree selection often forget that research programs aiming to be essential for the poor have to start from their perspective. Unfortunately, hedges and poor people often do not have a real lobby.

Trees and shrubs for different conditions - step by step guideline

The intended beneficiaries and experienced land users should be actively involved in all phases of species selection and testing. The following sequences may be useful:

- Identification of felt needs, preferences, expectations of target groups.
- Assessment of whether hedge systems can help to solve problems, and/or enhance the quality of life. This evaluation has to include the questions of whether trees in general can ease the situation, what the pros and cons of hedges in general may be, and the integration of hedge trees specifically.
- Observation of local use of hedges and how these trends can be utilized for hedgerow promotion.
- Identify major sociological potentials and constraints (for hedgerow growing see checklist Table 25).
- Draw up cost-benefit balance sheet with fundamental credit and debits criteria and ranking according to target groups and tree experts.
- Identify promising hedgerow candidates, assessing their species potentials and problems.
- Test some promising plants with local people and later some components on-station.
- Monitor the process of learning and evaluate it actively with the target groups .
- Create local and national networks and link them with international ones.

Lessons learned

Horticulturists, anthropologists, and local people should be included in species selection and testing. If this is the case, the present debate on pros and cons of exotic species will be of minor importance.

International exchange of information and seeds is important. Local networking and banks of local planting material deserve even greater support. Technical solutions that fail to take into account the socio-cultural context are inappropriate.

6 GENERAL TECHNICAL MANAGEMENT ASPECTS OF HEDGEROW GROWING

The following discussion summarises important technical considerations and those which are of a general nature, including species selection, propagation, establishment, shaping, maintenance, and harvesting aspects (for specific issues see also Chapter 3).

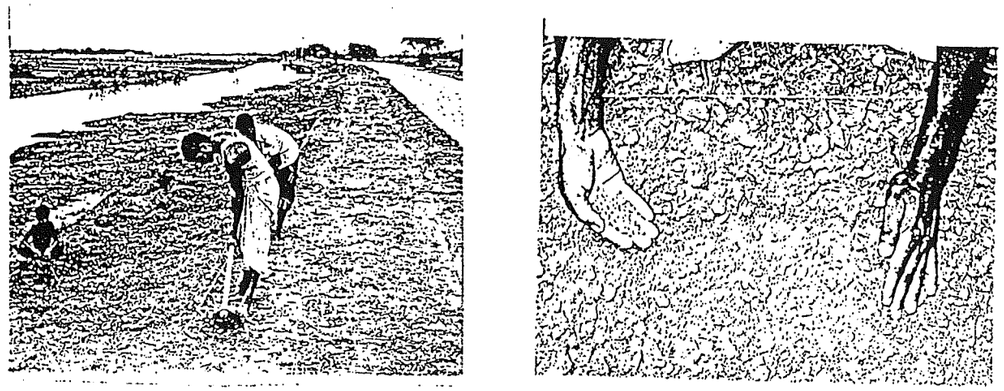


Figure 49: Establishment of *Cajanus cajan* as part of a community roadside planting in Bangladesh (122a)

The pigeon pea hedge should be sown in early May, before any seedlings are planted. A furrow is made on the outer edge of the road, above the slope.

The seeds are scattered in the furrow and covered gently with soil.

6.1 Planting and early care

General considerations of species selection have been dealt with in Chapter 5. The following discussion will evaluate different styles of propagation of hedges: generative (direct seeding, container seedlings, bare root seedlings and stump cuttings); vegetative regeneration, particularly cutting establishment.

6.1.1 Factors to consider in the selection of applied propagation

The choice of applied reproduction is dependent on factors such as germination percentage of seeds, availability of cuttings, costs and benefits, local know-how and preference, seasonal availability of labor, etc. Hedges can be established either generatively or vegetatively. Vegetative propagation is the asexual reproduction of individual plants, as opposed to reproduction from seeds.

The recommendation of a planting method must consider, first of all, the farmers' capabilities. For example, the tree population in alley cropping may require between 10,000 and 50,000 tree plants per hectare. Hence seedling establishment will not be affordable or is not economically justified in most cases.

The deliberately retaining and enrichment of existing strip vegetation may be another attractive option. This is the option least often considered in projects, but often the most cost efficient one.

6.1.2 State of knowledge of reproduction and application by development projects

There is generally a great amount of information available on reproduction, particularly on conventional nursery techniques for well-known species (for a brief summary on general technical aspects of species for trial and pilot projects see e.g. 38). Unfortunately there is less information available on the most popular establishment methods for hedges (direct seeding and cuttings).

Potentially important species may not be used extensively because of insufficient knowledge about storage, best methods of extraction, and control of seed pests. Equally serious problems arise from inadequate test grading and certification of seeds (112).

There is a tendency for research trials and development projects to rely on seedlings. This may be unaffordable for small-scale farmers if not subsidised (material and labour) The establishment method have to fit into the context of the land user. Establishment with cuttings, e.g for *Jatropha curcas* resulted in more initial yield compared with seedlings. However survival rate was less with cuttings (164a).

6.1.3 Generative propagation

Seeds: Supply, germination, and pretreatment

Supply: Seeds are less bulky and could therefore be distributed efficiently and at lower cost than, for example, stakes. Seeds are frequently in short supply when new plants are introduced. Establishment of seed orchards is important. For instance ILCA has prepared a small booklet describing the steps in *Gliricidia sepium* seed production (18) (for information on where to obtain seeds consult: for multi-purpose species e.g. 64; for nitrogen fixing trees the Nitrogen Fixing Tree Association, address see Appendix 2; for Australian species see 366).

Germination: The rate of germination has to be known for calculating the quantity of seeds required for the desired population in the nursery (formula: kg of seeds = desired number of seedlings/seeds per kg germination rate). An assessment of the germination rate for the nursery can be quickly obtained by placing 100 seeds in moistened, rolled towels. Seeds/kg see table 50.

Pretreatment: Some seeds with a hard seed coat cannot absorb water. In nature this usually results in seed germination over a longer period of time. The "hard" seed coats of e.g. *Acacia spp., Albizia spp., Cassia spp., Dodonaea* spp. must be treated to make them permeable to water and oxygen, so that germination can take place (91). In order to support uniform germination, the seed coat must be cracked (scarified) to hasten germination, Table 50 indicates for which species pretreatment may be advisable.

Direct seeding: This involves sowing of seeds or other propagules. This method is justified where seeds are abundant and/or cheap. They should also exhibit a high germination rate under field conditions and give root and seedling growth able to sustain adverse climatic conditions, thus making prolonged periods of weeding unnecessary (234, 369). The disadvantage is that direct seeding needs special care during establishment. Direct seeding can be very cheap compared with seedling establishment.

Seed propagation would appear to be the most convenient and reliable means in alley cropping, where up to 50,000 trees/ha may be required which can make stake establishment methods costly, inconvenient, and impracticable. Where a high tree density (e.g. mulch production) is desirable this can be achieved most easily by direct seeding (18).

Container seedlings: Advantages of raising planting stock in individual containers include minimum shock during handling and transportation, prolonged planting period, higher survival and faster initial growth, compared with bare-root seedlings (234). High costs and transportation problems are the major constraints. If transportation by pickups or by hand on steep slopes is important, small-size container may be the solution to overcoming the transport dilemma (250).

Bare root seedlings are planting material from whose roots the soil has been removed. Resistant bare-rooted species may be planted successfully on favourable sites. Bare-rooted stock should only be used in areas with ample, well-distributed rainfall, lasting at least 3 months, with high relative humidity or low temperatures during the rainy months. Elaborate land preparation and frequent initial weeding is necessary

Stump cuttings:These are seedlings which have been severely pruned, leaving only a short stump and a short piece of the main root. The main advantages of stump planting are: reduction of transpiration loss, easy transport and storage for a longer period, economy in planting, and extended planting calendar, enabling setting out before the rainy season. Species that can be planted successfully by stumps include *Cassia spp., Gmelina arborea* (384).

6.1.4 Vegetative propagation

Pros and cons

Advantages of vegetative propagation include: the seedlings develop rapidly, genetic origin can be controlled, some species can only be reproduced asexually; seed supply may be unavailable or unreliable (281, 381). The stake establishment method is simple, but suitable where only a few trees are to be established, such as for fence posts (18).

Disadvantages of using cuttings include the fact that cuttings are often less robust than seedlings, and that it is difficult to obtain enough woody branches to prepare cuttings in sufficient quantities, for example, if a new species is being introduced into an area. Where a very high tree density is required, direct seeding and not cuttings has to be considered in most cases.

Cuttings are sections of roots, stems, branches, or twigs selected from suitable mother woody perennials. This technique can be used both in the nursery and directly in the field, although only certain species lend themselves readily to this process. Many plants suitable for hedges have this capability.

With many trees, once the taproot is pruned or damaged in any way, it will not regenerate into a normal taproot; it will not reach the depth of a normal root, especially legumes. The same is true of trees propagated from cuttings. The result will be the development of a short pseudo-taproot and the development of an extensive lateral root system in the upper soil horizon. Therefore ITTA stopped using cuttings of *Gliricidia sepium* in alley cropping systems because of extensive lateral root development which competed for nutrients, water, and space with the intercrop (31a).

Suitable plants

Bougainvillea spp., Commiphora spp., Euphorbia spp., Gliricidia sepium, Populus spp., Tamarix spp. to name a few, can generally be established on site from cuttings. They also respond reasonably well to vegetative propagation in the nursery. Other species which can be rooted in the nursery and transplanted to the site once the root system is fully developed include *Albizia lebbek, Azadirachta indica, Cassia siamea, Erythrina senegal, Erythrina variegata, Moringa oleifera, Prosopis juliflora,* and *Ziziphus mauritiana* (381, 161).

Establishment by cuttings

Direct establishment: Planting cuttings directly at the site where they are to be permanently located saves time and expense by by-passing the need for initial propagation in the nursery, e.g. with a little rainfall (less than 200 mm) and soil moisture *Euphorbia spp. and Tamarix spp.* can be propagated on very dry sites (381).

The actual planting process is simple, quality controls are necessary for good survival. Generally once stems have been cut they should be planted with as little delay as possible; at least within 24 hours.

When stakes, e.g. for *Gliricidia sepium* are planted very densely there may be a higher mortality rate than with direct seeding (18). Reasons for high mortality rates of plants, e.g. in the case of *Euphorbia spp.*, are failure to make fresh cuts at the base of the stem, to dig deeply enough, and to backfill properly (381).

Nursery: Nursery beds or pots are used to start the new plants. The cuttings must not be allowed to dry out, or their ability to regenerate new roots will be diminished if not destroyed. Usually one or two leaves are left near the top and the cutting is carefully inserted into a growing medium where everything is done to stimulate root regrowth. These leaves are carefully removed from the cuttings in order to reduce unnecessary water stress to the vegetative material (281, 381).

6.1.5 Summary sheet

Highlights

- Many hedge species candidates belong to the group of lesser known species. Insufficient knowledge limits species selection.
- Hedges are not a research priority. Hence, most species trials and pilot projects fail to screen some of the important potential hedge plants and cost-efficient reproduction methods.
- Development and research projects have a bias towards reproduction by transplanted nursery seedlings.
- Direct seeding and cuttings are the major methods used for establishing hedges by local people.
- The method of reproduction will be determined by the ease of obtaining and establishing planting material. Finally, labour costs as perceived by resource-poor farmers will be of pivotal importance.

Key technical instructions

- Whenever justified, direct seedings or cuttings have to be chosen, or a combination of both.
- Cuttings are preferred for fencing because living fences established by seeds cannot be utilized immediately for fencing. Cuttings also need less care once established.
- Establishment with cuttings is simple, but suitable mainly for situations where only a few trees are to be established such as for living fence posts.
- With direct sowing a wider range of tree densities can potentially be obtained than with stake propagation.
- Particularly in a situation of inadequate or non-availability of parent trees from which cuttings could be obtained, direct seeding would appear to be the most convenient and reliable means of establishment.

- Transplanting seedlings may require less field preparation than direct seeding. However, a large number of seedlings can be required to plant a hedge (e.g. in hedgerow intercropping). Small containers can reduce the transportation cost and hardship.
- Bare-root planting is less labour-intensive than the container seedling technique. Stump cuttings and bare-root seedlings are lighter, and thus much easier to handle. They can survive brief periods of drought after planting, but are less tolerant to drought and weeds than bagged seedlings.
- Sometimes survival is higher with stump cuttings than with bare-root stocks.

Lessons learned

Active participation of the target groups and involvement of social scientists is important in species trial and pilot programs.

Hedgerow planting involves a large amount of plants. For hedgerow promotion, conventional propagation of species (nursery seedlings) has to be avoided in most cases. Regeneration by direct seeding and cuttings and/or deliberately retaining vegetation strips require different strategies.

6.2 Planting out

Once the uses and characteristics of the species required have been established and before species are actually chosen the special conditions of the planting sites need to be evaluated. Planting hedges does not differ much from planting other plants. Hence, only some aspects of hedge establishment are discussed, following the sequence of action. The main difference is that they may need more special initial care than other tree planting. Choice of propagation has been dealt with in previous chapters

State of knowledge

For information on various applicable establishment methods and techniques of tree planting in general a great number of texts are available. Many bilateral organisations have developed handbooks on specific subjects. Extension material exists in many projects. Specifically on hedges there is not much extension material available (see e.g. 34). Practical guidelines exist on site preparation, planting, season (competition of labour, staking out low-cost contour lining), planting options in general and adverse sites (procedure for technical site assessment see e.g. 38). On soil improvement a good deal of general data is available. Hedge specific knowledge is restricted. This is particularly true of plant association. More data exist on inoculation due to advances in this field.

6.2.1 Layout and design of hedgerow systems

Constituent elements of hedges

The following is a brief summary of important technical factors which have to be considered in the design of a hedgerow system:

- number of rows (single, double or triple row)
- consitituent elements (vertical structure) in the row,
- height at maturity
- planting density (inter row and intra row spacing),
- plant associations.

For design purposes the following main elements (example see Figure 50) can be distinguished:

- ground cover shrubs (undergrowth); undershrub (< 2 m),
- multibranched woody perennials, low growing trees and shrubs (5-8 m),
- hedge trees (8-15 m),
- filling elements (annuals, entanglers, etc.).

Mixing these elements depends on intended use, space available, state of knowledge, and know how.

Few designs for multipurpose and multirow hedgerow systems, and few scientific models are available. The state of knowledge is particularly poor on plant association (for tropical windbreaks in general see particular 153a).

There is a need for research on plant sociology to determine appropriate spacing and plant combinations. What is required is a screening of existing systems. Concerted efforts by experienced hedgerow gardeners in the tropics and plant ecologists may be important

Examples of layout of hedgerow systems

If the management goals are clear (main purpose and by products) the right design (plants, spacing, and sequence) can be chosen. Questions relating to design are what biophysical features the woody perennials should have, what is the desired planting distance, thinning etc., how many rows the land user is willing to allocate for hedges, etc. Apart from matching the right species to the site (soil, climate), the plants have to be compatible with each other to a certain extent. The following figures are examples of how to mix species. For band-planting it is also possible to plant several rows one behind another (for examples of multi rows see Figures 52-56). Other specific layouts are given in Chapter 3 under respective uses.

Spacing the plants

The initial spacing greatly influences the pattern of growth, weeding, and the economics of planting and tending. Poor land users may prefer single-row hedges. For advantages and disadvantages with regard to windbreaks see 3.10. For security hedges and wind and frost protection, close planting, fillers, and entanglers may be required to support the framework.

Initial planting of more shrubs than are required avoids bare soil between the plants. This implies added expense and this necessitates removing some shrubs when individual plants grow and need more space. To optimize space in a small hedge (situation of the poor), products obtained by pruning are welcomed. The removal of plants also accelerates incremental diameter growth. This silvicultural technique may be very labour intensive, but it is often not necessary, due to their self-thinning capacity.

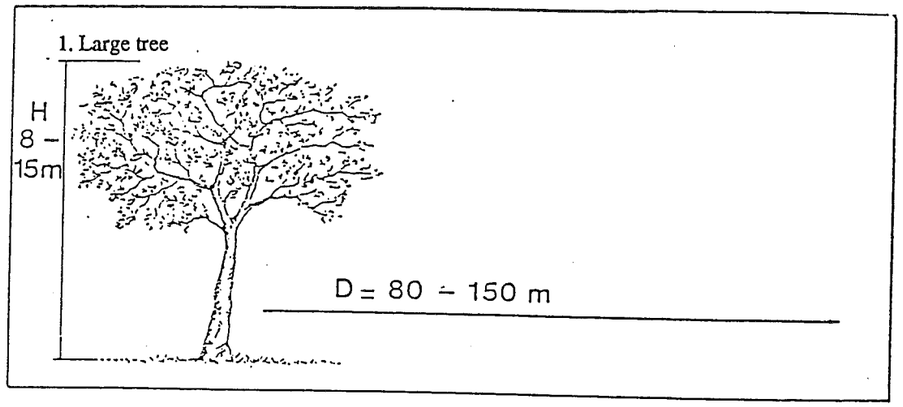
Another satisfactory solution is to set out shrubs at their recommended spacing and use fillers: annual plants, bedding or herbaceaous plants are all used for this purpose and need moving away. As a rule of thumb, in natural hedges the plant spacing should be wider than in trimmed ones (example see following Figure).

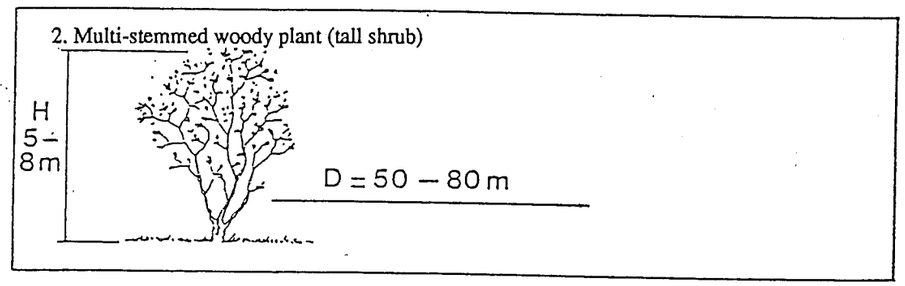
These are only general guidelines as recommended in temperate zones, in case the final distances are wanted. The exact spacing depends on the size and type of plants, the desired width of the hedgerow and the number of plants which the land user can afford. Biophysical factors like rainfall and soil status also affect the required spacing. The next table can be used when calculating the number of plants required for a hedge. One example of layout for living fences single or multiple rows of cuttings see diagrame below.

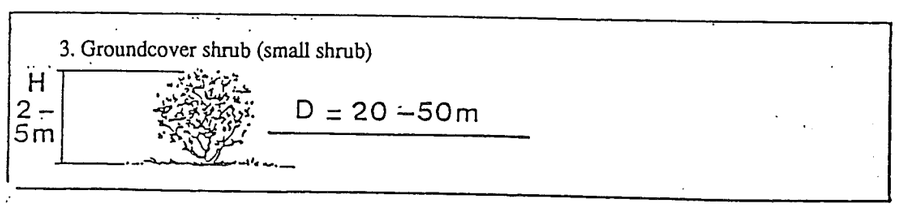
6.2.2 Planting season

A useful guide for early rainy-season planting, in particular for direct seeding, might be to plant at the same time as field crops.

The season of establishment can be particularly critical in subhumid and arid climates. Where there is competition for labour (particularly in more arid areas) planting at the end of the dry season is possible for some species, e.g. cuttings of *Jatropha curcas* (152, 208). Cuttings should be immediately planted out after obtaining from mother trees.







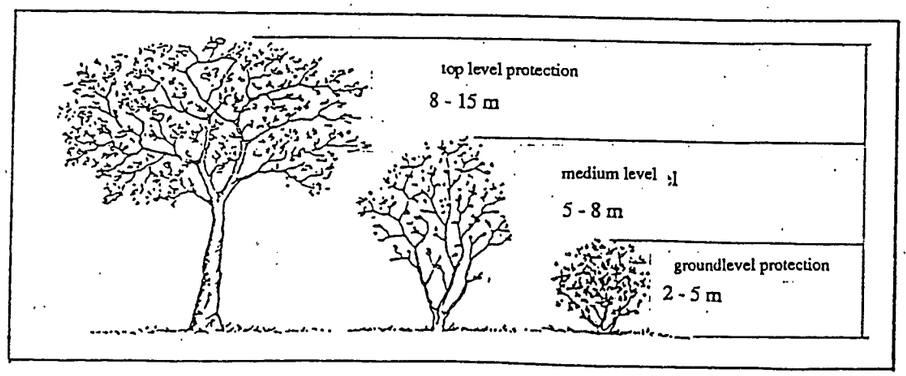
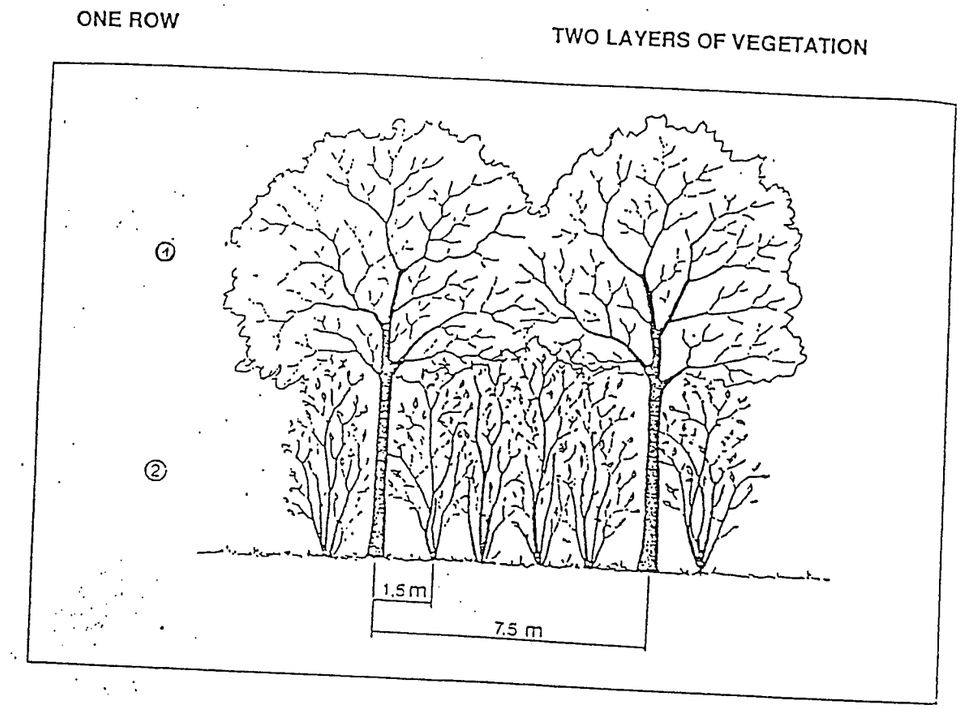


Figure 50: Constitutive elements (trees and shrubs) of windbreaks (153a)



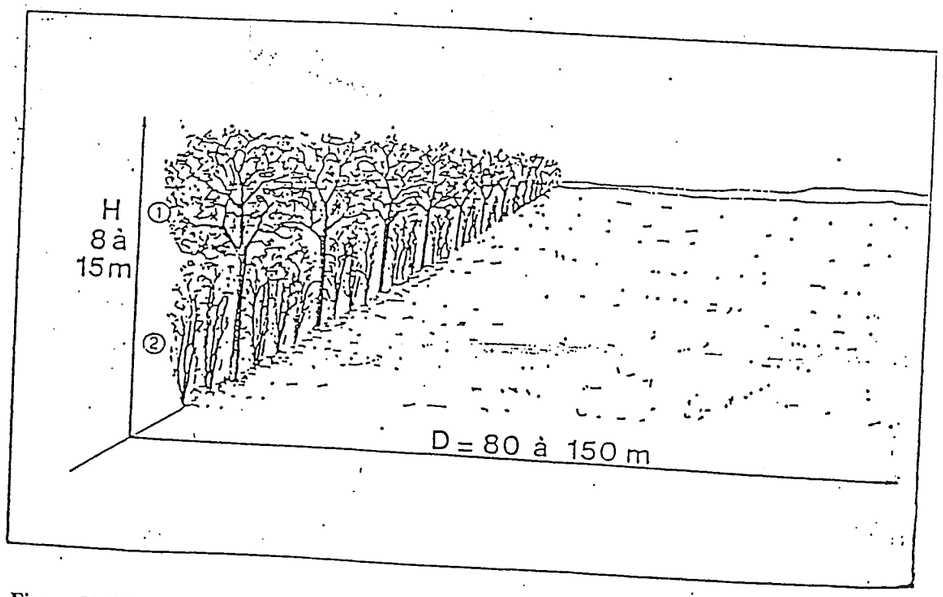


Figure 51: Mixing of trees with shrubs in a one-row windbreak hedge

1 = Large tree 2 = Multi stemmed woody plant

Two rows **Two layers of vegetation**

large scale

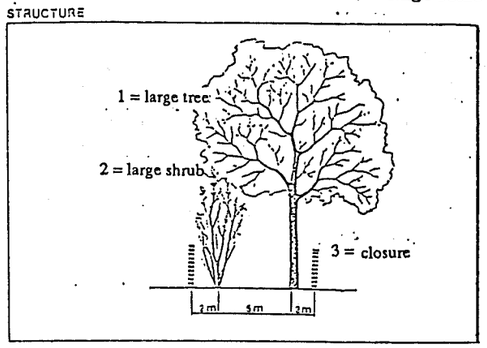


Figure 52: Mixing of trees with shrubs in a two-row hedge

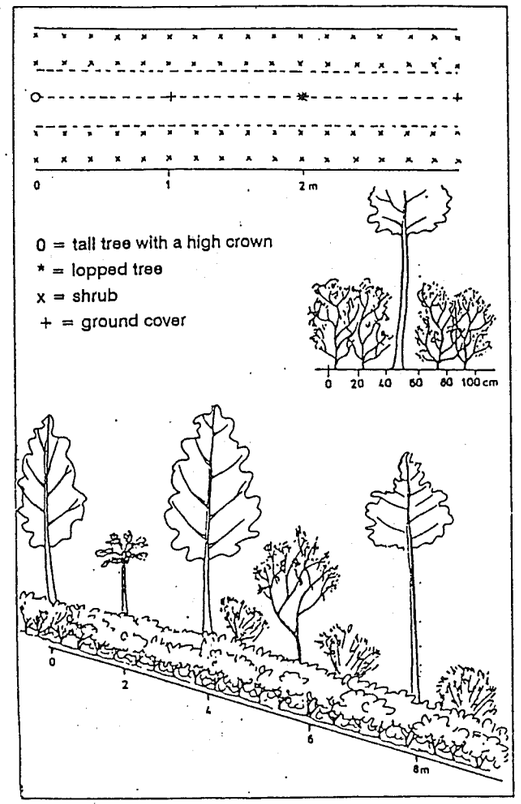


Figure 53:Layout of a multi row and multipurpose hedge in Rwanda (298)

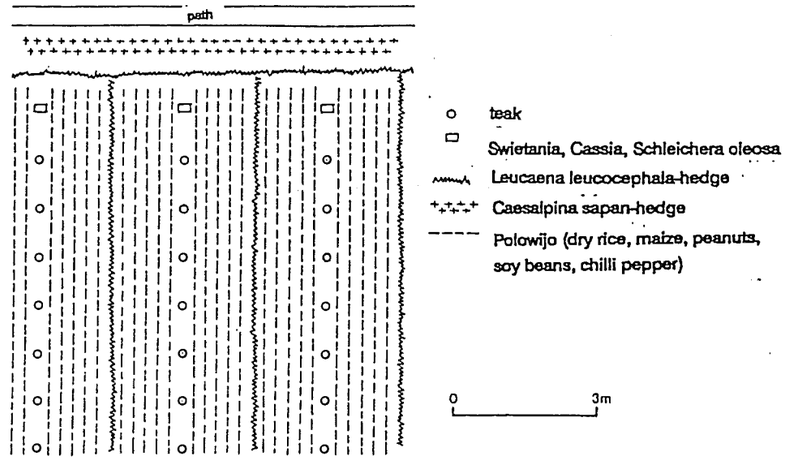


Figure 54: Hedges in an agroforestry Teak plantation in Java (243)

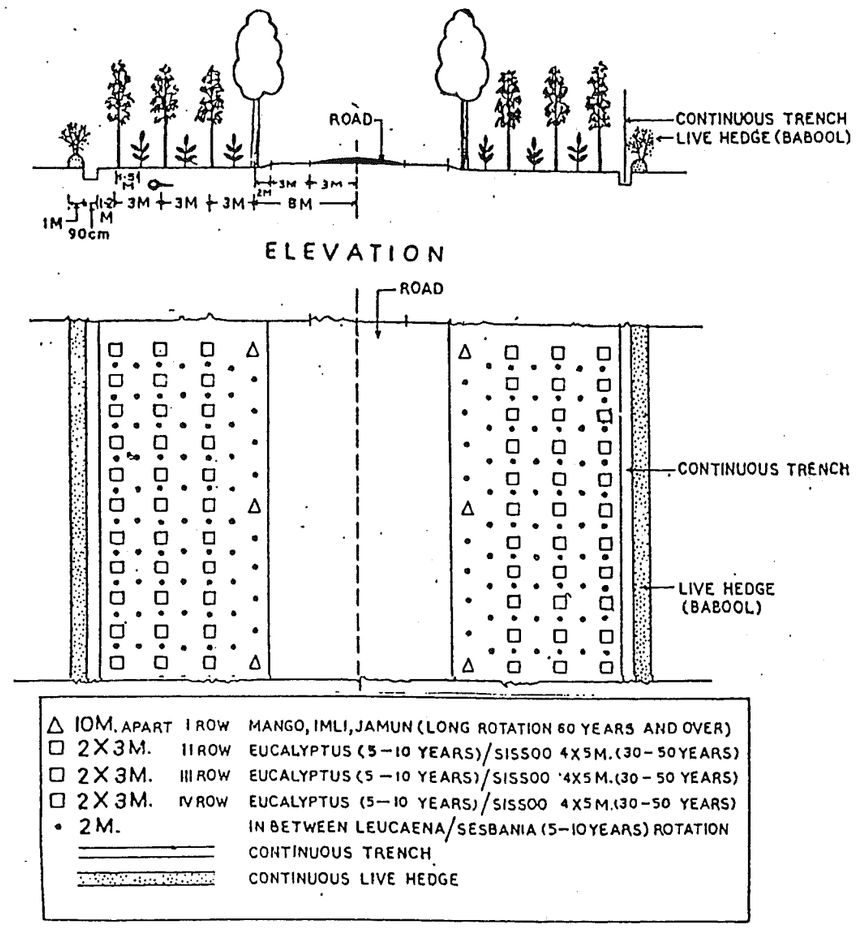


Figure 55: Multiple roadside planting for shade, firewood, fodder, and rural cottage industries

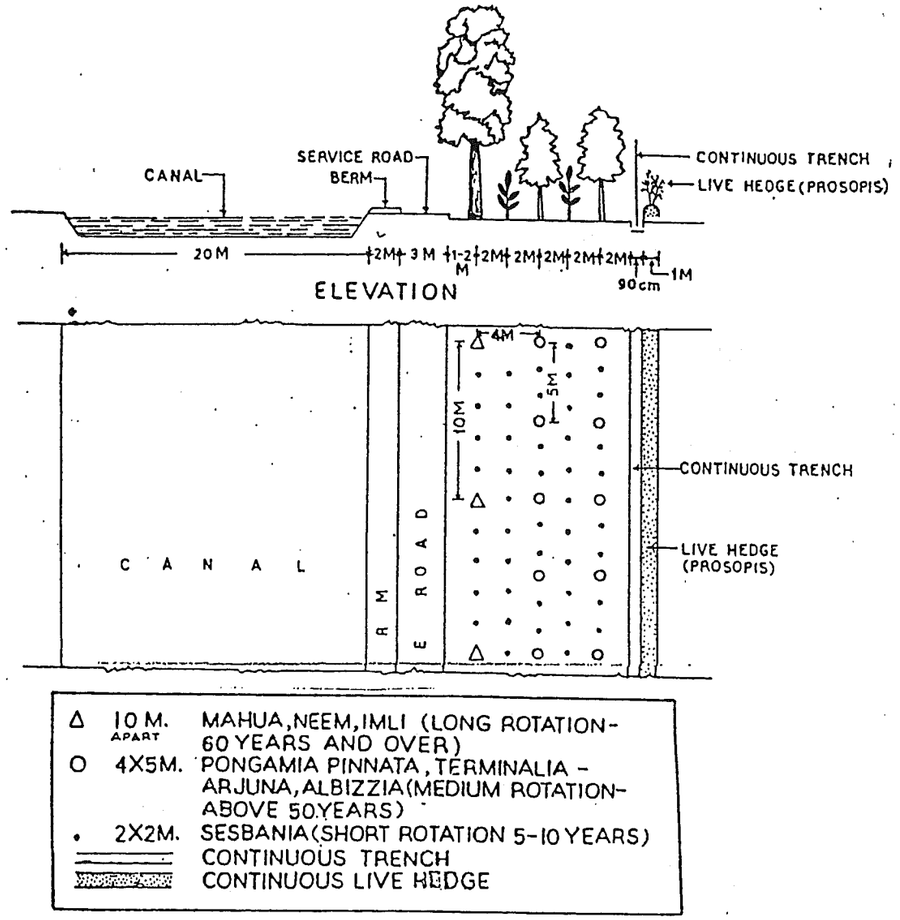


Figure 56: Canalside planting with a hedgerow component for fodder and rural cottage industries in alkaline soil in India

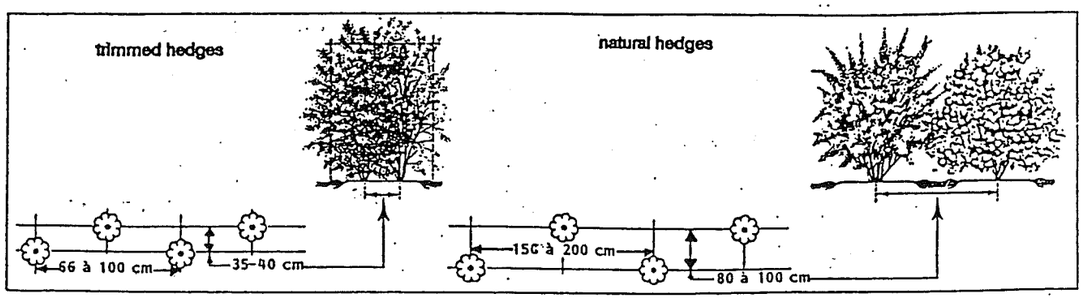


Figure 57: Example of different spacing requirements for trimmed and natural-grown two-row hedges

Table 36: Length of a hedge as a function of size of the parcel

size of field	perimeter of field	length of* hedge/ha	plants**/ha 0.25 m	1 m	1.5 m	10 m
1 ha	400 m	400 m	1600	400	267	40
2 ha	600 m	300 m	1200	300	200	30
3-4 ha	700-800 m	120 m	480	120	80	12
5-6 ha	900-1000 m	100 m	400	100	67	10
10 ha	1400 m	70 m	280	70	47	7
15 ha	1600 m	50 m	200	50	33	5

*in an average

**intra row spacing of hedge

Source (337)

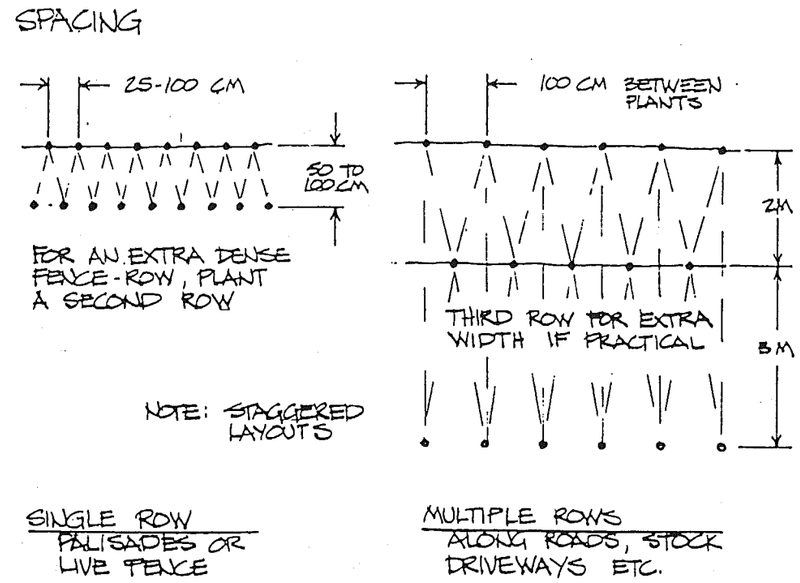


Figure 58: Spacing of single/multiple row living fences (381)

6.2.3 Site preparation

Staking out

Methods of marking the planting position have to be convenient for the land users. The line of the hedge has to be marked carefully. If a plough is used, a single straight furrow may be cut out before the soil is prepared. Otherwise the line can be marked with a set of stakes. On a long line a post is set at each end first.

One problem faced by farmers not familiar with contour cultivation is how to follow contour lines (planting hedges along the same elevation). Simple instruments that can be built from local materials are the A-frame (see Figure 29) and the hose level (370, 382). Hose levels consisting of 8-10 meters length of clear and strong tubing filled with water and attached to two stakes, are readily employed by farmers with sufficient precision to mark contour lines (398).

Bed preparation

Preparation of the plot varies depending on intended use, type of planting material, topography and vegetation of the area to be planted; hedge plants should be given special care at planting time to ensure good growth later. The effect of the ground preparation on hedge establishment and growth can be significant and last through the life of the hedge.

If the hedge is to have a ditch beside (often important to prevent animals,or for drainage), first the bed is prepared and then the ditch dug. Otherwise the ditch will get in the way, especially if a machine is used in bed preparation. Mechanical preparation may be done best with a rotary tiller. This may not applicable to small-scale farmers. It is also possible to prepare a ditch with a plough and plant the hedge on the ridge.

In general, the site should be cleared of vegetation (114). However, useful woody perennials should be retained if convenient. Destroying weeds which can overcome young seedlings is very important. In general, vegetation should be burned and/or ploughed). Grasses, particularly rhizomes, have to be removed. To establish *Leucaena leucocephala* hedges 80 cm wide, for example, the creation of a strip of 1.6 m width was recommended (298).

Steep slopes are usually too exposed, so planting of climax species, e.g. mahagony (*Swietania macrophylla*), is often not sucessful. Therefore it has been suggested that the hedgerow be established first to serve as partial shade for climax species to be established later on . *Cajanus cajan* seems to be very suitable for this purpose.

6.2.4 Irrigation and water conservation

In more arid areas water conservation is very important. Micro catchment, brush mulch, infiltration ditches, and other techniques are important to secure and enhance tree establishment (for an overview see 180, 381) (for one example, Figure 26).

In commonly occurs in desert soils that there is a permanently dry layer between the groundwater and the top soil which is wet only for a short period. Hence there is a need to irrigate the trees until they reach the groundwater (248). Near the Nile/Sudan it was found that with an initial irrigation for a period of only 4 months *Prosopis chilensis* hedge can grow up to 4 meters in one year.

In the Sudan *Acacia mellifera* is grown as a security border hedge round irrigated gardens, particularly in the desert in the Central Province. Often it is established on the top of the irrigation ditch. Some farmers even argue that the most appropriate form of *Acacia mellifera* watering is to establish it on an individual emergency ditch for *Acacia mellifera* and establish a second ditch for *Eucalyptus microtheca.* There will be enough seepage for the *Acacia mellifera* hedge. Only in emergency cases will the irrigation ditch for *Acacia mellifera* be used.

Under-irrigation can be as serious a problem as excess watering. Irrigation that comes too late will support the development of lateral surface roots, and not the necessary deep tap root. If the water supply is interrupted, e.g. due to failure of the pump, hedge plants which normally require plenty of water may suffer or may even not survive. Waste water is also used for irrigation of hedges. In the Sudan it was observed that in compounds women sometimes grow Henna (*Lawsonia inermis*) as a hedge, which is watered with wastewater(215a).

6.2.5 Improving the soil

Fertilizing

Application: Normally the farmer applies fertiliser to the crop and not to the field hedge. It is within this general restriction that the following discussion has to be seen.

Application of fertilizer is recommended for many tropical soils due to their poor nutrient status. Leucaena has a strong positive response to phosphorus. Leucaena yields are limited in acid soils. Liming of such soils with 1 ton of lime/ha improves the biomass yield by nearly threefold in acid soils (4.5 pH) in Malaysia. A less costly alternative is to plant species which are more tolerant of acid soils (e.g. *Inga spp.*) (252).

Organic manure: Mineral fertiliser may not be affordable or available for small-scale farmers, and even where there is a very positive response in growth of the hedges with little fertiliser, the farmers tend to fertilise their crops first. Hence organic fertilisers are most appropriate for small-scale farmers and gardeners.

In the highlands of Rwanda 1-2 kg of compost per meter of hedge were recommended (298). Spreading of one barrow load of manure or compost to every 2 m of a trench dug for planting the hedgerow may be essential for quick plant development. The deep incorporation of manure will encourage the roots to go down in search of nutrients, and thus, move away from the surface where they are most susceptible to drought. However, it is necessary to assess whether it is economically feasible to apply fertiliser.

Cactus cultivated for commercial purposes respond very strongly to manuring: 2-3 kg of manure per meter of hedge can be placed at the bottom of the ditch and tilled with earth before planting. The same amount should be added after each cropping every second or third year (43).

Inoculation: Nitrogen fixation, micorrhizae

A symbiotic relationship has developed between many plants and certain soil bacteria (actinomycetes) and fungi. This relationship helps the plant to survive in infertile soils.

Nitrogen fixation: Certain microorganisms convert nitrogen gas from the air into ammoniac, a soluble form of nitrogen. After conversion to nitrate it is readily assimilated by plants.

The appropriate strain of rhizobium is sometimes necessary for rapid establishment of Nitrogen Fixing Trees. In most countries where these species are native or naturalized, they will nodulate well with native bacteria.

In areas new to this type of species, trial plantings should be made to test for the presence of nodulating bacteria. Established seedlings can be carefully uprooted and checked for the presence of nodules (for sources consult e.g. Nitrogen Fixing Tree Association; information on resources see e.g. 64).

Micorrhizae: Many plants including *Eucalyptus spp., Leptospermum spp., Casuarina spp.* and many legumes from associations with various fungi. Through their roots, to which the fungi are attached, the trees derive certain nutrients (especially phosphorus) from the fungi: Soils which are deficient in phosphorus can be enriched with soils from existing healthy stands of trees with micorrhizae.

6.2.6 Site-specific planting practices

Different sites require different planting methods. For how to plant hedges along contour lines see under staking out and in particular Chapter 3.8. The following discussion is restricted to hedge-specific planting:

- on the flat with or without a ditch,
- on the top of a bank,
- on the side of a bank or on a ledge at the foot of a bank.

Flat sites

To plant a hedge on the flat with or without a ditch is a common practice unless the land needs more drainage than is possible with the ditch (see Figure 59).The size of the ditch, if one is needed, depends on the soil and on the level required to provide an even fall or good drainage (44).

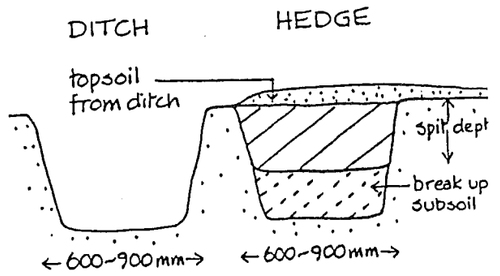


Figure 59: Planting a hedge on the flat with or without a ditch (44)

On top of a bank

Planting a hedge on a bank has the following advantages and disadvantages:

- Advantages are: The soil remains well drained even on wet land the bank is deep enough to give shrubs room to root.

- Disadvantages are: The labour cost is higher than for flat planting; the soil in the bank will be poor unless care is taken to keep the top soil on top and to renew the soil sometimes; the plant may not stay firmly on the bank.

The general method for building a bank is shown in the diagramm below.

When hedges are grown in swampy areas, it is necessary to form a bank. Planting on the top of the bank ensures that the hedge seedlings get a deep bed and that water is carried away from them. The bed is prepared along the hedgeline and dug alongside. The excavated soil forms a bank on top of which the hedge will be planted (305).

In the Altiplano/Andes that are soils waterlogged for several months, strong frost, and grazing inhibit tree growth. Wind protection has been identified as one precondition for agriculture (34). The traditional Waru system can be utilised for growing trees. It consists basically of a small dyke (camellones) (see Figure 61).

On the side of a bank or on a ledge at the foot of a bank

This method is for use on wetland where a bank and ditch are required for drainage, but where, in addition, the growing hedge needs protection from strong winds in exposed situations. Only one row of plants can be placed. Of the two variations, the hedge on a ledge takes up more space but has the advantage of keeping soil from slipping into the ditch. It is also easier to plant out. The following figure shows how to construct such a bank.

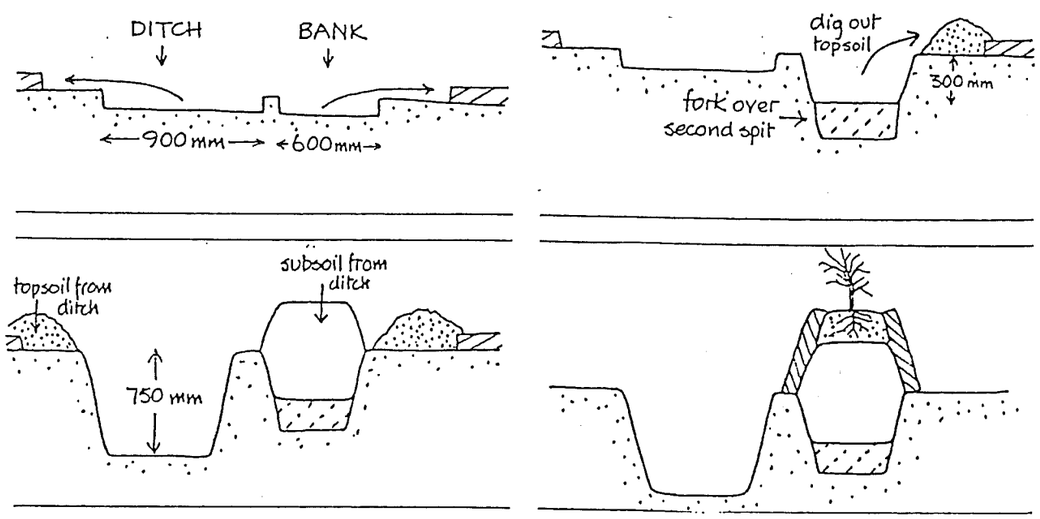


Figure 60: Hedges on top of a bank (44)

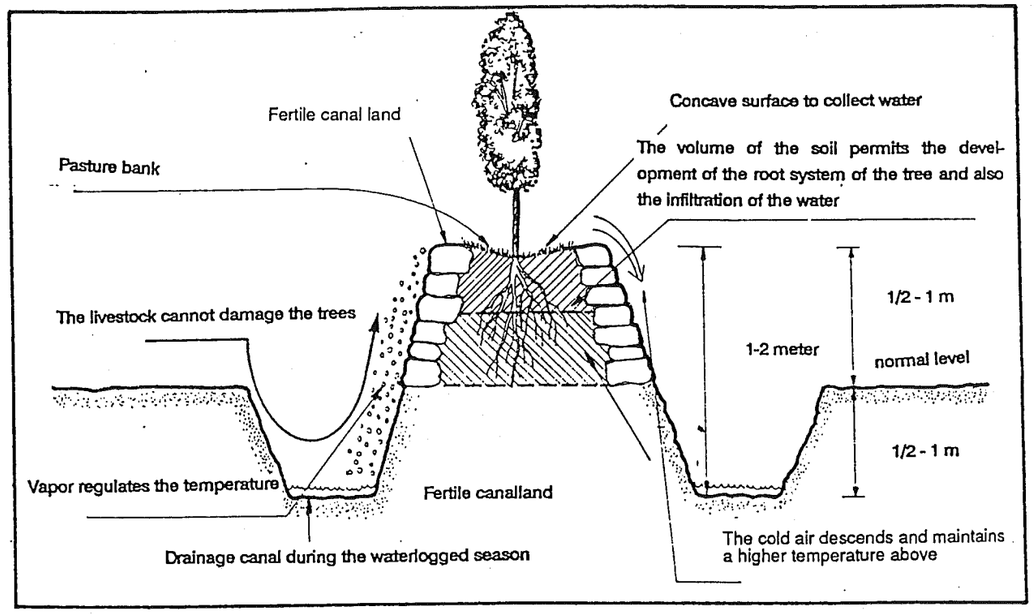


Figure 61: Traditional Waru waru approach in Peru: useful for establishment of hedges (44)

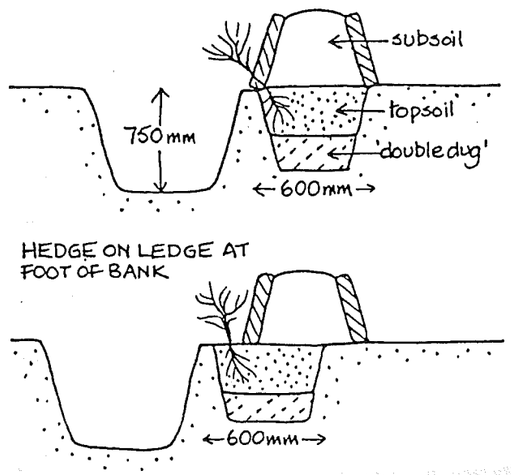


Figure 62: Hedges on the side of a bank or on a ledge at the foot of a bank

6.2.7 Putting in the plant

The choice of propagation depends on the specific context. For general information on propagation and techniques suitable for hedgerow growing see Chapter 6.1. The most likely ways of establishing a hedge are

- direct seeding,
- cuttings,
- in some cases, seedlings.

Direct seeding

Assuming enough seeds are available and the seed germination rate is known and pretreatments (if necessary) are made, it is necessary to know how much seed is required for, say, a 100-meter hedge. If the supply is very inexpensive the expense or labour involved in collection can be of minor importance.

There is not much concrete information available on the exact amounts of seed required. Recommendations for seed required vary considerably, e.g. for a dense contour hedge of *Leucaena leucocephala* in Indonesia up to 4 kg per 100 meter have been used on Flores/Timor (242). Other technical recommendations indicate less than 100 g (for more details on minimum seed requirements for various land uses for *Leucaena leucocephala* hedges consult Table 37). In Sudan between 0.1 kg and 1 kg of seed are used to plant 100 meter of *Acacia mellifera* hedge in the semi-arid regions (1, 215a).

When calculating the amount of seeds required, various factors have to be known. In a situation of sufficient supply (acceptable price or time for collecting) farmers are inclined to use more seeds and broadcast them. Recommendations to economise on seeds, e.g. to apply spot seeding or dibble, may not be accepted. Other species which have a high value like *Cajanus cajan* are often spot seeded using 3 to 4 seeds every 30 cm or 40g/100m.

Some farmers in the Sudan even use up to 3 kg of *Prosopis chilensis* per 100 m, because they found out that broadcasting them from the tractor just before the disk, is an economic way to establish border windbreaks. Since the children can easily collect seeds. they do not care about the quantities required.

Seed pretreatment may be recommended for many *Acacia* species. It was found out that for *A. mellifera*, if sufficient seeds are available, there is no need for pretreatment (215a).

When planting hedges, it is usually best to dig a trench rather than separate holes. This is particularly important (and often the only method) if seeds are planted with minimum intra-hedgerow spacing) (332).

One method applied is dibbling: Dibbling of *Leucaena leucocephala* seeds has been a cost-efficient way of applying rock phosphate. However if no fertiliser has to be applied this is a less efficient way.

Seeds can be sown by hand, with seed drills, or by hand japer into furrows. Site preparation has to be as thorough as possible to limit weeds. In alley cropping effective establishment has been achieved by planting seeds in the same manner as crops, thus reducing or avoiding initial weeding. On steep slopes it is important to form an earth mound to prevent the seeds from being washed away.

Cuttings and other vegetative material

There is quite a range of cutting sizes as applied by hedgers. For instance, for *Gliricidia sepium* the range in length is from a few centimeters to over 2 m depending on the purpose of establishment (18). In Mexico for living woven fences tall cuttings of willows up to 4 meter have been used (see Figure 84 in Appendix 1).

Planting material should be healthy and vigorously grown. Cuttings should be taken from dormant plants. In more arid regions collection of plant material normally takes place during the dry season. The stems should have several buds that have not yet begun to swell or open. A sharp blade should be used to obtain a clean cut. To prevent cuttings from drying out, they can be stored in plastic bags; whatever happens they have to be protected from the sun (381). Some species like *Jatropha curcas* can be planted in the dry season.

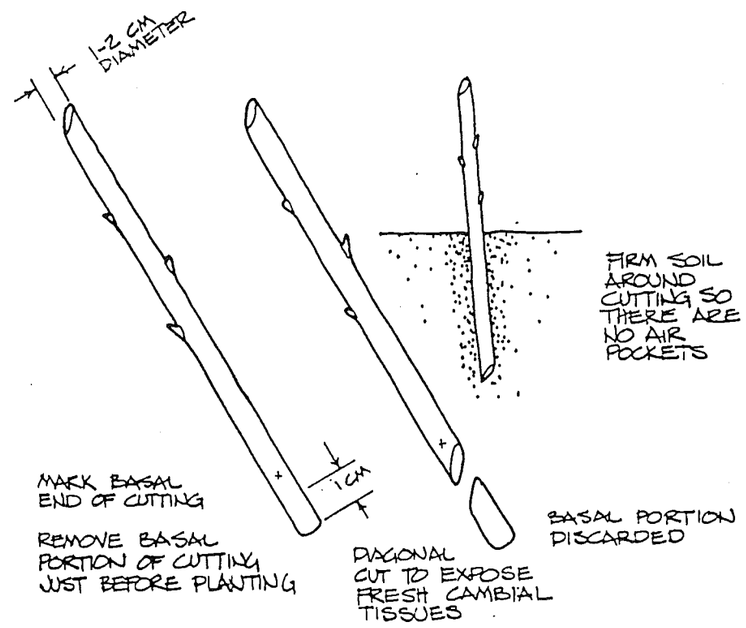


Figure 63: Preparing cuttings for planting (381)

Just before placing the cutting into the bed, the hedger removes about 1 cm of stem from the root end of the cuttings by making a clean diagonal cut. The freshly cut stem can then be placed in the soil. It is essential to make sure that the cuttings are completely surrounded by soil, with no air pockets.

Generally two different planting techniques have to be distinguished: shallow planting and deep planting.

Shallow planting: The following procedure for on-site propagation of *Euphorbia balsamifera* cuttings has been successfully applied in Nigeria.

- length of cuttings: 50-100 cm;
- diameter of cuttings: 1-2 cm; although thicker stems give satisfactory results, provided they are started during the cool season;
- the natural vegetation found on dune soils will be the best source of plant material for dune stabilization efforts;
- depth of hole: 30 cm (minimum depths 20 cm);

Other important requirements include: cuttings must be planted at their final location not later than 24 hours after they have been cut from the parent plants. To stimulate latex flow, a few centimeters are cut of the base off the stem with a sharp blade immediately before placing it in the ground (for layout of this example see Figure 64).

Deep planting: Another technique for establishing plants from cuttings directly on the site is the deep planting method. Dune afforestation with tamarix cuttings has been successful (for illustration see Figure 64). Sometimes a deep pit is dug rather than a bore hole. Deep planting may also provide a solution to troubles of establishing trees on soil with a high salinity (381). The type of cut is done by hedgers with great care like in Costa Rica (various cutting styles are shown in next figure).

The depth used by ranchers in Costa Rica with *Gliricidia sepium* cuttings for living fences was between 20-40 cm. Less than 20 cm was found to be susceptible to wind damage, and more than 40 cm caused difficulties in rooting (20.)

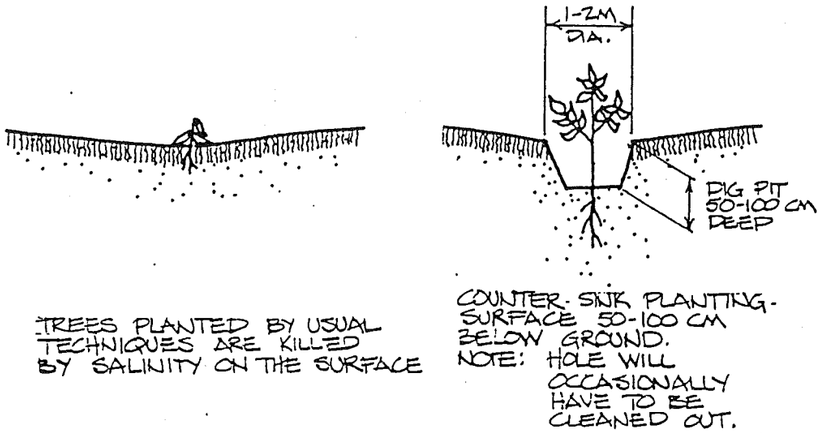


Figure 64: Deep planting technique to establish plants from cuttings (381)

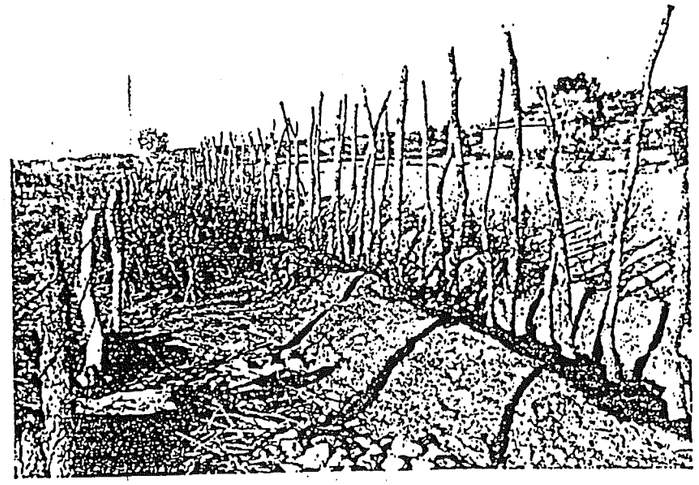


Figure 65: Cutting establishment (381)

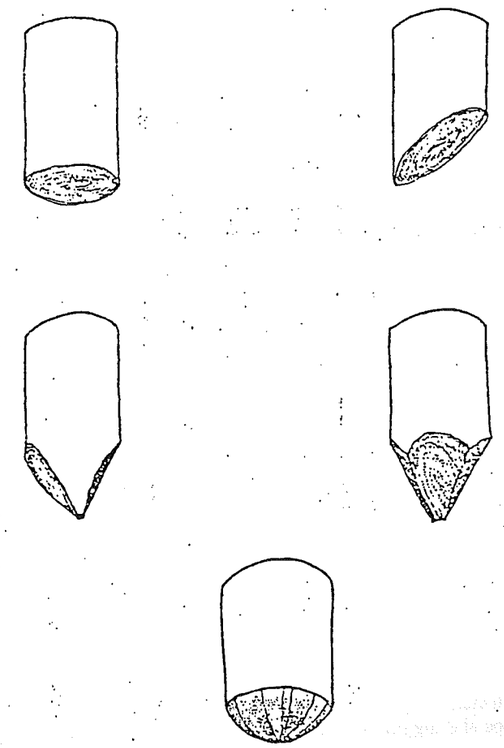


Figure 66: Type of cuts applied by rancheros in Costa Rica to Gliricidia stakes for living fences (20)

6.2.8 Establishment of hedge trees

The pros and cons of hedgerow timber have been summarised (see Table 37). Assuming that the hedger wants a hedgerow tree, the easiest way to establish them is to keep an eye out for straight promising saplings.

Although it is easiest to wait for the right seedlings to establish themselves in the hedgerow, ifthe hedger wants to supplement or speed up the natural process he/she can plant trees within or beside the hedge. Both methods have disadvantages, unless the trees are planted at the same time as the rest of the hedge. Given the difficulties of planting trees in established hedges a better idea may be to plant up waste space near but not in the hedge (44).

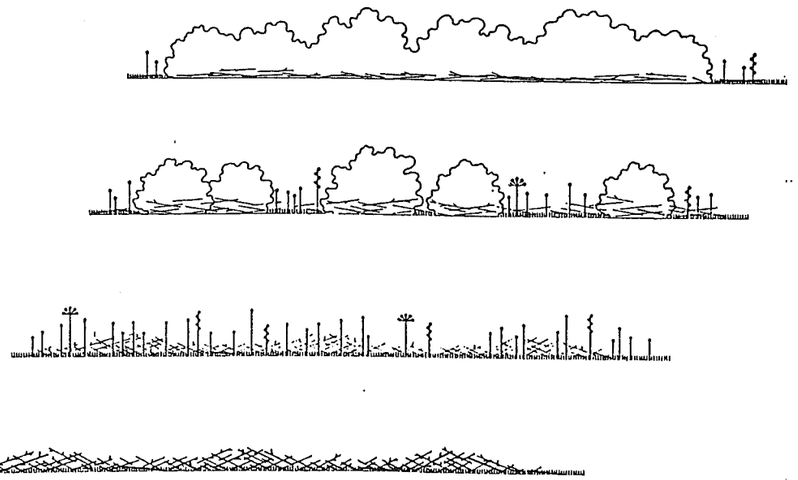


Figure 67: The Benjes hedge

The Benjes hedge is established with brushwood. This establishment method has been successfully applied in Germany. First a herbaceous hedge evolves, which gradually becomes a field hedge. In order to avoid a tree hedge it is necessary to cut back heavily at this stage of succession.

Source:32

Planting in the hedge

This is the best method if the trees are planted at the same time as the hedge. Otherwise this is difficult, impractical, and costly. To plant in the established hedge, the hedger first has to prepare individual beds for each tree by cutting away part of the existing hedge and digging a hole. If the hedge is well established the task may be insuperable.

The trees planted have to be reasonably large standards so that their crowns are well above the top of the hedge. This adds to the cost (44), unless it is possible to obtain wildings which can be transplanted, or very large cuttings. One successful way is the Bihaya approach, in which cuttings of fodder trees are planted (see Figure 19). The Benjes hedges, as successfully applied, use more or less the same approach. Although saplings will grow, it is usual to plant them in advance to avoid competition (32). This advance may be necessary if hedge timber trees are a top priority goal of a hedger.

Planting besides the hedges

Obviously planting the tree next to the established hedge needs much less care than planting in the hedge. However, the trees must be well protected since they are no longer sheltered by the hedge itself.

If the trees have to be planted to one side of a hedge with a ditch, they must be well clear of the ditch itself. When a hedge tree is planted on one side of a ditch and the hedge on the other side, there is a need for controlling the growth of the hedge. Otherwise it may take over the space and resources of the hedge trees. Pruning around the area planted with a hedge tree is recommended. Sometimes farmers plant e.g. an *A. mellifera* security hedge on one side of an irrigation ditch and *Eucalyptus spp.* widely spaced on the other side. Although some of the Eucalyptus will suffer much from the competition with *A. mellifera* hedge, and some will even die, farmers argue that there is no need for ditch maintenance because shading means that no grasses grow. For large-scale border planting this low level of management seems rational (215a).

Suitable species

In temperate zones there is a lot of experience of which species are very suitable for hedgerow trees (see e.g. 44, 189, 337). For tropical and subtropical zones, little information is available and the wisest recommendation is to inspect local practices in order to identify potential trees suitable for growing in hedges and close to them, and to inquire the reasons from local hedgers.

6.2.9 Planting up gaps

There is hardly any hedge which will not develop gaps, if not properly managed. For stockproof hedges, filling up gaps can be very important. For other hedges, e.g. hedges in alley cropping, gapping on a moderate scale may be less important (techniques relating to shaping to avoid gaps are dealt with later).

Tall and short fillers and entanglers can be used to fill up gaps. When there are gaps after planting, it is necessary to ask why the gaps have formed. Reasons can be:

- appropriate species,
- poor past management,
- or the death of individual weaklings,

Replanting the gaps followed by regular trimming will be adequate. For old and decrepit hedges it is necessary to decide whether the whole hedge should be replanted from scratch.

More often, a particular length will have lost its vigour. In this case it is better to enlarge the gap by taking out adjacent poor specimens than to replant an insufficient length. All unhealthy plants in and around the gaps may be removed. The gap may be enlarged so sound growth is found on either side. Soil improvement at the gap may be very important (44).

Local people, when they appreciate their security hedge, have developed various techniques to fill gaps, like using dead brushwood, or undersowing seeds. e.g *Ziziphus spina-christi* under *Prosopis* windbreak hedges. Sometimes cuttings from the hedge are also taken and put into the area where gaps exist in the hedge. This is a common practice where *Pithecelobium dulce* hedge gets gappy (215a).

6.2.10 Protection of new plantings

Young hedges as well as the newly planted gaps must be fenced on both sides against stock and if necessary against herbivores, e.g. (44). This is a very serious challenge, because the dilemma exists that living fences are used as a substitute for costly artifical dead fences.

Wherever it is possible to zone animals (temporarily) and/or advance planting is possible, hedges can be planted some time (preferably two years) in advance. For one example see case study on Bamileke, Appendix 1).

In most cases other options have to be found, e.g to invest for the last time into brushwood (illustration see Figure 68). It will depend on what has to be protected, e.g. if fodder tree establishment is the main concern the Bihaya approach may be useful. In Rwanda it was found that *Cassava* planted close to new hedges can give a certain degree of protection at the initial stage.

A ditch and/or bank, particularly when required for drainage or irrigation, can be a very useful way. However even if the ditch is more than 2 meters wide, goats are said to be able to jump over it (215a).

There is more to learn about how hedgers in developing countries manage to establish and protect the new plantings. Often a resource-poor farmer will not plant a hedge or any other tree in an open field, because he knows that he is unable to protect the young tree during the non-agricultural season. This clearly indicates that problems of land use beyond the farm boundaries have to be resolved at local level.

Managing the new hedge

There are various approaches to early care, but in every case the aim is to obtain a desired strength and form (for details see 6.3).

Good bed preparation and careful planting is a precondition. More is needed, however, especially when the hedger wants to train the hedge to a tight bushy shape for annual trimming. This can only be achieved where the species can stand it by shortening the leader to promote side shooting on every plant.

Whatever the specific regime followed, it is easier to train a young hedge gradually into the desired shape for annual trimming than to reshape it once it has grown away.

Routine care of established hedges: There is not much difference from other tree plantings: Tending the hedge includes control of weeds, pests and diseases, animals, fire and storms. Maintenance fertilizing may be necessary if symptoms are discovered in the field. Watering may be important in dryer areas, but is not always applicable. However only hedge plants which are regarded as very valuable, e.g. henna by women, will be watered regularly.

In hedgerow intercropping, it is important to avoid competition above and below the ground; root competition from hedges can be controlled by tillage or by digging trenches along the hedge in order to trim roots.

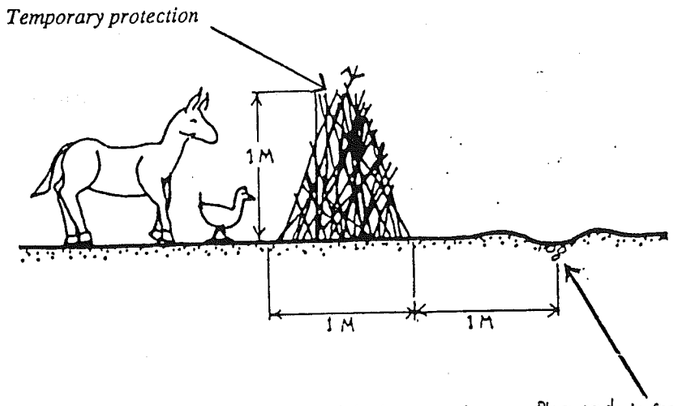


Figure 68: Direct seeding live fences with initial protection (381)

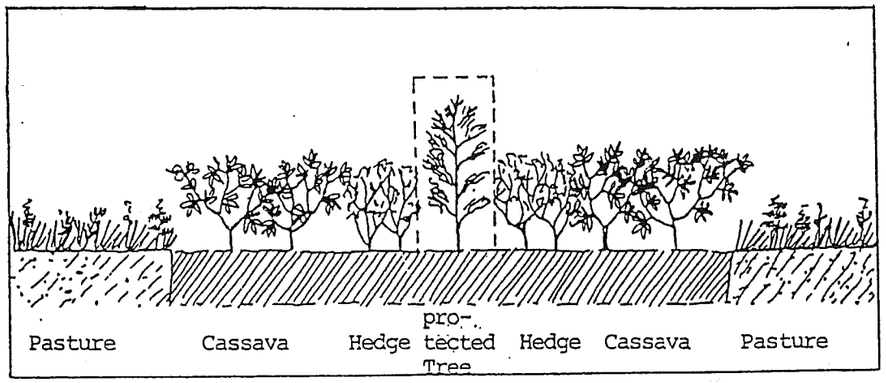


Figure 69: Temporary Cassava fence during early establishment phase of a hedge

6.2.11 Summary sheet

Highlights

- Planting hedges does not differ much from planting other plants. The main difference is that they may need more special initial care than other tree planting.
- Protection of trees, particularly of hedges, is often more difficult than planting or deliberately retaining plants.

Key technical instructions

- The planting season is critical in subhumid and arid climates; in desert climates initial watering and soil moisture conservation techniques, even for hardy species, are required.
- Soil improvements like fertiliser application can boost the development of a hedge.
- In direct seeding the seed required depends on availability, pretreatment, and method of application. If the supply of seeds is not limited, broadcasting of large quantities is recommended.
- Cuttings should be planted not later than 24 hours after they have been taken from the parent plants. To stimulate latex flow, a few centimetesr are cut off the base of the stem immediately before placing it in the ground.
- Hedges can be planted on the flat; on wet land on top of a bank; in wind-exposed sites on the side of a bank, or on a ledge at the foot of a bank is recommended.
- Hedge trees within or beside the hedge should be planted at the same time as the hedge.
- When planting in the established hedge, individual beds have to be made for each hedge tree. Reasonably large standards, e.g. wildings, should be used.
- Planting trees next to the established hedge needs much less care than planting in the hedge. However, the tree must be well protected. If the hedge is invasive and spreading, periodic pruning of the hedge may be necessary.
- Fillers, entanglers, dead brushwood, often obtained from hedges, can be used to fill gaps. Undersowing gaps may be considered as well.
- For a stockproof hedge, hedge trees should be avoided.
- Hedges need initial protection. A ditch and/or bank can be useful; however animals, particularly goats, cannot always be controlled by a small ditch.
- Protecting a young security hedge can be done by choosing unpalatable species, guarding it, or using temporary dead fences like brushwood; even solar-powered electric fences and digging trenches to prevent animal access have been suggested. Non of them have been totally satisfactory.

Lessons learned

In a situation of free-roaming animals, protection of the young hedge is the challenge, not planting out. If the land user is very keen to establish and maintain a hedge, on-site management issues can usually be tackled. Solutions to problems beyond farm boundaries (particularly protection from free-roaming animals) are a prerequisite for motivating resource-poor land users to plant and protect their hedges.

6.3 Shaping of hedges and hedge trees

The form and habit of growth and ultimate shape and size of any shrub will depend largely on the characteristics of its variety. However, form and feature can be influenced greatly by human interference. The following discussion focuses on how to shape hedges to achieve the desired management goals. The general purpose of pruning hedges and types of prunings and the effect of trimming as well as basic silvicultural techniquess with regard to shaping hedge trees are summarised.

6.3.1 Hedge-specific considerations of pruning

Pruning is the removal of any part of a plant. The general purpose can be threefold:remove poor quality wood; shape the plant: regulate the quality and quantity of outputs. There may be a necessity to remove poor quality wood, such as weak twigs, dead or diseased branches and damaged stems (168). (a standard text book on pruning consult 47).

A common feature of plants used as hedges is that they can usually tolerate heavy pruning. As the hedge grows, the ultimate shape and form must be determined. Training to the desired shape is easier than altering an impractical design.

Non-natural grown hedges need shaping. The aim is to alter the form or size of a plant; this can improve its appearance or usefulness. Several goals can be achieved by pruning:

- to stimulate a good regrowth of transplanted seedlings;
- to obtain a dense base;
- to harmonize the development of the above-ground and underground structure;
- to provide more material for the fortification of a hedge.

Pruning is essential to regulate plant vigor and development and to ensure healthy plants. Within certain limits pruning enables one to control shrub shape, size, and form. Pruning can either keep a plant small or make it grow taller; heading back a plant (reducing its size) keeps the plant denser and sturdier and creates a more formal looking plant.

6.3.2 Types of pruning

With regard to pruning, a basic distinction has to be made between a

- natural (informal) hedge and
- a trimmed (formal) hedge .

The natural look is achieved by exploiting the character and habit of the woody perennials allowed to grow in their own way. Informal shaping attempts to maintain the natural growth habit. The important pruning method is thinning.

A formal effect is achieved by cutting branches back to the main frame on the ground at frequent intervals and by removing only part of the branches. Formal shaping is the style of pruning for neatly trimmed hedges (e.g. vegetable hedges). An artificial growth habit is maintained (47, 168).

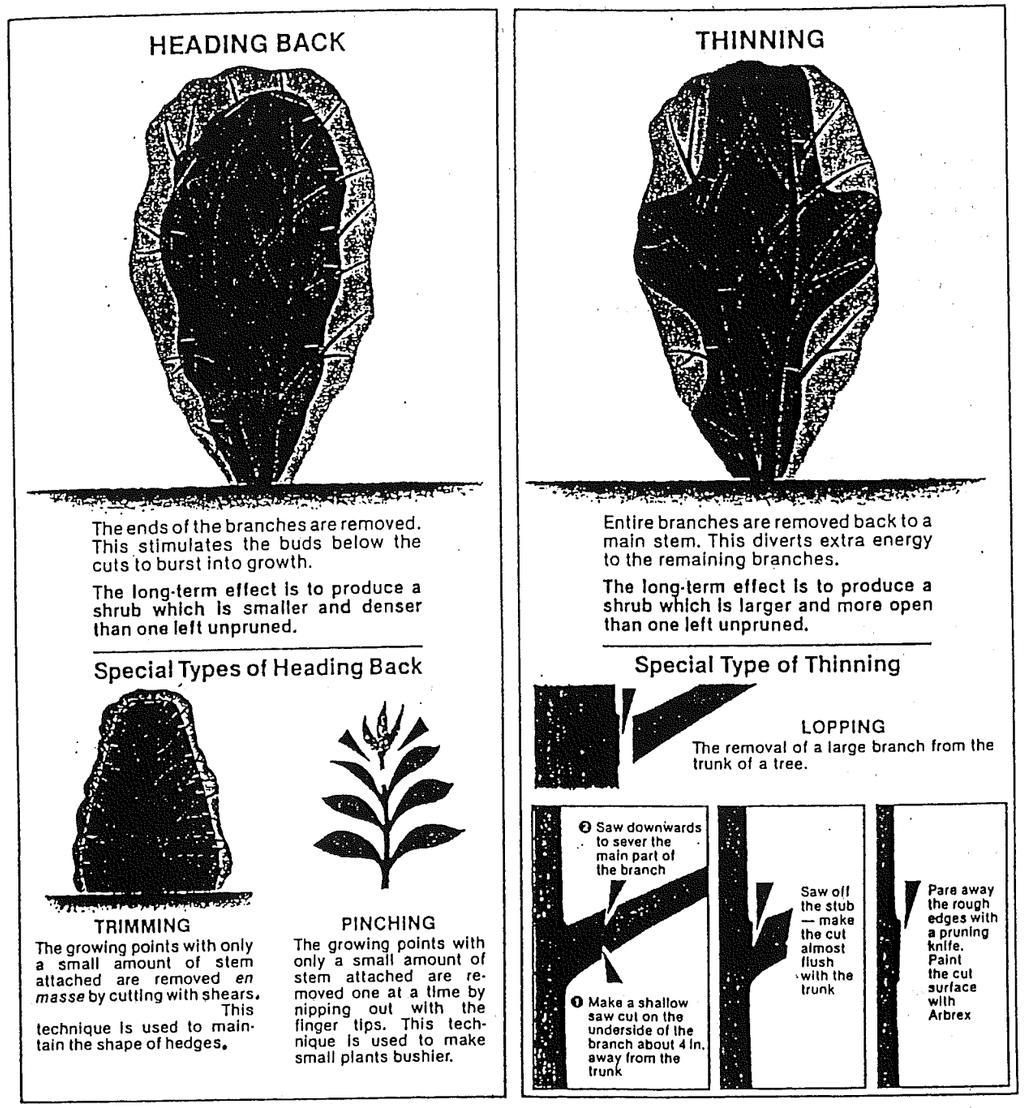


Figure 70: Heading back and thinning - two basic methods of pruning a hedge

modified from 168

The main types of prunings (illustration see Figure 70) are:

- heading back,
- thinning.

Heading back

This is cutting back the ends of the branches. This stimulates the buds below the cut to burst into growth. The plant will grow with multiple branches where there was previously only one. The long-term effect is to obtain a shrub which is smaller and denser than an unpruned one.

Special types of heading back are:

- trimming,
- pinching,
- coppicing and pollarding.

Trimming is performed by removing en masse a small amount of stems by cutting with shears or a machete, etc. This technique is used to maintain the shape of the hedge. This term is also used as a general category (168). Most hedges are trimmed frequently. Trimming usually means "short back and sides". This is the simplest form to cut but not the best one for hedge growth nor for birds (44).

Pinching is the technique by which the growing points with only a small amount of stems attached are removed one at a time by nipping out with the finger tips. This special form of cutting back is also called clipping (168).

Coppicing, i.e hard cutting to the ground of many shrubs results in strong new growth with fewer flowers and fruits of improved size and quality. Conversely, if one prunes lightly the vigor of new wood is decreased, although, at least initially flowers and fruits are freely produced. Hard cutting may be essential to start to form a straight bole but favours flowering and fructification.

Thinning

Taking out whole branches or plants is called thinning. With thinning the plant energy is diverted to the remaining branches, which will elongate. Thinning produces a taller, more open plant with a natural individual growth. One special type of thinning is lopping, i.e. removal of a large branch. Strong light pruning produces a thick growth of leaves, limbs, flowers, and fruits; weak light pruning usually produces thinner growth, fewer flowers, and fewer fruits.

6.3.3 The effects of trimming

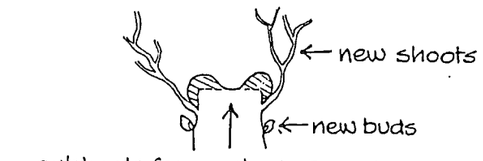
The effect of heavy trimming during the life cycle of a hedge

To understand better the impact of trimming it will be related to different life stages of a hedge. Although this example below draws heavily on experience in temperate zones it may be useful for a better understanding of the potential and problems associated with heavy trimming. Trimming seems to accelerate and exaggerate the ageing of the shrubs.

Hedges managed for trimming from the time they are planted never require heavy top-cutting and so keep healthier longer, with less distortion of their form, than mature hedges. Later they are topped and lopped to be forced into shape.

Shoots proliferate from just below the cut ends of the stems. There is some increase in side branching. Each shrub species responds slightly differently to trimming. In general, though, the effect is as illustrated below (Figure 71).

Phase one



Phase two

Phase three

Phase four

Figure 71: The effect of heavy trimming during the life cycle of a hedge (44)

The stems continue to thicken each year just as in normal trees. The cut surfaces develop into knobs of scar tissue as the cuts heal over. The first stage continues, leading among lateral- branching shrubs to increasingly deformed and interlocked branches. This happens gradually over several years. The result is similar to the natural stunting that occurs where hedges grow in harsh climate conditions. During stage one and two the hedge remains stockproof and may become even stronger due to the increasingly dense outer growth and the interlocking of branches of each plants with those of its neighbours. Eventually, the bottom and inter branches die back. This leads to the development of gaps at the base of the hedge and a shell-like growth form. In temperate zones it has been observed that this may occur after around 10 annual trims or in some cases not for half a century. At this stage gapping is a big problem.(stage three). Finally the hedge gradually loses vigour, signalled by slow regrowth after trimming and the beginning of die-back in weaker plants. (stage four). The main stems continue to thicken but there are now only a few very gnarled side branches. Foliage is confined increasingly to the top of the hedge. Gaps may become extensive as weak plants die completely (Stage five).Finally the hedge is dying or derelict, more gaps than barrier, although surviving shrubs may spread into the air space left by neighbours. Some suckers may fill the gaps. In other cases only occasional half-alive stumps remain. It is high time for replanting.(Stage six)

Early pruning (trimming): Purpose and timing

Purpose and principle: The new hedge is first trimmed regularly until it takes on an appropriate shape. Regular trimming of hedges stimulates the growth of the side shoots making the hedge dense and eventually stock proof.

Early pruning is needed to shape or direct growth as well as fastening the plant to a support structure. Hence, undesirable development of a hedge is avoided which may be difficult to correct; thus making work quicker and easier. There are two basic reasons for early cutting back:

- harmonising growth patterns of different hedge plants;
- and giving the desired shape to a hedge;

To reconcile different vegetative rhythms of the species grown together in a hedge, it is essential to prune those species which grow very fast, to avoid suppressing the slower growing plants. *Cajanus cajann* association with *Leucaena leucocephala* ends to overgrow during the first years after establishment. Once *Leucaena* is well established, this disproportion disappears. This disturbed balance has to be compensated particularly when the purpose of the hedge is to produce animal feed or mulch. *Tithonia* grown together with *Leucaena* also has a different growth rate. *Leucaena* can be cut back at a height of 80 cm, while *Tithonia sp.*is cut at a height of 20 cm (Figure 73). If necessary, it is also possible to prune the fast-growing species more frequently (298).

From the standpoint of resource-poor land users, early trimming may be regarded as the first harvesting, e.g. to obtain vegetable material.

If the goal is a well furnished and thick hedge at the base (necessary for erosion, frost, and noise protection) it may be advisable to cut back the hedges sufficiently and frequently while young, and during all periods of active growth (332).

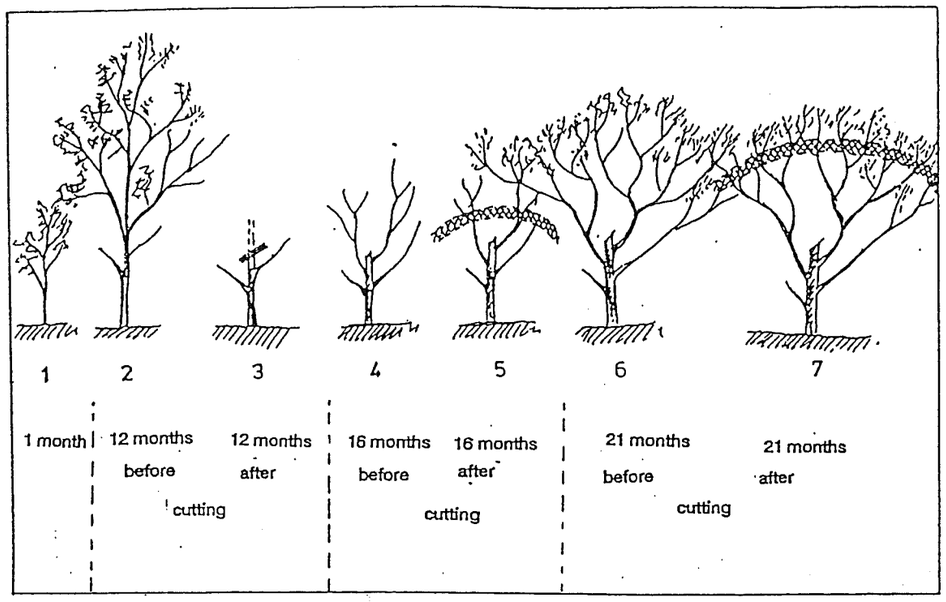
Bare-rooted plants are intended to produce a dense hedge and should be pruned to about half of their original height. Container-raised seedlings and other plants that will naturally produce an open hedge should be pruned back about a third, both on the top and on the sides. Hedges can develop a bare base when there is not enough light at the bottom of the hedge.

This problem may be aggravated by insufficient water and nutrients. Trimming should be done upward or rather narrowly towards the top. By this measure the lower part will not be overshadowed by the upper part, it will be kept thick and lasting longer (231, 277).

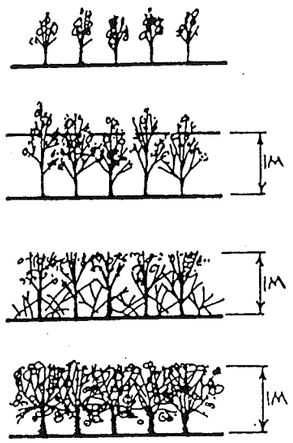
Trimming the new hedge once is not enough; it needs trimming back several times a year. It is important to avoid trying to achieve the final desired hedge height at once. The developing of gaps at the bottom of the hedge has to be discouraged. The only way to prevent this is by pruning, but pruning before the hedge grows too large.

Timing: The pros and cons of pruning hard at the time of planting is often debated. Provided that all care is taken in the operation and it is done at the right time, establishment may be more certain. When a lack of roots is suspected, hard pruning of the main shoot, back to more dormant buds, is often a great help (47).

An example from Rwanda



Proper fence pruning



Trees in fence line are getting established. At this stage they may well need protection until they become stronger.

Ready for pruning. Cut all branches above desired height. Use cut branches to plug holes between plants.

After pruning the fence looks like this. Further growth will fill in remaining voids.

From this stage on hedge only needs periodic trimming.

Figure 72: Formation of a hedge (298,381)

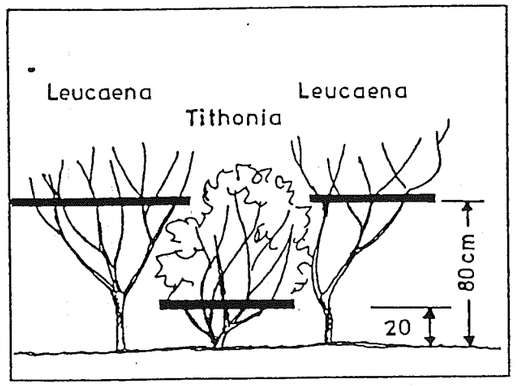


Figure 73: Managing different growth rates in multi-row hedges (298)

Sometimes it is advantageous to make the first pruning late in order to allow a good root system to be established and to control weeds. With *Leucaena leucocephala* and *Calliandra calothyrsus* the first cutting should be made when the diameter is about one thumb thick. Frequent prunings will increase the volume of the hedge until its definite form is reached (see Figure 17). The need for early pruning has to be balanced against the advantages of late pruning in a site specific context (298).

Profile and height of trimmed hedges

As the hedge grows, the ultimate shape must be determined. The previous discussion showed that training to the desired shape is easier than altering an impractical design.

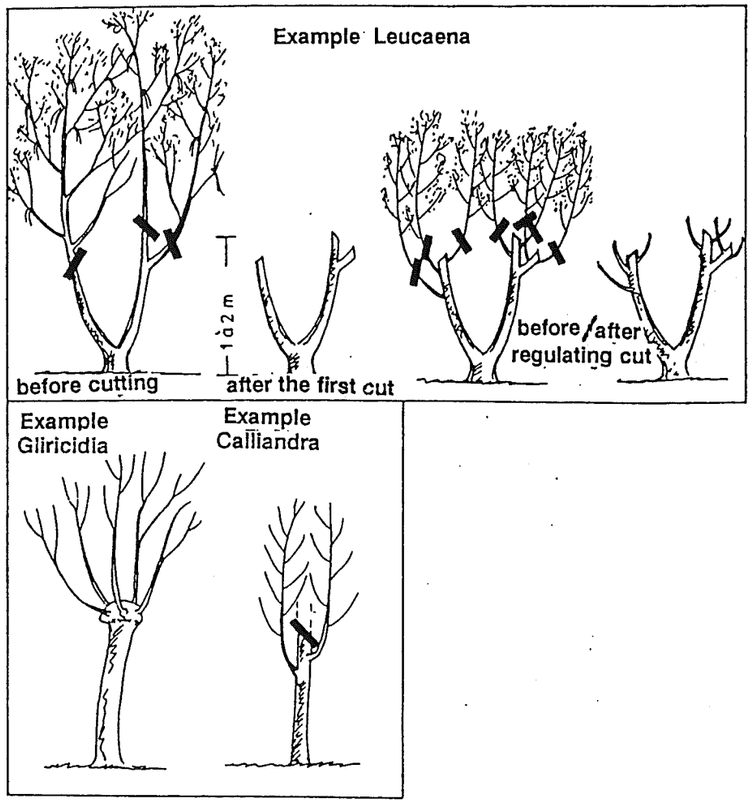
There are various options about the best shape, but there is a consensus that a hedge must have a sound bottom (163). Exceptions are living fences supporting wire.

Basic profiles to which hedges can be trimmed are depicted in the following figure. The height can be varied relative to the width to produce any final shape. The profile of a hedge is of some importance both from the point of view of its effectiveness as a barrier or windbreak, and also for saving labour in maintenance.

The choice of profile and height depends on several factors:

Stock fencing requirement: The only limitation here is that the hedge be high enough and that long term growth be enhanced as much as possible. A 100 cm hedge may be adequate for sheep (breeds differs in their hedge-running abilities), but up to 130 cm required for cattle. The A-shape, because it tapers to the top, must be left longer than the other forms to keep it cattleproof.

A bushy shape is also of great value to wildlife. A height of at least 1.8 m is important for sheltering livestock and wildlife.



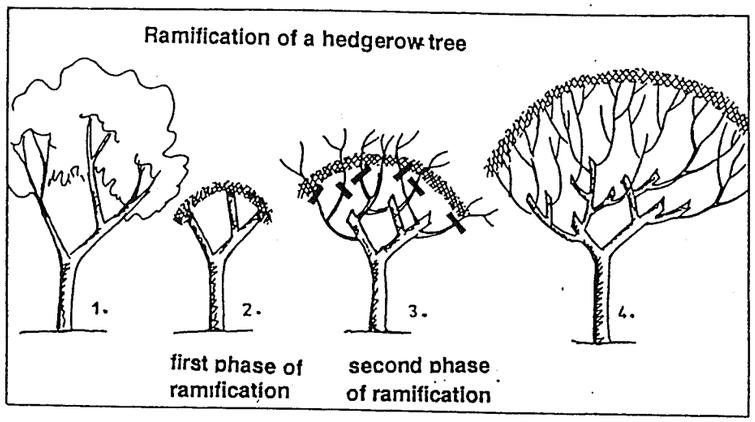


Figure 74: Formation of a pollarded and lopped tree

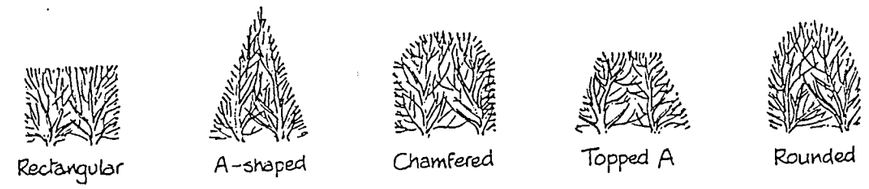


Figure 75: Profile and height of trimmed hedges (44)

Shelter or windbreak requirements: The A-shaped or topped A-hedge makes the most effective windbreak (44) (see also 3.10). For windbreaks, the height should be at least 1.8 m, narrow in the base, with straight sides, and clipped to stimulate growth; the leader should not be cut until the desired height is reached (233).

The A-shaped hedge exposes both sides to maximum sunlight. Regrowth is best if the more shaded side is trimmed to a more gradual batter (= the slope of a hedge), allowing low branches to get as much light as possible. Rectangular hedges which show signs of gapping on the shady side can sometimes be brought back to a satisfactory condition by trimming to the A-shape.

Against the A-shape is the argument that trimming "nibbles the shoots" on the near or ditch side, due to its asymmetrical cross-section (this is illustrated in the following diagram (44).

To conclude, the rectangular pattern is the most problematic. The dense top casts shade on the branches below, inhibiting much of their growth and eventually killing them. The bottom of the hedge becomes too open and no longer stockproof (44). If this type of hedge shows signs of gapping on the shade side this can sometimes be improved by trimming to the A-shape (163).

The A-shaped profile has several advantages, especially if cut to about 1.8 m. Cutting is easy and requires only two runs, one on each side. Its slope allows trimming to fall off so that the hedge itself is not easily damaged. The narrow top facilitates the passage of air, causing the minimum of turbulence. Extensive cutting of the top encourages active growth lower down providing a firm barrier and also good cover for wildlife. The high apex also facilitates the inclusion of young saplings which are otherwise left projecting above the line of the hedge.

The topped A-shaped and chamfered types aim to combine the advantages of the other two and are both widely used, especially in conditions where the land users requires a bulky hedge. Their disadvantage is that they are less economical to maintain, requiring four runs of cuttings. Round hedges have been used when all maintenance is done by hand. They are confined almost exclusively to recreational areas (93).

Stock-proof hedges should be allowed to grow to a certain height of at least 1.4 m and either be trimmed to a certain width or left bushy at the base, trimming towards the apex.

*Cupressus spp.*in dense hedges often produce a disequilibrium between the rapidly developed parts above ground compared to roots. This results in a shedding of leaves and great sensibility to wind, caused by insufficient rooting. Climbers like *Desmondium spp.* and *Caesalpina spp.* need special care to prevent them from growing out of control.

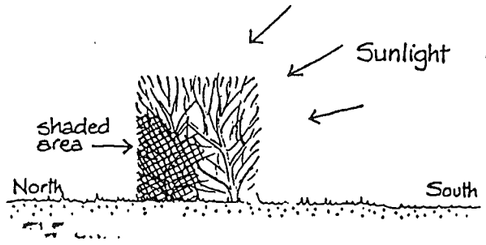
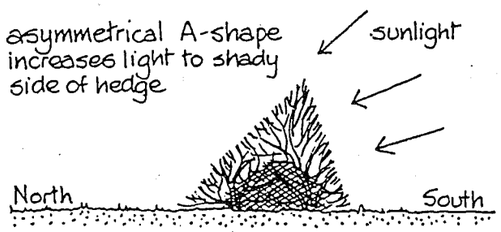


Figure 76: Self-shading of a rectangular hedge (44)



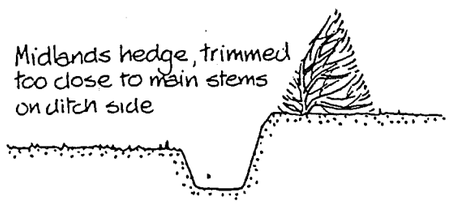


Figure 77: Effects of an asymmetrical A-shaped hedge (44)

6.3.4 Shaping hedge trees

Hedge trees can be grown from nursery stock or spontaneously in hedges. Small-scale farmers often leave a few vigorous trees uncut when trimming hedges. Poles or even high quality timber can be produced in this way.

Tall trees need training to ensure height and marketable timber. For good quality (commercial) timber the section of trunk without branches has to be as long as possible.

Principles of directing growth of a hedge tree

For an open-grown tree the terminal shoots on all scaffold (principal) branches are left and all laterals are eliminated or shortened. For a tree with a straight trunk all branches below approximately 2 m above the ground are cut off. Cutting should be done when the tree is tall enough to retain 3-4 scaffold branches.

Pruning of a hedge tree depends upon age and maturity. The general principles of pruning as a means of correction and improving the shape of a plant are valid for hedge trees as well. However, there are certain factors which need special consideration, particularly to obtain a straight bole (branchless trunk).

With many species, early training affects the ultimate form and size. The retention and vigour of the leading growth will be the decisive factor. By training, the shrubs may grow to a small standard tree. Different types of trees need specific manipulation (overview for bushtree, standard with leader, conifers, etc., see 47).

Trees developing on site: When pruning and training hedgerow trees in the field, it must be realised that the environment as a whole has probably been changed.

A hedgerow tree, properly cared for and maintained, often has a more settled and favourable habitat than before; for there are no grazing cattle sheltering beneath to compact the soil, and to rub off the bark or to eat the lower branches. There is also little chance of damage from close cultivation, etc.

The need for correction of any fault is important for following reason:

- The balance of the tree may be lost and a gap will occur which will often take several years to correct.
- The increased light will fall on the stems following the removal of a large limb and may promote the production of epicormic growth in this part of the branch system.
- The loss of a large branch is a severe shock to a young tree's root system. A portion of it may be killed, increasing the risk of infection (47).

Basic silvicultural techniques

If the aim is to produce high-quality timber the basic silvicultural techniques applied to hedgerow trees are coppicing, develop a leader, high pruning, and thinning.

Coppicing: Some plants may recover after planting or extreme hardship like drought, and have minimal growth. The only way to solve the problem is to cut at 15-20 cm above ground, to produce new vigorous growth. This operation must only be done after the plant is well rooted. Cutting back may be also necessary in order to restore the balance of shoots and growth.

Development of a leader: The period of rapid growth following establishment is often very noticeable, especially with faster growing shrubs. A completely new leader is often formed, and this is welcome, provided that it has developed from the original one. If necessary the lower branches of the old crown may be gradually removed. Further selection and training of the prominent leader may be desirable. All this manipulation also supplies material for use as fuel, manure, etc. Maintaining the dominance and the vigour of the terminal leader allows the tree to develop in height and straightness, favours the growth of the trunk and diminishes the growth of the lateral branches. When the terminal branch is accidentally destroyed the lateral branches will develop and the tree forms several leaders. They have to be replaced by a branch best located for this purpose.

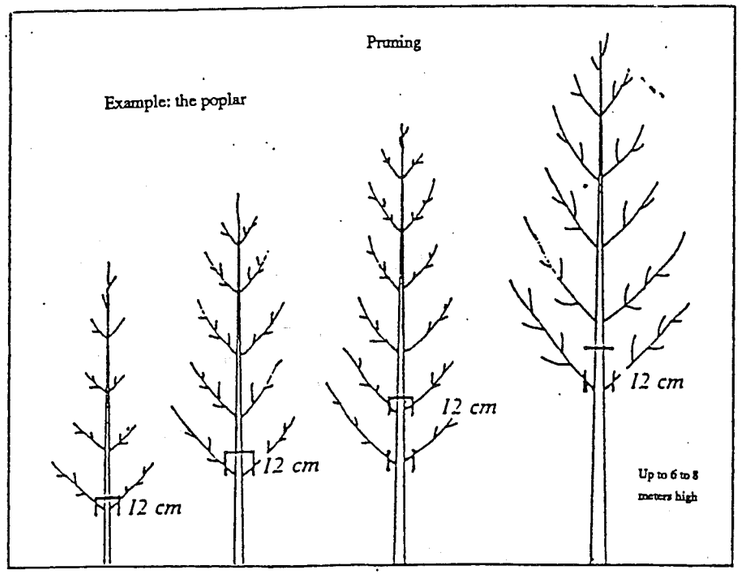


Figure 78: Forming a straight bole by high pruning (189)

At the developing site it is obviously necessary to train a leader. Encouragement and selection are usually necessary in the first instance. This may not be possible until vigorous new growth is evident. Fertilising and mulching is advisable to encourage this. When growth is very long and straggly, perhaps as a result of development through a tall, sheltering hedge, some cutting back may be necessary (47).

High pruning: Forming a timber with commercial value requires high pruning. It is important to have a trunk without branches (see Figure 10). The lateral branches have to be cut when the trunk reaches a diamanter of 10-12 cm (compare Figure 78).

Thinning: The removal of plants may be important to reduce the population and accelerate incremental diameter growth. There should be no hesitation in deciding to destroy poor and unsuitable species. Replacement may be the better policy.

Trees are frequently used as a means of supporting fences with nails or staples driven into the trunks. The policy must be to remove them if they can be pulled out without further damage; but otherwise it is better to cut them short leaving the remainder to be buried. If wires encircle the trunk these should be cut. Epicormic growth on the trunk and branches should be cleaned up.

Growing close together

Mature or semi-mature hedgerow trees growing close together call for special care. It is wrong to expect too much of each of these trees individually, for a shapely plant cannot be produced under these conditions. In a line of trees in the direction of the prevailing wind each benefits from the shelter of its neighbour and is thus slightly taller. Each one depends on its neighbour for protection and the removal of one may affect the others to such an extent that if a gap is formed the remainder on the lee side may be blown over or severely damaged.

If the removal of one or more of these trees becomes necessary, it must be carried out very carefully in order to avoid damage to those which remain. In order to minimize root disturbances it is often necessary to cut the stump off at ground level. It may also be wise to reduce the height and spread of those in the immediate vicinity of the gap so that there is less chance of them blowing over.

Often after opening out, thickets of epicormic growth appear on the main branches and even on the trunks as a result of more light (47).

6.3.5 Other techniques: laying and pollarding

For stockproof fences bending or layering may be essential. Pollarding and the closely related lopping are basic management techniques applied to taller trees.

Laying

The purpose of laying a hedge is to make a poor hedge into a stock-proof barrier and/or to rejuvenate the hedge plants themselves by encouraging them to grow fresh shoots up from the base of the old stem. There are a number of different ways of laying a hedge .(description see e.g. 44, 163).

It is also called cut-and-lay: i.e. the process of cutting part of the way through a standing tree and then bending and positioning (laying or layering) the stem to form a barrier. Synonyms include cut and peach, pleach, plash (44).

The basic technique of all hedge laying is to cut and slash the main stem of a hedge sideways, intermingling stems and shoots to form a stock-proof barrier; stakes of hedge plants about 40 mm in diameter are driven into the hedge bark between the stems of the cut and placed at intervals of 4.5 to 6 m (44, 163) (see also under 3.5).

Pollarding

Pollarding is essentially coppicing at a height sufficiently above the ground to prevent stock from grazing the young shoots. The main effect of this pruning technique is to develop a long bole (trunk of the pollarded trees). The trunk is cut at a height of 1.5 to 3 m above ground. The rejected branches and shoots are exploited after 1-3 years. The techniques of pollarding at optimum time varies from species to species.

To reach the desired height of the bole it is important to cut the lower branches. With the help of this method, one can obtain additional wood (e.g. firewood) and get a crown above the general height of the hedge (298).

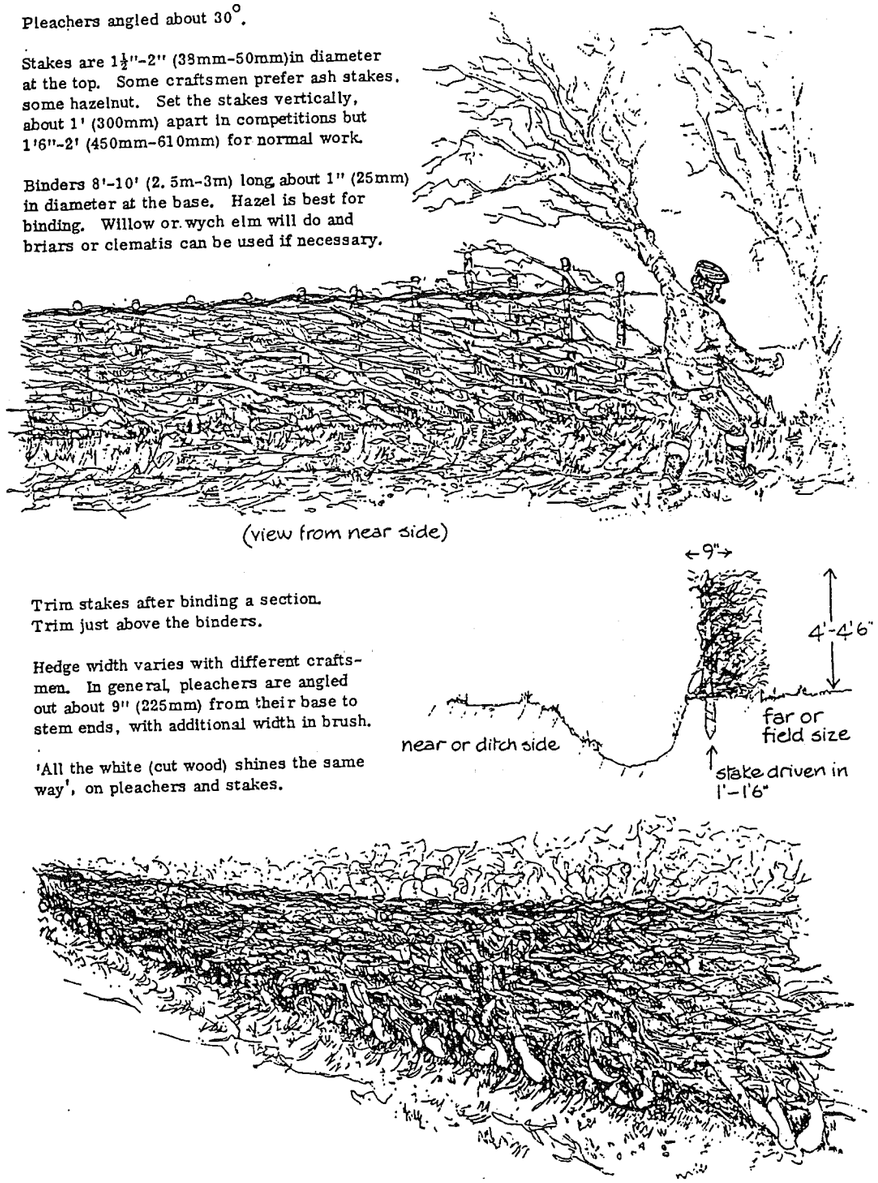


Figure 79: Principles of laying

6.3.6 Summary sheet

Highlights

- Basic style of pruning depends on the main purpose of the hedge and availability of land and labour.
- The management/manipulation strategy has to fit into the farmers' context, e.g. if a very dense structure is necessary (e.g. for frost protection), this can be achieved by planting a natural hedge (structure will give the effect) or trimming a hedge, and possibly planting it on a ridge to increase the plant density.
- Pruning can be labour-intensive and not worthwhile for resource richer farmers. For small-scale farmers pruning may be welcome to obtain additional fuel, fodder, etc.

Key technical instructions

- As the hedge grows, the ultimate shape and form must be determined. Training to the desired shape is easier than altering an impractical design.
- The basic types of pruning for hedges are heading back (trimming, pinching, coppicing) (formal hedges), and thinning (informal, naturally oriented hedge).
- Early pruning is essential for regulation of the growth and shape of a hedge. Regular trimming stimulates the growth of the side shoots.
- To avoid gaps at the base of the hedge, trimming should be cut upwards or rather narrowing towards the top (A-shape), to avoid overshadowing of the lower parts.
- The choice of profile and height depends on purpose and management intensity. Stock fencing requires a minimum height. An A-shaped hedge must be left taller because it tapers to the top. For shelter and windbreak a minimum height is required. An A-shape or topped A-shaped hedge is the most effective windbreak.
- If long-term growth is of prime concern (e.g. stock-proof hedge) an A-frame usually gives better results than rectangular hedges.
- To produce high-quality timber from a hedge tree the main leader has to be maintained and high pruning performed.

Lessons learned

Local hedgers and tropical horticulturists often have skills in pruning. Hence there is a strong argument for incorporating in existing extension programs special components designed to help poor land users with appropriate pruning of hedges and hedge trees.

6.4 Harvesting and rejuvenation of hedges

Hedges are grown to meet demands and/or solve problems. Harvesting obviously depends on the type of intended product(s), site, species, and management. How various management techniques and styles can be applied to obtain desired output(s) will be summarised in this chapter (to details of specific uses see Chapter 3). Old hedges have to be rejuvenated. This is also dealt with.

6.4.1 Harvesting techniques and tools

State of knowledge

Research: In the past, silvicultural research focused on harvesting methods (clear cutting, coppicing) to maximize production. Multipurpose management with traditional harvesting techniques like pollarding and lopping is very often applied by local hedgers in developing countries. Not surprisingly the organized knowledge on these traditional techniques is to a great extent empirical, based on farmers' trial and error. For a limited number of species data exist on yield and how to optimise biomass. This is all very useful, particularly in understanding management options.

What is even more important is that research has to fit into the context of the target groups. For user-friendly hedgerow technologies, ease of management or other labour considerations are more important than maximising yield.

By comparison with our knowledge about production data from single species, our knowledge about multipurpose management of hedgerows is very underdeveloped. The examination of nutrient drain caused by multiple harvesting also deserves greater attention.

Development: Today countless projects recommend multipurpose tree use. The technical recommendation and extension material with regard to appropriate harvesting exists only for a few species (best informaton on *Leucaena*: fuel (267) and fodder (266) and *Gliricidia* (265).

Promotion schemes for fast-growing multipurpose trees by development organisations often ignore the danger that total tree harvest and/or short rotation can lead to a nutrient drain.

Techniques

Certain tree and shrub species have the capacity to regenerate new growth from stumps, roots, or branches after being cut. There is no general agreement on harvesting terms. Pruning is the most comprehensive one related to all kind of removal of plant parts

An illustration and a brief description is shown in Figure 80 (for further information consult Table 50).

People sometimes manage hedges and hedge trees to ensure a steady supply through coppicing and pollarding of certain species: both can be effective methods of obtaining a sustained yield of small-diamter wood from a stand of trees over a long period.

Coppicing: Probably the most useful and widespread form of early management is coppicing, where the hedge is cut back close to the ground and allowed to regrow; normally a number of shoots replace the original single stem. It may be the oldest form of hedge management. This is one of the most widely used harvesting methods for arid regions and very common among farmers.

Coppiced hedges usually give a high total biomass yield and are specially suitable for the production of fuelwood. Several rotations of coppicing are usually possible with most species. Some have been harvested on an annual rotation for more than 30 years in humid zones. Harvests from the second onward can give more yield, because stool and roots are well established.

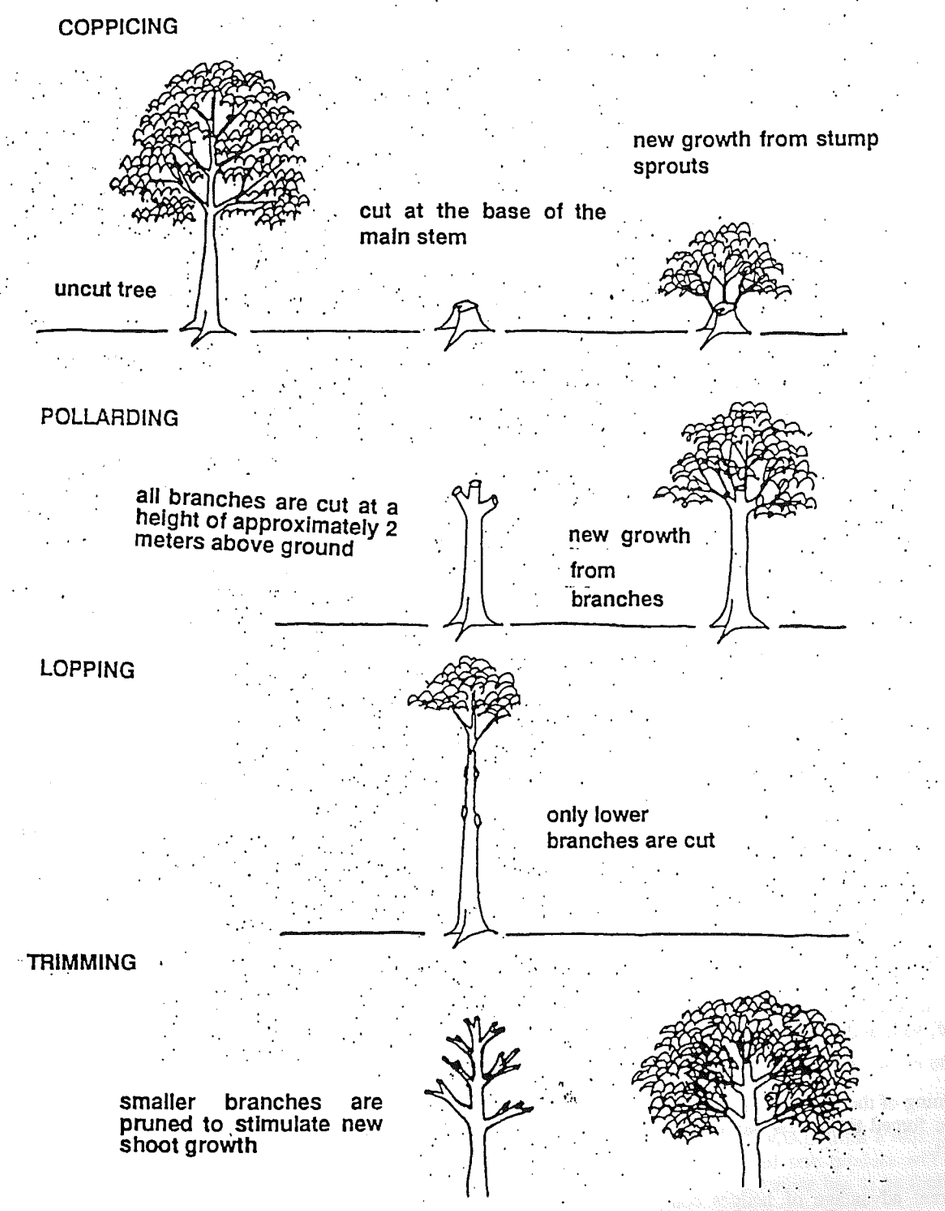


Figure 80: Different harvesting methods for hedges (381)

Pollarding: This is a technique for cutting off the crown of the tree leaving it to send out new branches from the top of the stem. It is important where animals are not to reach the leaves for browsing (e.g. forage reserve for dry season).

Lopping is the name given to the technique of cutting off one or more branches from a tree. Villagers in many countries e.g in Nepal and Mexico have mastered the fine art of lopping branches off tall trees for use as fuel or fodder, without killing them. Hence lopping is particularly suitable for hedgerow trees.

Trimming: In developed countries, trimming of hedges is regarded mainly as form of intensive management to develop or keep the desired shape of a hedge. For the hedger in developing countries, this may be primarily considered as a quick and constant way of harvesting. Pinching, a special form of trimming, is very useful for harvesting leafy vegetables from hedges.

Tools and style of harvesting

Mechanical harvesting of hedges is practised by wealthy farmers. For poor farmers manual harvesting is very common. Controlled grazing may be considered as well. Tools used for harvesting like machetes, axes, and saws are the ones farmers use for other jobs. More low-cost tools may be needed.

A compromise has to be found between maximising yield, achieved by very high (forage) or low cutting height (fuel). Ergonomic considerations are important as well. Ease and flexible harvesting may be more important than maximising yield.

For *Leucaena* forage hedges, a cutting height of 80-100 cm is advisable. This height allows plants to retain enough leaves to ensure rapid regrowth after harvest and is comfortable for harvesters using sickles or knives. For the first cutting height has to be low to stimulate branching for forage.

6.4.2 Harvest timing and frequency

Frequency

Harvest intervals will vary greatly with temperature, light, the variety used and, desired output(s). With higher temperature and high light intensity harvesting can be expected to be more frequent than in colder, darker regions. Regular and frequent harvest is possible with plants which have a high capacity for coppicing or pollarding. Certain vegetables can be harvested on a weekly basis. Biomass for forage may be harvested several times a year, or if need be, once a month. Forage should be harvested before flowering occurs or forage quality declines (as stems become more woody). For fuel the harvest intervals should be greater.

Beginning, subsequent harvesting and season

When to start: The time to begin the first harvest is an important question. The time is predetermined by plant, climate, soil, and management. In more arid zones and/or poorer soils, harvest starts later than in more humid zones.

The timing of the first harvest also has to be adjusted to needs (subsistence, contingency). Resource-poor people may be forced to harvest before the optimum time, e.g. soil conservation versus fuelwood need may be one conflict.

The great advantage of hedges compared with conventional tree harvesting techniques is that hedges are particularly suitable for early harvesting in most cases.

Hedges for vegetables, fodder, mulch should not be harvested until they are well established, which can take six months in optimum growing conditions and up to a year or even more in less well suited areas, e.g. vegetable hedges can often be harvested after 2 months. To obtain more woody biomass for fuel and allow the development of a good rooting system (erosion control) the first harvest should be later.

For hedge trees or pollarded/lopped trees, harvesting can generally start after 4 years in the humid tropics, in semi-arid regions after 10 years.

To stimulate branching and increase total biomass yield (fodder, mulch, etc.) in later harvests, it is advisable for many species (like *Leucaena leucocephala*, *Gliricidia sepium*) to cut back to 20-30 cm for the first harvest. Other species like Cajanus cajan (most cultivars) need a higher cutting height.

Subsequent harvests: Subsequent harvest intervals must be set to obtain a balance between yield of plant material and quality, e.g. for forage, longer intervals increase yield, but the quality of forage decreases as stems become more woody.

Season: The harvest season can influence the sprouting response; generally it should take place while the plant is dormant. Many plants are fairly flexible (e.g. *Eucalyptus*) about the time of harvest; but more research is needed to determine the optimum cutting period.

Wildlife and harvesting

Wildlife considerations may require special care. For many animal species, particularly birds, trees form the most important component of the hedgerow flora (see 3.11).

The preservation of desired saplings may be important both from an economic and ecological point of view. A general rule is not to cut the whole hedge at the same time (93).

6.4.3 Multipurpose management versus maximising one output

Multipurpose management

Diverse outputs are important for small-scale farmers and poor people. A good example of multiple management has been noted on the slopes of Mount Kenya: during the life cycle of *Grevillea robusta* local people have mastered continuous lopping and pruning to obtain a steady supply of fuel and fodder, and a quality timber tree (see more 3.6).

Most of the vernacular hedgerow systems give more than one output, e.g. in the Combretum-rice system, green manure and fuelwood are the main outputs; in the Sierra of Peru, wind protection and fuel are most important; in floodland farming, fertiliser trapping, and fuel and timber as a by-product (see Appendix 1).

As mentioned, pollarding can contribute to fuel and fodder production. The rejected branches and shoots can be exploited after 1-3 years. With this method it is also possible to avoid cutting all biomass at the same time. The same technique of growing a straight trunk but pruning more foliage can be used in order to get extra fodder products in the hedge.

Maximising output

Hedges can produce a wide variety of products, but can best serve only one main purpose at a time. For example, leaves are produced when the hedge is frequently coppiced and hence does not produce seed. If both seeds and leaves are desired from one plant, the production of both will be lower than it would be when only one product is regularly harvested (300).

The realization that it is rarely, if ever possible to maximize the production of all products from a multipurpose tree simultaneously, must be taken into account in design. Increasing the yield of one product will almost inevitably reduce the amount of others. The implication is that some sort of compromise has to be looked for, either by managing the tree to maximize one product or by compromising the multipurpose design (331).

Pods vs. wood: With some plants like *Prosopis juliflora* or *P. chilensis* the pods are a very important source of animal feed in arid regions. Experiments with *Leucaena leucocephala* confirmed that the number of pods formed was least in high-density stands. Consequently the number of seeds produced per plant was also altered by this manipulation of the biological environment.

Table 37: Technical management recommendations for smallholders growing Leucaena hedges in Indonesia (300)

	Planting			Cultural practices			
	Spacing	Material	Population (seed required)	0–12 months[a]	Older than 12 months	Primary product[b]	Secondary products[b]
			Main purpose: Conservation, reducing erosion				
Slope 0–15%	Double rows: 25 cm × 5 m	Seeds	16000/ha (3.6 kg/ha)	A food crop that does not excessively shade the leucaena is planted between the double rows	Replace dead plants; coppice for secondary product if diameter is >3 cm	Reduced erosion	Leaves (5–10 t/ha by fresh weight) for green manure (growing season) or animal feed
Slope >15%	Double rows: 25 cm × 2 m 10 cm × 2 m	Seeds	40000/ha (8.9 kg/ha) 100000/ha (22.25 kg/ha)	A food crop that does not excessively shade the leucaena is planted between the double rows	Replace dead plants; coppice for secondary product if diameter is 3 cm	Reduced erosion	Leaves (10–20 t/ha by fresh weight)
Terrace -	Raised bed: 0.5 cm × 10 m	Seeds, seedlings, stumps	2000/ha (0.4 kg/ha)	Interplanted food crop	Replace dead plants; coppice/ induce leaf shed if diameter is >3 cm	Not yet studied	Leaves (no measurement of production yet)
	Bench: 1 m × 2 m	Seeds, seedlings, stumps	5000/ha (1.0 kg/ha)	Interplanted food crop	Replace dead plants; coppice/ induce leaf shed if diameter is >3 cm	Not yet studied	Leaves (no measurement of production yet)
Home garden	25 cm in the row	Seeds, seedlings, stumps	400/100 m (90 g/100 m)	Interplanted food crop	Replace dead plants; coppice for secondary product if diameter is >3 cm	Reduced erosion, leaves	Leaves, firewood, food (no measurement of production yet)
			Main purpose: Leaves for animal feed				
Fence	0.75–1 m	Seeds, seedlings, stumps	100–133/ 100 m (22–30 g/ 100 m)	Coppice, when trunk is 3 cm in diameter, 0.7–1 m above ground	Coppice every 3 months during the rainy season, every 4 months during the dry season	Leaves from two coppiced trees/day for each head of cattle being fattened	Firewood, green manure
			Main purpose: Firewood				
Fence	1–1.5 m	Seeds, seedlings, stumps	67–100/100 m (15–22 g/ 100 m)	Do not cut	Cut the tree 30 cm above ground when trunk diameter is 7 cm	Firewood (20 m³/ha after 2 years)	Leaves (when tree is cut)
			Main purpose: Trees for shade				
				Do not cut	Depending on the shade required, coppice first time when the trunk is 3 cm in diameter	Shade for other cash crops (coffee, cocoa)	Reduced erosion, green manure, animal feed
			Main purpose: Green manure				
Slope 0–15%	Double rows: 0.25 m × 5 m	Seeds	16000/ha (3.6 kg/ha)	Do not cut	Coppice when trunk is 3 cm in diameter, 0.7–1 m above ground	Leaves (5–10 t/ha by fresh weight)	Leaves for animal feed once during the season

[a] For all the main purposes, the leucaena requires weed control and protection from fire and animals in the 1st year. Only the additional measures have been listed in this column.

[b] Both primary and secondary products are for trees older than 12 months unless otherwise indicated.

The reduction in the number of pods in close spacing may have some benefits; the energy expenditure of the plant could be channelled to production of more wood and biomass rather than reproduction. Thus thin stems, twigs and boles formed would be ideal for firewood purposes

Wood and natural insecticides from neem: *Azadiratchta indica* has several uses. The trunk and branches are used for buildings, because they are extremely resistant to termites. It is also very often used for firewood and charcoal.

It is also a very useful natural insecticde. *Azadiratchta indica* is the most important insecticide substance contained in the plant; even in small doses it has a growth disrupting effect on many insect larvae. Other pests, such as grasshoppers, stop eating the plant as a result of this substance.

If the branches are pruned (lopped or pollarded) for firewood or poles it will be some time before the trees again produce fruits, as they will first try to re-establish branches.

Therefore the combined use of *Azadirachta indica* for insecticide and firewood is only possible when the tree is left undisturbed for several years. In other words, in order to produce insecticide the original branches should be left intact (fruit production begins after the third or fourth year). Only trees that are at least ten years old should be used for firewood and then only after the younger trees planted later have begun to produce sufficient fruits (152a).

There is a further need to develop hedgerow systems fitting into the specific context of resource-poor land users.[1]

6.4.4 Renovation and management of old hedges

Renovation can be achieved either by new planting or hard cutting or thinning and enrichment planting. The selected trees are indicated by a mark made with a scrip or marking hammer. Many neglected old grown shrubs can be transformed into valuable assets with sensitive pruning.

Attempts to trim all branches to the same height can make the regeneration of trees difficult or impossible, as the older individuals die or are cut down. To solve this problem, saplings may be considered if it is advantageous to keep hedge trees growing.

If succulents like *Opuntia spp.* planted in a hedge become invasive they should be uprooted in part and covered with soils. Without light succulent plants soon die and rot. In this way, e.g. *Opuntia lenni* (bad fig) is controlled by villagers in Yemen (104).

There is not much recorded evidence on lifespans of hedges in tropical and subtropical countries for hedge species in general: This depends on species, site and management. With good management, long lifespans can be expected. Indications of a hedge decaying due to trimming have been discussed (see 6.3.3) and need no further elaboration.

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1 For example, assuming that Neem produces an average of 30 kg of seeds per tree and 0.5 kg of seeds are required for 10 liters of insecticide (152a), extensionists can develop, together with farmers, hedgerow systems with a multi-purpose neem tree component.

6.4.5 From mono specific alley cropping to multi-functional hedgerow intercropping

Hedgerow intercropping has drawn the widest attention with regard to hedgerow research and development in recent years. However adaption by resource poor people is marginal (see also 3.7).

The potentials of hedgerow intercropping are not fully exploited because it emphasises only the production of arable crops of the alleys and the use of two exotic tree species, namely *Leucaena leucocephala* and *Gliricidia sepium*, in the hedgerows. Proposals for broadening the scope of alley farming by making some interventions in the hedgerows, including multiple use and selective pruning are welcome. On the alley the interventions should include increasing and varying the width, incorporating timber trees in a mixture with a wider range of food crops, growing of fruit trees with food crops, and growing of forage trees with food crops. The following models were suggested to address the multiple problems faced by small and medium sized subsistence or mixed subsistence/cash farmers in Nigeria. The first concept is for the humid tropics, the second one for the derived savannah.

Model A: Humid tropics

Different pruning treatments, in which trees at regular intervals in the mono-specific hedgerow are left unpruned to provide a desirable product. For example in a hedgerow of *Pterocarpus santalinoides* trees left unpruned at 3 intervals will flush and provide vegetables while the rest is pruned regularly for provison of mulch and organic matter.

Using mixture of species which provide various uses and varying the spacing of such species. For example cuttings of *Pterocarpus spyauxii* or *P. muldbraedii* can be planted for vegetables at three-meter intervals within a normal hedgerow species such as *Acioa barteria, Alchornea cordifolia, Gliricidia sepium* which are planted at the usual spacing.

Planting of budded seedlings at 7-8 m apart within normal hedgerow to provide fruits. The budded seedlings, such as of *Ireculia africana, Irvingia gabonensis, Chrysophyllum albidum, Pentaclethra macrophylla* will yield fruits early within 4 years, while maintaining a low stature, to minimise shading effects. It is however, advisable to increase the width of the alley when this practice is adpoted in view of the eventual crown size of the budded trees.

Derived Savannah and Southern Guinea Savannah zones

Any model which aims at intensification and diversification of products on the alley must allow for increased width of alley from 4 m to 30 m, and more representation of woody components on it. Such a wide alley will enable the establishment of trees at 3 m for wood products, and 7-8 m for budded fruit trees, and for unbudded farm trees a 10 m spacing. With the increased width, the following form of permanent and integrated land use is possible within the alley.

Indigenous fruit and vegetable tree plantation crops can be grown within rows of pure or mixed fruit trees, using budded seedlings for early yield and dwarf habit, spaced at 7-8 m, and *Pterocarpus spp.* cuttings planted at 3 x 3 m. The hedgerows are pruned to serve as an additional source of organic matter, in addition to the nutrient recycling of the trees. The introduction of fruit trees in alley farming will also popularise the system and increase its functionality.

Farm trees and multipurpose species: Planted at wide spacing, not exeeding 10 x 10 m, using unbudded seedlings of species with deep root systems, light and narrow crowns and multiple uses, the farm trees provide wood, fruit, browse and shade as well as playing a useful role in recycling nutrients. Agricultural crops and the farm trees are grown simultaneously on the same unit of land, i.e. within the alley while the hedgrows provide prunings which are extremely useful as mulch during early stages of establishment. For the savannah area *Parkia biglobosa, Afzelia africana, Tamarindus indica* and *Prosopis africana* are useful.

Browse tree plantations: Browse trees can be established on the alley at 3 x 3 meter spacing to provide forage. The hedgerow also provides additional browse, manure, and mulch. The suitable species include *Albizia lebek, Ficus capensis, Leucaena leucocephala, Gliricidia sepium, Moringa oleifera, Treculia.*

With such an intensification of and improvement in the knowledge and state of the art of hedgerow intercropping, there is bound to be greater agricultural productivity and a decline in the rate of deforestation. This clearly has forest conservation implications (273a).

There is still a further need to carry out specific research towards developing or improving techniques and systems which envisage the use of multipurpose hedgerows to address the multiple problems faced by small and medium-scale subsistence (or mixed subsistence/cash) farmers and other land users with very limited external resource inputs.

6.4.6 Summary sheet

Highlights

- There are various harvesting methods like coppicing, pollarding, and lopping, which have been developed by local people for specific needs. Multipurpose management is the rule.
- Generally the aim of research into harvesting is confined either to conventional techniques (clear-cutting, coppicing) for a few commodities. Investigation into multiple harvesting has recently begun.
- For small-scale farmers and poor people, multiple and flexible harvesting is a necessity; various hedgerow systems fit well into this context.
- Freedom to harvest any time (contingency right), is very important to stimulate hedgerow promotion. Freedom without security (land/tree tenure) or restricting harvesting by law, may both lead to an over-exploitation of natural resources.
- Sustainable yield can be obtained by sound multipurpose management; however, on marginal sites (together with marginalised people) hedges are not a panacea.
- The basic challenge in the design of appropriate hedgerow systems is to build on felt needs of users, while incorporating less-perceived ones (e.g. conservation).

Key technical instructions

- The most important harvesting techniques are coppicing, pollarding, lopping, trimming. Combinations are also possible.
- Regular and frequent harvesting is possible with plants which can withstand heavy pruning.
- The timing of harvesting depends on outputs and needs; it can start as early as 2 months after for vegetables and five years and later for fodder from hedge trees.
- It is rarely, if ever, possible to maximize the production of all products from a multipurpose tree simultaneously. Some sort of compromise has to be looked for, either by managing the tree to maximize one product or by compromising on the multipurpose design.
- To maximize/and or optimise requires a different management strategy for different outputs (see Chapter 3).
- There is a urgent need to depart from one-dimensional alleycropping in favour of multi-purpose hedgerow farming.
- The renovation of old hedges can be done either by new planting or hard cutting back, thinning, and enrichment planting. Hedge trees can also be regenerated by saving saplings while trimming a hedge.

Lessons learned

Research organisations focus on maximising one output, particularly by conventional harvest techniques. Implementing organisations have a tendency to favour multipurpose management for the poor on marginal sites. Both have their drawbacks.

Freedom of cashability of hedges and hedgetrees by resource-poor land users (restricted only by local consensus and not law enforcement) and support in marketing any surpluses deserve as much attention as developing technical packages for multi-purpose management.

There is a need to carry out specific research towards developing improved technologies and systems which, through multi-purpose and sustainable hedgerows, address the multiple problems of resource-poor land users.

APPENDICES