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Tree Planting in Africa South of the Sahara

by David Kamweti

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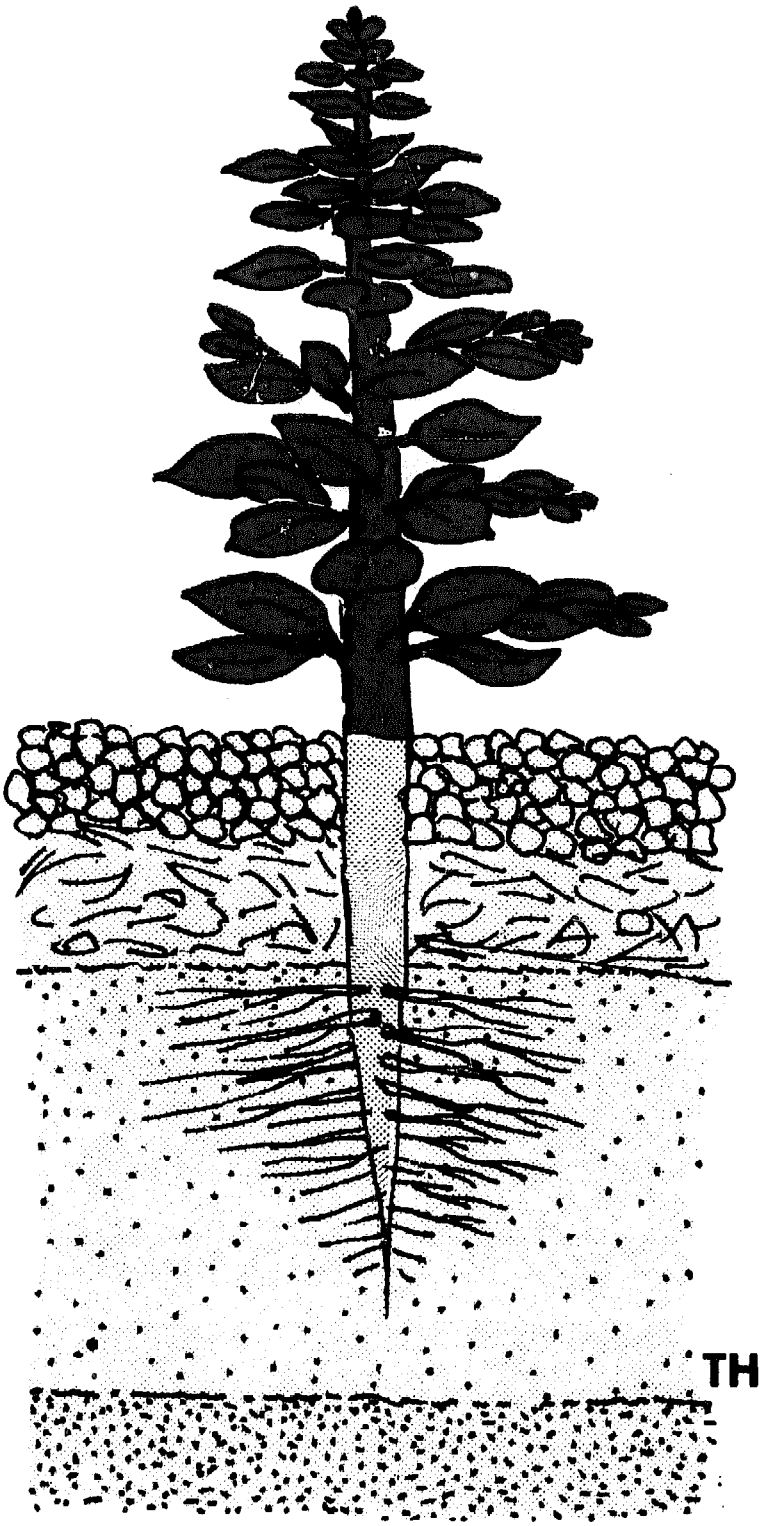
Tree Planting in Africa South of the Sahara



David Kamweti

THE ENVIRONMENT
LIAISON CENTRE

1982

The Environment Liaison Centre (ELC) is an international non-government organization (NGO) which helps NGOs, particularly those in developing countries, work on issues related to environment and development. It assists them in their liaison with each other and with the United Nations Environment Programme (UNEP) and other UN agencies.

The ELC has consultative status with the UN Economic and Social Council (ECOSOC), consultative status with the UN Educational, Scientific and Cultural Organization (UNESCO), and a special working relationship with UNEP.

TREE PLANTING IN AFRICA
SOUTH OF THE SAHARA

David Kamweti

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THE ENVIRONMENT LIAISON CENTRE
P.O. Box 72461
Nairobi, Kenya

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Preface

IN MANY parts of the world the loss of vegetation cover is causing widespread soil erosion and desertification, further leading to siltation of rivers, lakes, dams and oceans. It is also threatening the majority of third world populations with loss of their primary source of fuel for cooking and heating.

In African countries, the scale of deforestation has reached such alarming proportions that citizen groups of all kinds - churches, schools, women's groups, conservation organizations - have initiated tree planting and reafforestation programs.

In an effort to assist the hundreds of environmental NGOs in Africa that have begun to replace felled trees with new young seedlings, the Environment Liaison Centre (ELC) has sponsored the preparation of this booklet on tree planting techniques. It is intended to act as a general guide for a wide range of groups which may consider undertaking such a program. Available in both English and French, the booklet is being distributed to interested NGOs in African countries and may also be requested directly from the ELC, by other groups.

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- Other ELC staff members for editing and proof-reading assistance.

The author retains full responsibility for any errors or omissions and invites suggestions for improvements to be sent to Environment Liaison Centre.

Contents

Introduction

FOR MOST of the African populations in the rural areas, where fuelwood is a major source of energy, tree planting is therefore an essential activity to achieve a sustainable supply of fuelwood. Although tree planting requirements in Africa vary, one needs to follow some general principles and techniques to achieve success. In most cases tree planting is undertaken by laymen, and these will continue to play an important role in the activity.

One can safely say that, generally, governments, non-government organizations and many individuals realize the importance of trees and the need to plant more trees in deforested areas. The tempo of tree planting is quite high in African countries but for various reasons, the hopes are usually not fulfilled due to many factors, such as:-

a) There is, for example, the issue of shortage of finance to do large-scale tree planting, for tree planting is a long-term investment and is unlikely to attract many investors.

b) There is also the issue of incentive in tree planting. One can say incentives in tree planting, in many parts of Africa, are not devised, but if they were worked out they might go a long way to stimulating viable projects.

c) Besides financial problems there is, of course, the oscillation of weather in many parts of Africa.

d) There are some cases where skilled manpower, mainly for supervision, may be lacking although a number of countries will soon be self-sufficient in professionally trained manpower for imaginative tree planting programmes.

e) In some countries, due to pressure to use suitable land for food production, the land available for tree planting is indeed limited.

f) While there may be institutional potential to carry out some effective afforestation schemes, there are indeed effective situations in some countries where the land tenure system itself does not facilitate tree planting, and this is particularly so where land is owned communally.

g) Some scanty information on tree planting is available but substantial information is lacking partly because some concerned institutions may not be aware of the magnitude of the tree shortage. For example, tree planting experience in French-speaking African countries is not readily available in English-speaking countries.

h) It is also true that communication limitation acts as a bottleneck in tree planting in some cases. For example, some research is being undertaken in several corners of Africa but the coordination of results is not as effective as it should be. There is a need for people to know which species of trees will succeed in different sites before they incur the expense involved in tree planting.

Due to a combination of many of the above factors tree planting in Africa has often fallen short of expectations among those charged with tree planting. It is important to consider these constraints in evaluating tree planting projects.

This booklet is a useful guide to tree planting. It explains the relevant aspects and factors worth considering in tree planting, such as climate, type of soil, ecological zones and species adaptability. It outlines the essential steps in tree planting, from acquiring seeds to the actual field work. Recognizing that tree planting schemes have failed due to lack of adequate care, leading to high seedling mortality, the author has given some advice on how to look after young seedlings both in a seed nursery and in the field plantations.

The Relevance of Tree Planting

WHY PLANT trees? Since the earliest time, man has maintained a close relationship with trees. Early man derived his livelihood from forest products, such as fruits, nuts, roots, leaves and shoots. Even today trees provide large quantities of the dietary requirements of humans and livestock. People have also depended on trees for shelter as well as for numerous other purposes.

Trees play an important role in our daily life - no wonder a tree has been termed the best friend of man on earth. However, due to the population explosion and the expansion of land under agriculture, the economic demands on forest products have been enormous. Man has deforested large areas of indigenous forest cover leaving bare earth behind. Desert encroachment in Africa is now seen as a reality and the only practical way to combat desertification is to plant appropriate trees using appropriate techniques.

Most African governments are striving to raise the standard of living of some 90% of their rural populations through rural development programmes. One way of alleviating poverty is to undertake projects that will generate local employment opportunities and which are locally self-supporting.

The benefits accruing from rural development also flow to urban areas, especially to the majority of urban poor who depend on rural products for daily subsistence. In a way, then, employment in rural areas permeates the broad spectrum of the society.

Apart from employment, the benefits of trees to mankind are otherwise too many to enumerate. Below are but a few examples:

a) There is the provision of timber for construction and joinery, plywood, pulp for paper, posts and poles;

b) pharmaceutical oil and medicine;

c) some minor products such as honey, fodder, fruits, resin, gum, fibre, rubber, and myriads of food products, all play a very important role in some communities (Kamweti). For example, in Sudan, gum Arabic from *Acacia Senegal* and other species produce an annual income of about 4 million US Dollars (Amin).

There is also the all important issue of biomass energy. Fuelwood and charcoal are increasingly becoming very important sources of energy not only for domestic use but also for various industrial uses. While the fossil fuel price continues to

escalate, it is comforting to bear in mind that fuelwood is a renewable resource, provided it is harvested in a sustainable way. Woodfuel plays such an important role in Africa that in some countries like Kenya nearly 100% of rural people depend on fuelwood for domestic energy and in urban areas 80%, mainly in the form of charcoal (Kamweti).

Elsewhere in Africa, the same general trend exists. In fact it has been estimated that at least half the timber cut in the world still serves its original role for mankind - as fuel for cooking and heating (Spears). In most of the West African countries, 80 - 85% of wood harvested is used as fuelwood (Okigbo). In Africa as a whole, it is estimated that woodfuel accounts for 63% of total energy (Burley). In absolute terms, it is estimated that about 300 million cubic metres of fuelwood is consumed annually (Poulsen). The percentage share of wood consumed in the form of energy in Africa is impressive - as can be inferred from the following sample countries (Ishengoma):

- Kenya 75%
- Malawi 89%
- Tanzania 96%
- Uganda 90%

Woodfuel is no longer a poor man's commodity. As consumption continues to rise above supply, planting of trees must be done close to population centres, otherwise situations will arise where, for example, a housewife spends the equivalent of a full work-year gathering wood for fuel. In other cases woodfuel has become very expensive. In Niger, for example, an average manual labourer spends one fourth of his income on firewood and charcoal.

Firewood is indeed an essential commodity in life just as food is. To minimize fuelwood shortage, it is important to apply good tree planting techniques to avoid high rate seedling mortality. In helping to solve energy problems, experimental results from Ghana suggest that 40,000 ha. of plantation of fast growing species can produce the equivalent of 50,000 tons of coal per year without unusually large inputs of capital-intensive technology (Myers).

Trees are also capable of providing many indirect benefits, some of which may not be quite obvious at the first instant but are nevertheless important:

a) Trees do improve microclimate; they provide shade for livestock and people. It has been observed that temperature in the sun can be greater than that in the shade by as much as 10^{o} centigrade (Norman et al).

b) Trees are effective tools for water and soil conservation, a major issue in most of the African countries.

c) Trees also provide a habitat for wildlife - an important consideration for genetic conservation (Myers).

d) Tree play a major role in protecting, maintaining and improving the environment. Trees, especially in the form of forests, because of their sponge effect on rain water, play a critical role in regulating the flow of water and trapping any suspended matter which would otherwise pollute water.

e) As for land degradation, there is no better cover for soil than trees. Some experiments in USA have demonstrated that volumetric loss of top soil (15 cm deep) under tree cover has been 1% and under concentrated vines 20% in the same period (Norman et al). In many African areas, soil losses from erosion have been estimated at between 200 and 2,000 tons per square kilometre per year. In terms of value, it is the greatest per capita loss in most African countries, especially in sloping areas denuded of trees. The prevention of soil erosion by the use of tree cover in turn means minimizing siltation of rivers, canals, and dams (World Bank).

f) Also for combating and even reclaiming deserts, tree planting is the best tool. It is one of the recurring recommendations since the U.N. Conference on Desertification held in 1977 in Nairobi. The Conference noted that on the Southern edge of the Sahara alone 650,000 sq. km. of once-productive land has become desert within the last 50 years. This is an annual loss of 13,000 sq. km.

g) The air people breath is purified by trees as they exhale oxygen - no wonder forests have rightly been called "Nature's Lungs" (Douglas & Hark). An acceptable environment without trees is unimaginable. Indeed one can say that agriculture in marginal lands may be disastrous but trees are the only solution (Douglas & Hark).

h) Trees are usually not depletive on the earth in which they are growing; they tend to enrich soil by their nutrient recycling effect. A number of trees, such as the *Acacia* species, have a fertility effect by their ability to fix atmospheric nitrogen (Wilson). It is known that if one plants legumes it may not be necessary

to add fertilizer to improve the nitrogen content in the soil. Leguminous crops can add up to 500 kg of nitrogen to the soil per hectare per annum (National Academy of Science). Indeed any substitute for fertilizer is most welcome in Africa, bearing in mind the cost of fertilizer and also the energy needed to make it. Trees are a partial solution to this problem which is often associated with foreign exchange expenditure. Hence, besides ameliorating the site for themselves, trees also nurse other economic crops.

It is necessary to keep in mind the above-mentioned uses of trees because, if tree planting is looked at from one angle only, it may be discarded because it does not meet some economic criteria. It should be emphasized that a number of trees have many advantages, or rather they play a multi-purpose role in rural development. In fact it is common knowledge that forestry supports agriculture.

In view of the above advantages of trees, it is a logical conclusion that, for those African countries with a deficit of wood, massive planting programs should be undertaken. There are essentially three categories of areas where such planting should take place;

a) Land devoted to afforestation or forest reserves where large plantations could be created.

b) Farm land where agroforestry could be practised.

c) On roadside reserves, in towns, and on any unused land earmarked for such tree planting.

Whatever category of the area to be planted there are essentially four categories of plantations (Lundgren):

i) The eucalyptus species.

ii) The tropical hardwoods.

iii) The softwood, mainly conifers.

iv) The legume species.

The concept of tree planting is simple if the techniques are well understood.

Tree planting programmes have failed for many reasons, such as bad planting methods, improper ground preparation and inadequate care at the early stages of growth.

To have a successful tree plantation, the people need to be trained in basic skills that would help them to look after their plantations successfully. To achieve community participation, they must be made aware of the economic values of trees as relates to their daily lives.

For people providing the plants, some silvicultural knowledge of the behaviour of different species is essential. It is most unlikely that the local community will reject a tree unless it is obviously unsuitable for the particular end-use in mind. There are a few cases when there is a belief that some species will take too much water e.g. *Eucalyptus* species. But in most cases people will plant what is made available by the relevant authority issuing seeds or seedlings. It is therefore of paramount importance that suitable species which have been tested and appropriately selected are used as much as possible. Local species which may have withstood burning, overgrazing, pests, and diseases are likely to be successful candidates in planting for that particular locality.

If growth performance of a species is known and a knowledge of appropriate planting methods, considering climate, soil, and locality, are well communicated to the people involved, then planting of trees is likely to succeed. It is the aim of this booklet to analyse the relevant factors and current planting methods which have been used in Africa with some success. There are a lot of local variations for which local experience is necessary. In an attempt to increase productivity per unit area (in most countries suitable land for tree planting is definitely very limited), most people are inviting failure by planting exotic species without a proper provenance trial. It is common knowledge, and indeed a reasonable precaution, to plant those trees which have done well in other areas with similar or almost identical growing conditions such as climate, soil and altitude.

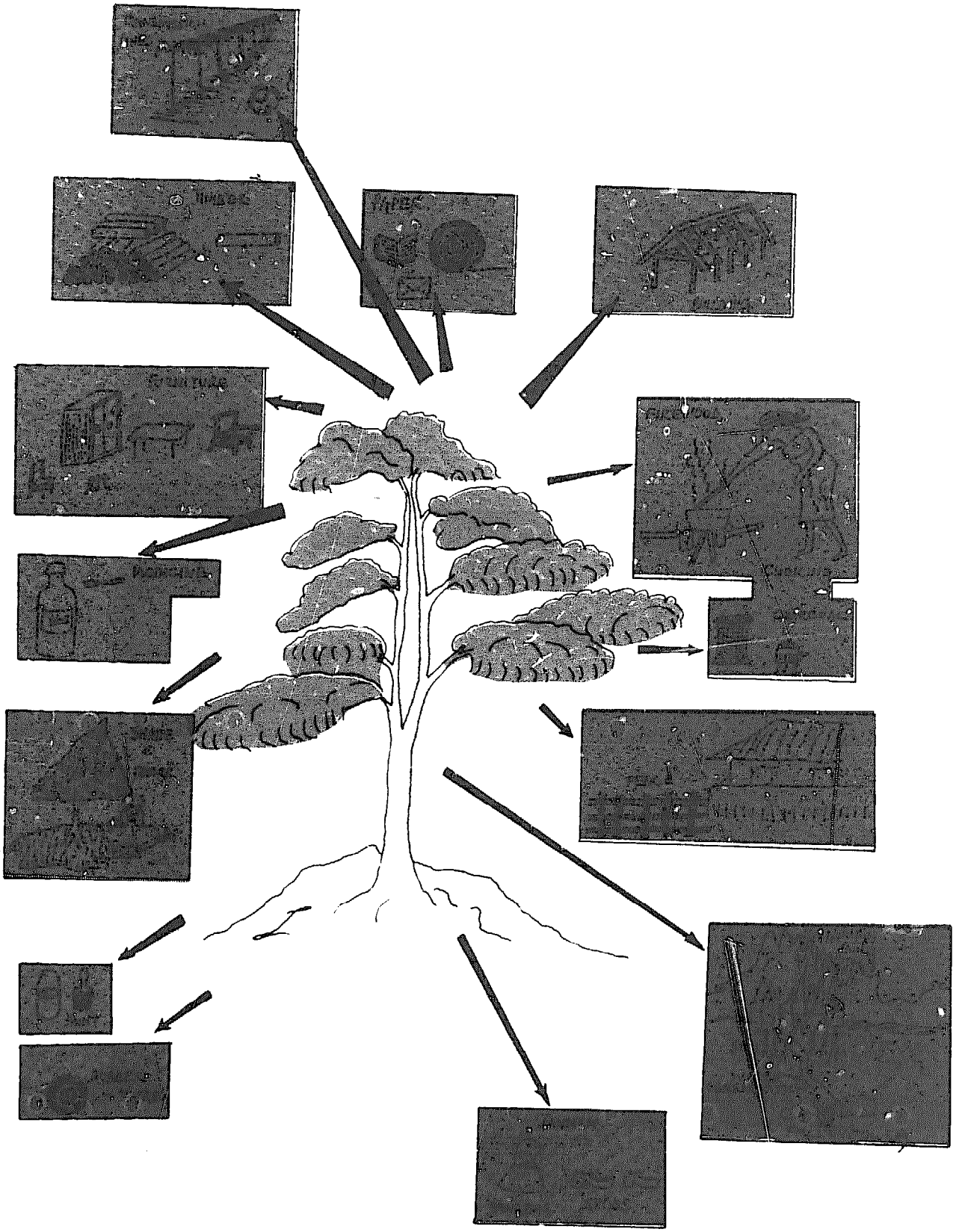


Figure 1 : Tree Benefits

Climate and Tree Planting

IN AFRICA, climate is the single most decisive and limiting factor to tree growth. By climate we mean temperature, precipitation and to some extent wind. Wind is important in the sense that it accelerates evapotranspiration and hence decreases the amount of moisture available for plants in any locality.

Diversity of vegetation in Africa is mostly tied to the climate of a particular zone. In fact, as will be seen later, the map of major climates is naturally correlated to the major vegetation in various parts of Africa. Usually in making the choice of species for planting, the major question, other than the purpose for which a tree is being planted, is whether the species will have the ability to grow in a certain climate. If the answer is "No", the species is immediately discarded no matter how important it may be otherwise. There is a great diversity of climate in Africa; the continent has been described as both the hottest and the driest in the world.

TEMPERATURE

Temperature affects tree planting in various ways. Usually when it is very cold, a number of plants slow down in their growth. In most cases the majority of plants will grow faster at a higher temperature than at a low temperature provided the high temperature does not lead to undue moisture loss. Indeed high temperature may lead to high evaporation (evaporative demand is highly influenced by temperatures), and the trees may then grow better in a low temperature with relatively more moisture. Extremes of very high temperature may be mortal to plants, especially when they are young. It has been observed that high temperature both during the night and the day, can affect the growth of some species (Huxley, personal communication). Net photosynthesis has an optimum for most species at around 25^{o} - 35^{o}C (Lundgren).

The equator is characterised by low ranges of temperature and high mean temperature. Northwards and southwards temperature ranges become high. Mean temperature is higher at 15^{o} - 20^{o} North and South of the equator, mainly due to cloudiness at the equator. Usually temperature is not a very limiting factor in tree planting in Africa. Although as a general rule temperature decreases with latitude from the equator, altitude has a big influence on the temperature and precipitation of an area. The higher the altitude of an area the lower the average temperature due to more reradiation (lowlands have more of a blanket effect on air); there is also less evaporation, due to cooler temperatures. Due to the influence mountains have on wind, it is a common experience that rainfall generally increases with altitude.

This means that even in the equatorial zone, some temperate climate exists, for example in the highlands of East African countries.

RAINFALL

Rainfall is, however, the most important parameter in climate as far as tree growth is concerned. Climate is influenced by the biannual swing of the sun across the equator and the attendant wind system. Wet seasons follow the sun, lagging behind about a month with the heaviest rainfall, usually being associated with the northwards movement of the sun. Mean annual rainfall is the critical factor and for tree growth seasonality and distribution of rain make a big difference. Well distributed rain will be more effective than a downpour which is concentrated in a short time. The absolute amount of rain falling will have different effects on plant growth depending on other factors such as evaporative demand; whether water penetrates the soil or is lost as a runoff; and also whether soil will hold water in such a way that a plant has regular doses of the moisture. An example of a very different effect coming from the same amount of rain on vegetation is evident in the northern Sahara, south Algiers, where 10 mm of daily rainfall in March, April and November, on less sloping areas, supports forests of evergreen oak, and in the Southern area, north of Nigeria, where the same amount of rainfall just supports savanna bush (Goor & Barney).

One feature of rainfall in Africa is that rain is very unpredictable. There is a wide variation in some localities from one year to another. In fact, one area generally considered to be drier than another may have the rainfall pattern reversed in some years. Not only that, rainfall seasons cannot be described as constant. Rain may come at a period when it is not supposed to rain and vice versa. Local experience is quite often better than any systematic prediction of rainfall pattern.

It should be noted for tree planting purposes, two wet seasons are better than one single wet season. Where wet seasons coalesce into one - followed by a long dry period - such areas would require about 250 mm more rainfall than areas which have two wet seasons. The single wet season pattern begins at about 8^{o} north and south of the equator.

Any successful tree planting takes place only where there is enough moisture in the ground. As a general rule for tree planting one should remember that the length of dry season increases as the total rainfall decreases. Also, usually, high rainfall areas have lower potential evaporation demand and low rainfall zones have higher potential evaporation. With these considerations in mind, tree planting techniques should be modified to meet rainfall variation.

It must be emphasised that where there is no rainfall at all, unless there is underground water or irrigation is contemplated, the question of tree planting should be discarded. There are also some cases where evaporative demand is so high that all the precipitation that falls is immediately evaporated due to high temperature and low humidity. Such areas qualify as desert where plant growth is generally impossible unless irrigated.

For convenience, the climate in Africa can be simplified into five major categories:

a) Mediterranean climate with wet winters and long dry summers;

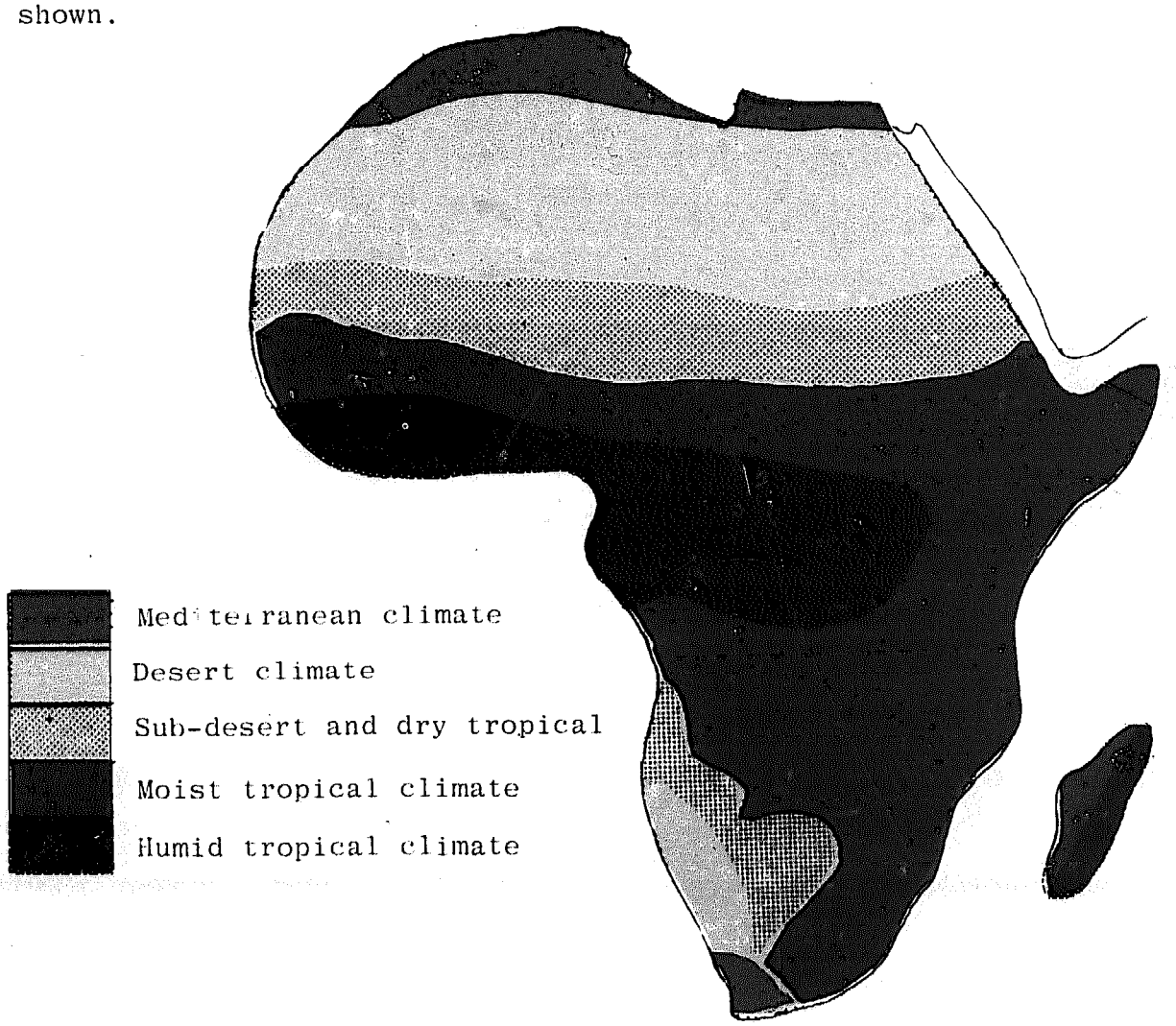
b) desert, where there is no rain for all practical purposes;

c) sub-desert, extending to dry tropical;

d) moist tropical covering wide ranges of climate;

e) and the humid tropical zone of Zaire and southern parts of West Africa.

It is emphasized that this is a very simplified outline and there are numerous variations with major climatic zones, outlined as shown.



Map 1 : Major climates of Africa

Soil Consideration in tree planting

IN A tree planting program, reference to the soil on the site to be planted is inevitable. Soil itself is formed as a result of many factors, the climate being a very important one. Other factors are the living organisms which include vegetation; parent material; time and topography (Lundgren). There are many classifications of soil thus formed and it is possible to correlate major species which are suited to various categories of soil. From such a list one could choose the species with the best chance of success in the soil of the site to be planted. Soil is an important factor because it provides trees with water, nutrients and anchorage.

The FAO/UNESCO have classified soils of the world into 26 major groups and most of these soils are found in Africa. Of particular interest to tree planting in Africa is the group commonly referred to as *latosols* which include *ferralsols, acrisols, nitosols, luvisols, cambisols* and *arenosols*. In general, one main feature of *ferralsols* and *acrisols* is that they are the most weathered and leached soils while *luvisols* and *cambisols* are the least weathered and leached (Lundgren).

Without going into details of soil science and the appropriate species, one can safely say that the most important attributes of soil for tree planting are:

a) Soil depth;

b) permeability;

c) pH of the soil; and

d) soil fertility.

SOIL DEPTH

The depth of soil is important as it affects the rooting depths of many trees. There are two major categories of trees as far as rooting depth is concerned: the deep rooted and the shallow rooted species. Indeed some tree species, like those of *Acacia*, have roots reaching as far as 30 metres below the soil. Where the soil is shallow, say less than 2 metres, there is a large group of deep-rooted species which will not grow. As for shallow-rooted species (such as *Cassia siamea*) a relatively shallow soil will do. *Eucalyptus camadulensis* and *casuarina* species, otherwise suitable for dry areas, will require deep soil as they are deep-rooted species.

Depth of soil is extremely important, especially in agroforestry when the aim is to plant trees which feed at much lower levels of soil than agricultural crops, which feed on the upper zones of soil, and hence minimize the nutrient and water competition in the whole plant community. Because of possible higher rate of erosion on sloping areas than on relatively flat areas, unless there is impeded drainage, deep-rooted species should be planted at the bottom of valleys, and shallow-rooted species would be more appropriate for the sloping areas where, in fact, a major role of the trees would be soil stabilization.

PERMEABILITY

Permeability, or structure, is another important factor as far as trees are concerned. A tree needs water for survival and when it rains, the amount of water which will be available to the tree will depend on the amount of water which will be retained in the soil. When water falls on soil, there are three major possibilities of where that water will go, ignoring evapotranspiration:

a) Water may run off, especially on steep slopes.

b) Water may be infiltrated and pass beyond the reach of the plant.

c) Water may be retained in the soil for a fairly long time at plant-available tension; this is the water which is most important for trees.

The reality, in most cases, is that all three above possibilities take place. The ability of soil to take and retain water for plant use depends on the physical properties of soil. Specifically the water retention attribute depends on:

a) Porosity of soil;

b) structure, i.e. the components of the soil;

c) texture, e.g. very coarse or fine soils may not hold water well;

d) organic matter in the soil; organic matter has a sponge effect when it comes to retaining water in the soil.

Generally, in lay person's terms, one can recognize two extremes of texture: sandy soil and clay soil, at either ends of the scale. In between lie various combinations of soil texture in which loam soil is a term used generally for soils of medium texture and the ones with humus content. One can say that except for kaolinite clay, clay soils have impeded drainage. In wet periods waterlogging is the prominent feature and few species will withstand waterlogging (*populus* species might have some success).

This category of clay soil is the black or grey soil, normally referred to as 'black cotton soil' *(vertisols)* in Central and Eastern Sudan and some parts of East Africa. As the soil is impervious, some subsoiling in the wet season might improve conditions for tree planting. Care must be taken in subsoiling as this, in fact, might create pockets of water below the soil surface and this would naturally choke the roots of trees adjacent to such water. Especially for ornamental tree planting, clay soil is improved by the addition of red soil (loam soil).

Red soil owes its colour to the presence of iron hydroxide. Red soils, when leached, can have a problem of 'hard pan' (murram or laterite) which stops further root development, especially of deep-rooted species. Murram can, in fact, occur all the way from the surface of the soil (in which case all the water simply runs off) or some distance below the surface (as in the case in Turbo, in Kenya, where plantations for a pulp and paper mill have been drying prematurely due to this 'hard pan').

Sandy soil, on the other hand, is very pervious and all the water percolates beyond the reach of a number of plants. Trees once established on such soil improve it by their leaf fall and hence they also improve soil for some crops which would never establish themselves on such soil. Sandy soil, on account of its drainage, is useful in nursery management. In fact even in otherwise wet areas, drought-resistant species should be the target because most of the water goes out of reach of the trees immediately after a downpour, unless a tree has very deep roots. It is reckoned that a metre depth of sandy soil can only store about 6 cm available water whereas a clay soil may store 20 cm and possibly more if some organic matter is present (Leyton).

pH OF SOIL

The pH of soil, whether it is acidic or alkaline, is important because some species have a range of pH under which they can grow. It is known, for example, that pines do well in acidic soil while *Azadriachta indica* is known to favour less acidic soils (pH more than 6). Usually alkalinity or acidity is not a factor to worry much about. Most African soils are acidic unless the soils are derived from calcareous rock. Where a certain pH is desirable, there are ways to decrease or increase the pH value. Very acidic soils can be improved by the addition of lime; or if soil is very alkaline, sulphur can be added.

Related to the issue of pH is the question of salinity. Most tree species will not tolerate too much salt in the soil. In fact the issue of salinity (usually caused by the presence of sodium salts - chloride and sulphate) must be borne in mind whenever irrigation of trees in dry areas is contemplated. Some of the species which have been known to tolerate high salinity are: *Casuarina equisetifolia, Phoenix dactylifera,* and, of course, several species of mangroves (Weber).

SOIL FERTILITY

In large tree planting projects, it is wise to analyse soil for the major nutrients. Soil fertility will normally depend on the parent material, organic matter and whether the soil has been cropped several times with agricultural crops. It is a proven fact that while most trees and vegetation have a tendancy to enrich a site, agricultural crops have the opposite effect. Provided a tree gets essential elements in the early stages, it will usually grow, though slowly, even in infertile soil, unlike agricultural crops which are very sensitive to nutrient status.

The essential elements in tree growth are nitrogen, phosphorus and potassium (N.P.K.). Potassium and phosphate, for example, improve lignification of poplar but an excess of nitrogen can render the plant more vulnerable to attacks by fungal parasites such as *Dothichiza* (FAO 'Poplars in forestry and land use'). Periodic burning reduces nitrogen in the soil. In fact, it has been known that nitrogen content is generally low in Central and West Africa, Sudan, Angola and Zimbabwe (FAO).

Phosphorus also shows a general deficiency both in total and in the amount available. In West Africa, studies have shown that total available phosphorus is low and Zambia also has a phosphorus deficiency (FAO). A cure for such deficiency, other than by fertilization, is to leave the ground without fires or other destructive agents for about five to ten years and some considerable amount of phosphorus will accrue. In fact Nye and Greenland have shown that forest soil contains more total phosphorus and calcium in the surface horizon, and to a lesser extent in the immediate sub-surface horizon, than in the lower horizon.

In general, savanna soils have more potassium than forest soils. This element is usually in the soil for the necessary growth as has been demonstrated in Ghana, Senegal and Nigeria.

Calcium is not as important a factor but apparently some species are sensitive to calcium deficiency, e.g. Teak. On the other hand, experiments in Sudan show that excess calcium can limit growth of *Eucalyptus tereticornis* (FAO).

Trace elements are apparently essential to all species and particularly some species of *Eucalyptus*. On the whole, however, these nutrients are more important during the raising of seedlings in a nursery where it is necessary to have a healthy stock. It is also safe to say that generally most volcanic soils are rich in the necessary nutrients for plant growth. The problem of infertility of soil occurs primarily where soil erosion has taken place, or on kaolintic weathered soils where organic matter is depleted - the seriousness depending on the thickness of top soil with organic matter. Sandy soils, which have minerals leached can withstand more erosion than those soils with a top fertile layer, especially in marginal areas. Sandy soil is the only case where removal of surface soil might have some beneficial effect on plants which would not otherwise be able to reach leached minerals.

As a general rule, one can say that, other factors remaining equal, heavily weathered and leached soils are poor in nutrients (*Ferrasols* and *Aerisols*) while less leached soils are richer (*Luvisols* and *Cambisols*). Usually *nitosols* are the most favourable for tree planting originating from mineral rich rocks like lava, while *arenosols*, formed from quartz (sandy) soil, are extremely nutrient-poor in wet climates.

Major Ecological Zones

IT IS necessary to consider some major ecological zones for tree planting because some tree planting techniques applicable to one zone are not necessarily applicable to another. The ecological zones themselves are as varied as the climate zones. In fact some places, even 20 kms. apart can have different ecological zones.

Some zones look like islands and in identifying any particular vegetation type there is no substitute for local knowledge, based either on experience or on the observation of existing vegetation (often a fairly reliable indicator). One may find some pockets of rainfall, and hence rich vegetation, and in other cases dry pockets with very little vegetation. For example, in East Africa, patches of mountains have created local ecological zones by reducing temperature and increasing rainfall.

In spite of the above diversity of ecological zones, for the purpose of tree planting, six major ecological zones can be delineated on the map of Africa. The zones which are distinctly different are:

a) Deserts;

b) mediterranean zones;

c) semi arid;

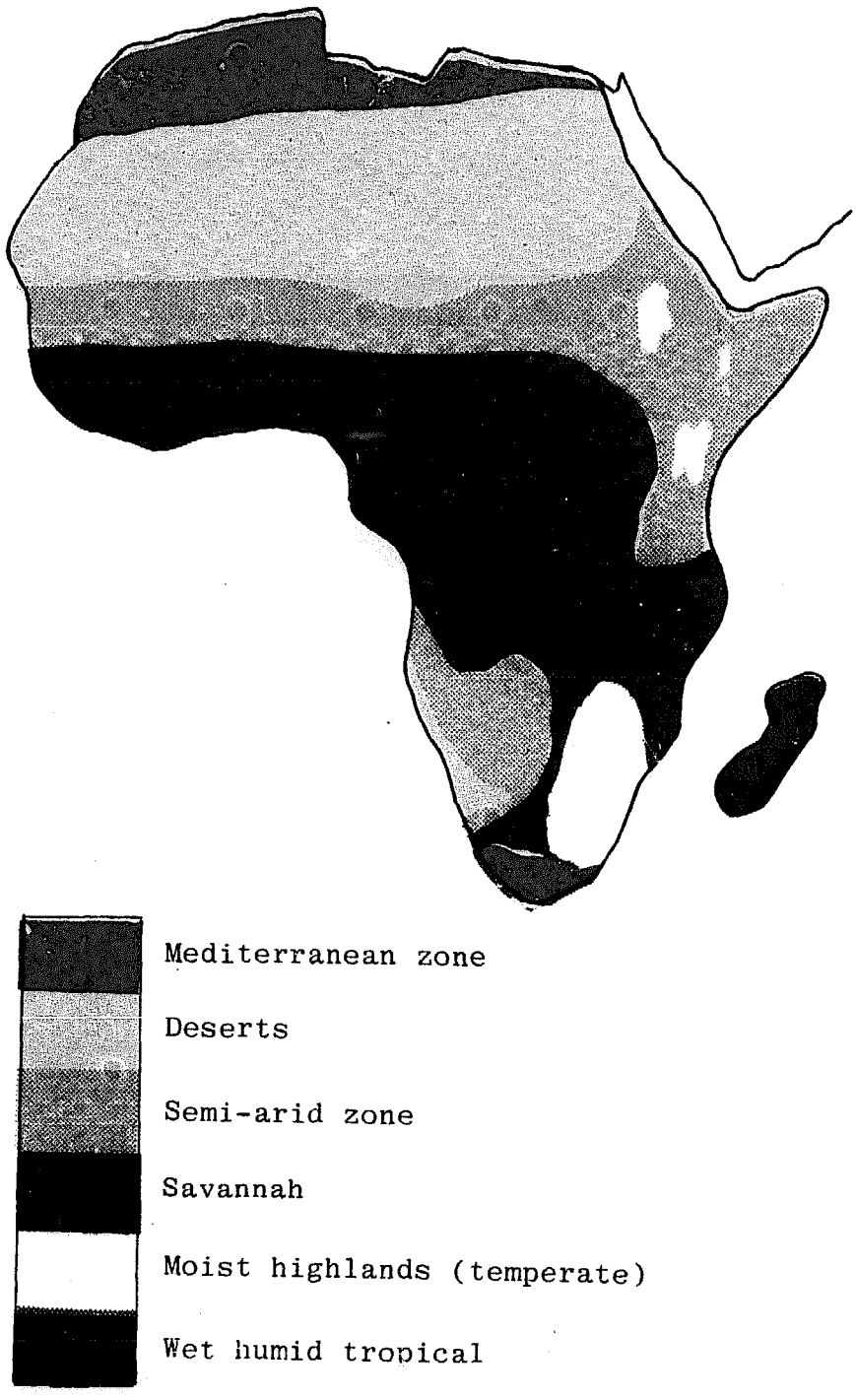
d) savanna;

e) moist highland (temperate);

f) wet humid tropical.

In considering ecological zones, one should bear in mind the concept of biological integrity. Vegetation supports other vegetation and, for example, any disturbance of vegetation in one spot has a chain effect on vegetation in other areas, creating a different ecosystem in spite of similarity of soils, climate, altitude and latitude.

The major zones usually correspond to the precipitation of each area. In some cases, however, temperature may vary due to altitude or latitude and naturally the vegetation will change even though the absolute amount of rainfall is the same. It all depends on the effective moisture available to vegetation.



Map 2 : Ecological Zones in Africa

DESERTS

Deserts are areas devoid of any vegetation, although some areas with a few shrubs do qualify as desert. Deserts have precipitation of less than 200 mm and usually have 10 to 12 dry months. A dry month is one which has less than 30 mm of rainfall or less (FAO). Besides very little rain, a desert zone has a very high evaporation rate. In some cases precipitation evaporates before reaching the ground. Mean temperatures are in the order of 28 - 32^{o} and the nights can be very cool.

One main feature of both the Sahara and Kalahari deserts is that they are expanding. Neighbouring countries are threatened with desertification. There is evidence of petrified wood that indicates that the Sahara supported extensive wooded area. The most effective means to combat and reclaim deserts is to plant trees. For example in Niger, a Sahelian country threatened by desertification, *Acacia* has been found to be a successful plant to halt desert encroachment, according to Oxfam.

Hardy species can be planted even on sandy soil and, due to leaf fall, they will ameliorate the site for themselves and also provide nurturing conditions for other sensitive economic crops. For example *Tamarisk* has been found suitable for stabilising sand dunes in North Africa. In the Kalahari *Acacia hebeclada* occurs in sands rich in calcium (Timberlake). The species can withstand very severe droughts (Hart & Douglas). Other species which are good for sand-dune fixation are: *Acacia cyanophylla*, *Pinus pinea* and *Elaegmus angustifollia* (FAO).

MEDITERRANEAN

The main feature of this zone is that, as can be seen from Map 2, it lies outside latitude 30^{o} North and South. In North Africa it extends from West to East. Generally it is wetter on the west and temperatures are higher in the east. One other main feature is that rain falls in the winter months and none in summer, and this means there is little evaporation compared to the areas near the equator with the same amount of rainfall. Planting trees is therefore better done in winter when temperatures are in the order of 13^{o}C (Pritchard).

Because dry periods are long, deep rooted trees must be planted so as to reach winter moisture below the soil surfaces.

The wet parts of the mediterranean region have open forest in the west, to almost desert conditions in the East. In Egypt, for example although it has a mediterranean climate, it would be dry except for the Nile delta. In the west, a forest of Cork oak, cedar, Spanish chestnut, pine and fir trees may be found. In the South, Transvaal and Free State have almost pure grass.

In North Africa especially, in countries like Algeria, the good area of the country is rather mountainous. One major aim of tree planting would naturally be soil stabilization. It is quite common to terrace the ground and this is a programme which can only succeed if combined with tree planting, mainly for multiple purposes. In some localities the problem is to terrace, irrigate and drain some marshes in order to get a good standard of soil (Hobley). Planting of trees may also be aimed at minimizing siltation and in some cases could be used for sand dune fixation.

Although tree planting is undoubtedly very important in the prevention, arresting and reclamation of desert, it must be remembered that in true desert conditions unless there is underground water, such as in the case of an oasis, or water for irrigation is introduced, there is no question of planting trees. Effort, therefore, has not been expended in trying to plant trees in deserts, although work is being done at the edges of deserts, mainly to halt its advance; where desert reclamation has succeeded, such as in Algeria, subsequent planting of citrus trees and figs has been possible (Douglas & Hart).

SEMI-ARID ZONE

The semi-arid ecological zone is very extensive and in some cases it can appropriately be called sub-desert. The zone is between Africa savanna and desert; it is, in fact, a transitional zone. Desert encroachment is very common in semi-arid areas. In semi-arid areas, one can see bald patches here and there and within a short time the few surviving trees succumb to inhospitable conditions; the rate of succumbing can be very fast when man comes in, searching for fuelwood and food for his livestock.

Rainfall in this zone is between 200 mm and 500 mm but it can vary very much. Mean temperature range is between 25 - 32^{o}C with very high evaporative rate. Many schemes for halting and reclaiming desert, are actually being started in this zone. The natural vegetation is made up of many drought resistant species. Trees in this zone have adapted to withstand long dry months which in some cases may be up to 8 months.

Moisture is the most critical factor for survival and growth of vegetation in this zone. There is great competition for water and generally, when planting trees, wide spacing is recommended. As a result of water scarcity, the trees which grow in this zone are drought resistant, e.g. *Xerophytes*. The *Xerophytes* have various adaptations allowing them to survive in these dry areas:

a) One major adaptation is storage of water in succulent stem, roots or leaves. *Euphorbia* species are an example of *Xerophytes* with stem succulence. Other trees or vegetation of dry areas have tubers, etc.

b) Reduction of leaves to avoid much transpiration *(microphyls)* is another adapation.

c) In some cases leaves are wax-coated to minimize transpiration.

d) There is also the familiar shedding of leaves and some species have altogether lost leaves (Wattle species).

e) For *Xerophytes* to succeed, some species have roots penetrating very far down and the rate of root elongation is pretty fast. Rapid root elongation is necessary to be able to keep ahead of progressive drying in the soil. For example, *Acacia albida* has been found to grow 1 metre per week in loose soil (Weber). Some *acacia* species have roots penetrating more than 25 metres into the ground. *Prosopis juliflora* will usually go down more than 20 metres below the surface (FAO). The deepest plant roots ever recorded were those of *Prosopis Veluntina* where, in an open copper mine pit, roots of the species were found at a depth of 53 metres (National Academy of Sciences, Tropical Legumes).

   The advantage of this root adaptation *(edaphic)* is that, when everywhere is dry, some trees will still survive and form the only food for livestock. Proper selection of species could therefore utilize underground water which would otherwise not be used by surface feeder crops and trees. *Acacia tortilis* is a useful example.

This is the most challenging ecological zone in tree planting due to its extensiveness and lack of suitable soils. In the Sahel countries it covers most of the land.

SAVANNAH

African Savannah is also fairly extensive and it is the zone which seperates the semi-arid zone from the wet, humid, tropical zone. The word "savannah" brings to mind different connotations of vegetation type. It can, however, be generalized that savannah is very varied, ranging from open grassland, to grassland with scattered trees and shrubs. It usually consists of lowlands with undulating hills and the main feature that distinguishes it from forests is that the tree canopy is never so thick as to totally exclude grass. Umbrella-shaped *Acacia* are a common feature. There may, of course be pockets of thick forests or some patches which qualify as semi-arid. Rainfall is generally between 500 mm and 1000 mm and the mean temperature is 25 - 31°C.

One main feature of savannah is that, due to repeated grazing and burning as well as cultivation, the savannah is encroaching on wet tropical forests. Rarely is the reverse the case. It has been demonstrated that if overgrazing and burning is prevented, for example, by fencing, fairly heavy vegetation can grow and luxuriant grass will also result. In fact most of the savannah is of secondary vegetation due to burning and cultivation (Hopkins).

When planting trees it is wise to keep in mind that natural vegetation can easily grow, and thought should be given to enrichment planting rather than first clearing all vegetation only to replant. One can say that while moisture is the limiting factor on the outskirts of savannah - towards the semi-arid areas - competition for light and nutrients is of greater importance in the areas near wet humid, tropical land. In this area agriculture is widely practised and it is an ideal zone for agricultural crops, particularly cereals.

MOIST HIGHLAND

This zone is not very extensive and examples of moist highlands occur only in the East African and Ethiopian highlands. The area with this type of vegetation would usually fall in either semi-arid or savannah zone had it not been for the altitude which has made all the difference in climate and hence vegetation. Even where one could expect to find equatorial climate, the high altitude makes the area considerably more humid and cool, given the same amount of rainfall. Rainfall ranges from 1000 mm to 1800 mm and the mean temperature between 21 - 27°C. Nights can be very cool and some mountain tops have snow.

In terms of agriculture, this zone is a high potential area with mostly volcanic soils. Temperate species such as *Pinus patula*, *Pinus radiata* and a variety of *Cupressus* species have been planted successfully in Kenya. Planting of trees in this zone is really not a problem. Perhaps the only problem is availability of land and also the selection of species which do not unduly compete with agricultural crops, especially in agroforestry systems.

Moist highlands ecological zones have high risks of soil erosion. They need careful management and land preparation before embarking on tree planting programmes.

WET HUMID TROPICAL

In this zone, trees will grow on their own and the planting problem is indeed one of weed competition. The zone is rich in flora and fauna and the main task here is conservation and reforestation in deforested areas. Rainfall is very high, more than 1800 mm per annum, and temperatures are also high with a mean of 30 - 32°C. The area is fairly low in altitude, from sea level to about 500 metres. Most of this area lies in Volta, Niger and Congo River Basins.

The area does not produce a lot of agricultural crops. When forests are cleared the trees' effect of nutrient recycling is lost and, due to heavy leaching, the soil can be very poor within a few years. Retention of some of the existing indigenous species in an agroforestry system is particularly relevant in this zone in view of nutrient recycling. It should also be remembered that in tropical Africa most of the nutrients are in vegetation rather than in the soil (Eckholm).

When a need arises to replace indigenous species with exotic species, or any different species, the problem is that of land preparation, which can be very expensive. Clearing land and sometimes uprooting stumps which could coppice profusely makes planting expensive. Many species can, however, succeed in this zone.

Seeds

NO MEANINGFUL tree planting programme can be achieved without due consideration of seed procurement. Tree planting techniques must of necessity start with seeds from which most tree species are propagated. Perhaps it is fair to generalize that seed procurement is a major problem in tree planting. The point here is to discuss some relevant processes such as seed collection, extraction, cleaning, storage, testing, viability, pretreatment and sowing. The majority of the important tree species produce seeds and it is only in a few cases where a certain species does not produce seeds, or it produces weak ones, that we turn to vegetative propagations, in which case seed provision does not play a significant part. *Poplar* and *Millingtonia* species fall under this category of vegetative propagation.

SEED COLLECTION

Seed collection is an arduous and expensive job and, indeed, one of the limiting factors in the whole process of seed management. One should therefore collect only good quality seeds. In the field one can cut open a seed if in doubt as to its quality. To avoid rotting, seeds should be collected when ripe either from seed orchards or ordinary trees.

Collection of seeds should be selective and timely. Many trees have ripe seeds only for a short time. One may climb a tree and with a hook detach cones or fruits. Alternatively, seeds can be collected from the ground at the bottom of a tree after they have fallen to the ground on their own or after seed bearing branches have been shaken.

It is wise not to mix seeds of different species during collection, otherwise subsequent treatment will present problems because different species have different and important characteristics such as:

a) Flesh pulp or other waste material;

b) viability;

c) germinative capacity;

d) pretreatment quality.

It is also necessary to keep a record of what is being planted for future reference, especially where there is doubt as to the species' ability to grow.

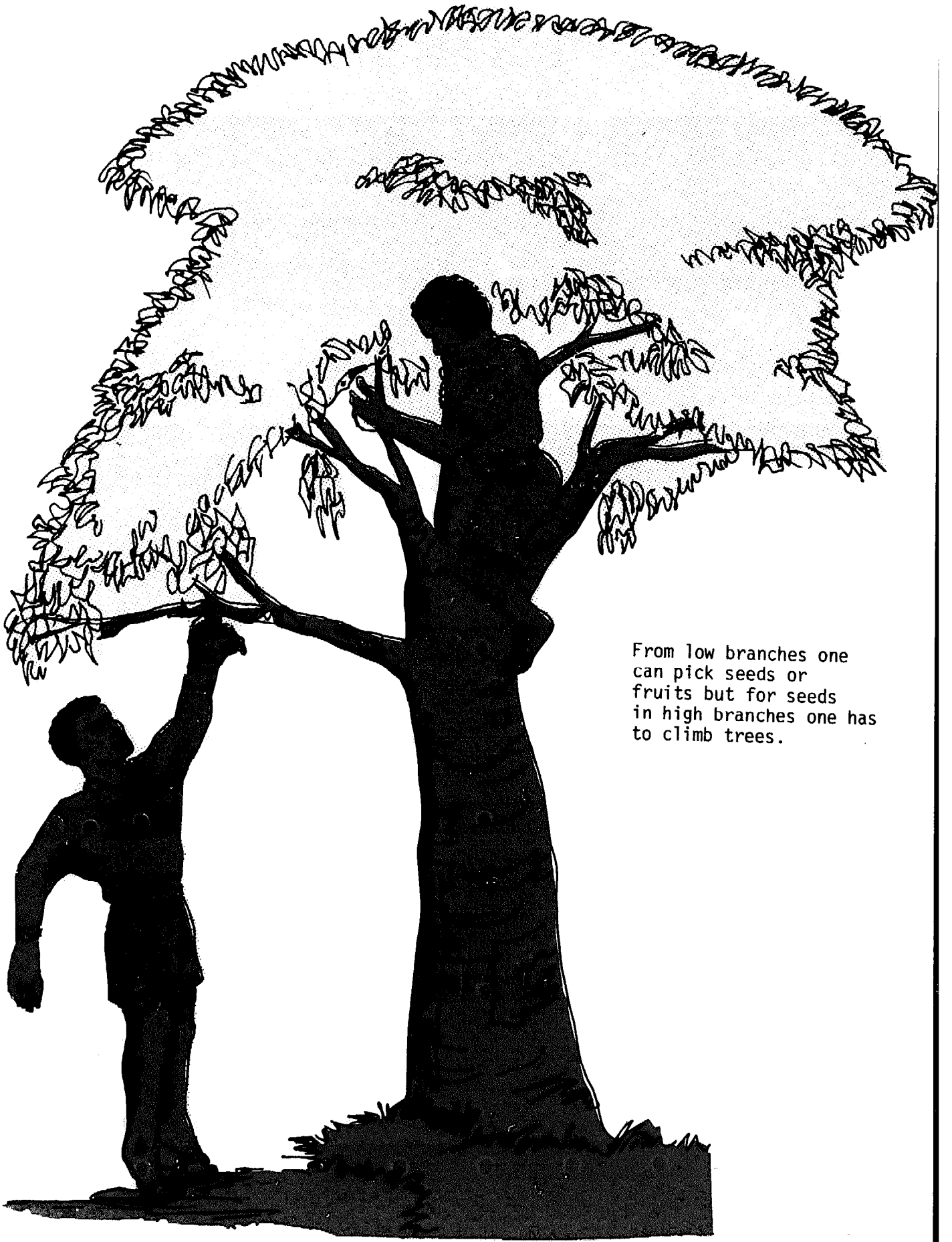


Figure 2: Seed Collection from trees

EXTRACTION OF SEEDS

There are basically three categories of seeds:

a) Those in the flesh pulp of a fruit. The seeds must be extracted by removing pulp and possibly drying the seeds within the fruit. Unless this is done the fruit will ferment and the seeds might decay, thus losing viability. *Chlophora* species, *Ocotea* species, and *Alberia coffra* belong to this category.

b) The indehiscent hard pods or capsules (dry fruit) which dry with the seed enclosed. Seeds would not decay but they should be extracted or the capsule cut at one end to allow seeds to germinate. *Pterocarpus angolensis*, *Gmelina* species and *Juniperus procera* belong to this category.

c) The common dehiscent pods from which seeds can be extracted simply by thrashing, and others break out automatically, as in the case of most legumes such as Jacaranda. These are the true seeds.

The point in seed extraction is that seeds should be separated from their container before storing for planting purposes. In the case of pulpy fruits, one can use water to remove pulp, such as in the case of coffee. Fruits like those of *Alberia coffra* are put in a drum and then stirred to separate seeds from fruit. The content is sifted through a wire mesh and waste is subsequently dried to avoid rotting.

Some seeds in cones, as in the case of pines, are dried and then thrashed. Cones can also be rolled in a drum to extract the seeds which can be removed by winnowing.

CLEANING

Most seeds, when extracted, contain some impurities either from the fruit or from the vicinity of work. All these extra materials not necessary for seed germination must be removed to reduce overall weight and volume - a necessary consideration in costing for subsequent handling of seeds. For the purpose of determining the germination rate, impurities must be considered. Some pests can also be removed during the cleaning process.

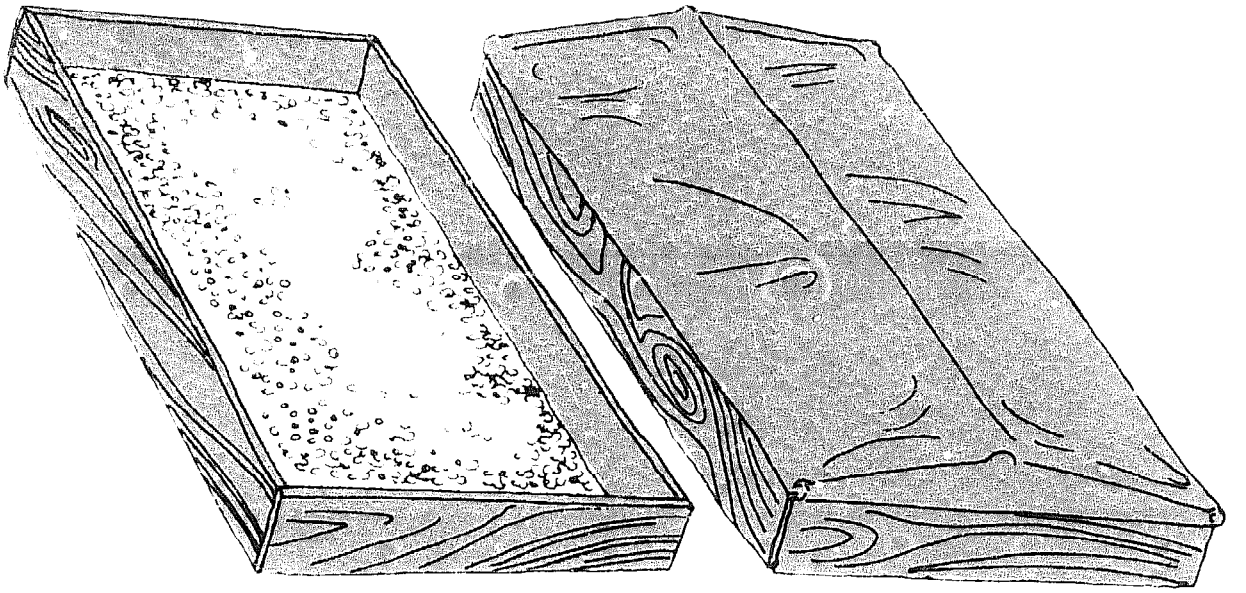


Figure 8a: Seed drying using Solar Energy

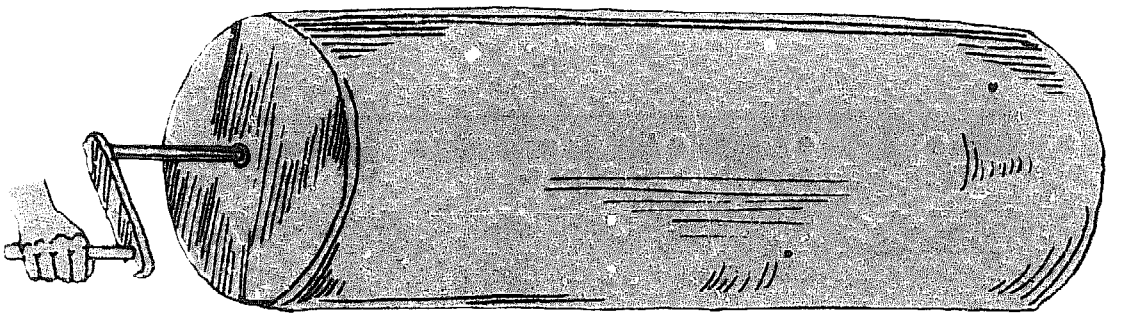


Figure 8b: Seed extraction using Drum

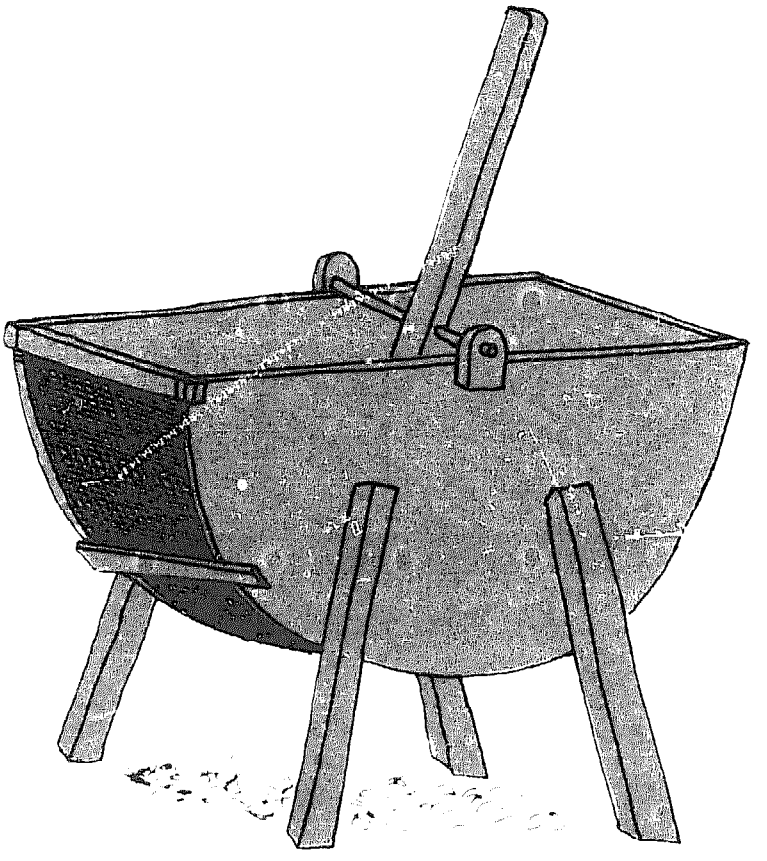


Figure 8c: Seed extraction with wire mesh.

STORAGE

After cleaning the seeds, it is quite common to store them for use later or for distant transportation. Seeds should be stored in cool, dry containers in order to minimize seed metabolism. If an area is humid, some dehydrating substances should be used. Pine seeds, for example, should be dried to between 6% and 10% moisture content and preferably kept in containers at between 3 - 5°C. Although some seeds can be stored for long periods, especially in air-tight containers, it is advisable to use seeds which have not been stored for too long. The shorter the storage period the higher the chances of germination.

VIABILITY

Viability refers to the ability of seeds to germinate once planted. Any seed will lose viability if stored for too long, since it is a living tissue and must respire, thus expending some energy stored in the seed. For example, *Chlorophora excelsa* loses viability within a year and *Grevillea robusta*, a favourite species in some agroforestry systems, must be planted immediately after harvesting. Other species which lose viability quickly are *Khaya* in Nigeria, *Lovoa*, *Entandrophragma* and *Azadirachta* species.

Trees which lose viability easily must be planted without delay. Synchronizing seeds to planting time presents a challenge. The chief problem is when the seeds ripen so quickly that planting in the field will be difficult to synchronise. It is necessary to ensure that seeds sown in a nursery reach planting stage by the start of the rainy season. If the seeds must be sown immediately after ripening and if the planting and sowing of seeds cannot be matched, it is best not to use that species. The species can only succeed if some irrigation or presence of underground water can be relied on.

For some of the seeds which lose viability quickly, refrigeration should be used if they have to be stored, and it might even be effective to coat seeds with glue. For example *Auracarias* seeds are difficult to germinate on a large scale (FAO). Also as a general rule fatty or oily seeds are very perishable, retaining their viability for a very short time.

Occasionally, one may not be sure whether seeds will germinate. It is necessary to test their viability. One may even cut a seed and tell whether it is fresh or not. Floating in water has also been used and in this case sound seeds are heavy and will sink, while non-viable seeds are light and will float on water. A conclusive test is to germinate a sample of seeds and count germination rate. If germination rate is too low the seeds should not be used. It is a good precaution to sow only what will germinate to avoid unnecessary cost and waste of time.

PRETREATMENT

Before sowing seeds, it is necessary to know if the seeds require pretreatment to facilitate germination; some seeds have very strong and hard testa - difficult for water to penetrate. For germination, moisture, warmth, and oxygen are essential. If seeds require pretreatment, as in the case of several species of *Acacia*, various pretreatment methods can be used:

a) Soaking in hot water;

b) immersing in sulphuric acid for 15 minutes; and

c) partial digestion by animals can speed up germination.

Acacia arabica is propagated by goats. It is paradoxical that goats, the single most blamed animal for desertification, can also help in regeneration. Tackling the problem of desertification, therefore, needs an integrated programme rather than wholesale condemnation of goats, which are in fact the basis of economy for people living in Sahelian and other fragile zones. Birds are also an important agent in seed propagation.

DIRECT SOWING

Direct sowing really refers to planting seeds directly on site where the trees are expected to grow. In theory the method is perfect as it avoids all the nursery costs. In some hilly, inaccessible areas, a tree planting program can in principle, only be done by aerial sowing. An instant forest could, therefore, be created in otherwise open areas.

In general, the ideal species for direct sowing are those that either have fairly large seeds or those that are prolific producers of seeds: *Croton megalocarpus, Acacia megalocarpus, Acacia mearnsii, Cassia siamea, Tamarindus indica, Eucalyptus Citriodora* can all be sown directly. In Gabon, *Maesopsis eminii* has been sown directly. Local experience can show which species are suitable for direct sowing. For example, in West Africa successful direct sowing has been obtained by planting *Borassus, Anacardium occidentale,* and *Acacia albida* (Weber).

In the course of direct sowing, seeds can either be broadcast or line-sown or, in some cases, spot-sowing is done. Treatment to control density is usually done after the seedlings have grown to the desired height. The concept of direct sowing is very appealing and the only reason why the method is not very popular is simply because factors which are essential for growth in the early stages are not controllable in the case of direct sowing. Technically,

any seed which can germinate can be directly sown. However, in the early stages, seedlings are very delicate and mortality rates could be high in direct sowing.

The agents which bring high mortality are:

a) Inadequate moisture, especially rapid drying of surface soil where seeds must first establish themselves;

b) pests and diseases such as cutworms, rodcuts, birds, damping-off, etc.; and

c) acute competition for moisture, nutrients and light from the already existing vegetation.

For young seedlings it is evident that growth or survival will be a gamble in direct sowing. As a result of high mortality, seeds must be made available in large numbers to compensate for the death rate and large supplies of good seeds are not easy to provide. Because of alternate drying and wetting of surface soil, seeds which can survive in direct sowing must be those which can send their tap root quickly into the soil. While a big seedling can withstand drought for some time, a newly germinated seedling will die. It is for these reasons that sowing in a nursery, though expensive, is often advocated in most tree planting programmes.

Tree Nursery Management

SCIENTIFICALLY planned nursery management is a prerequisite in any tree planting programme. There are permanent and temporary nurseries. A permanent nursery, apart from having water available, must be sited in such a way that it serves the maximum area to be planted without undue costs. There are pros and cons of centralised nursery management although many small nurseries may indeed serve different localities more efficiently in terms of distribution. Moderately big nurseries have the economy of scale. Each programme should choose between the two extremes.

In hilly areas and places without an adequate road system, there may be no alternative to but have small tree nurseries. In easy terrain with transportation infrastructure, moderately big nurseries could be appropriate. There is also a case for small nurseries where a farmer would like to raise his own seedlings. In Agroforestry systems such a small nursery may carry on all the functions of a standard nursery. In other cases, a farmer may buy small seedlings and nurse them for planting in his nursery. The job is justified, especially where one farmer may sell seedlings in addition to raising them just for his own requirement. A temporary nursery, on the other hand, exists to facilitate planting in the field. It is a kind of tree depot but should have adequate water.

SITING OF NURSERY

In siting a permanent nursery there are some important factors which should be taken into account:

a) The site should be frost free.

b) The ground should be fairly level or, if not, terraces should be made.

c) Good soil, or if poor, some good soil should be imported especially for the seedbeds.

d) Good drainage is essential and water logged sites should be avoided.

e) Nursery sites should be accessible at all times.

f) Ideally, tree nurseries should be near residential areas to enable regular supervision and monitoring of changes as seedlings grow.

g) Where a nursery is sited in a forest area, the alignment should be East-West, to allow enough sunlight.

NURSERY ADMINISTRATION AND PLANNING

There are some important records which should be maintained in a nursery; for example time and location of sowing should be entered in a record book. A nursery should have a storeroom in which some garden tools and special soil can be kept. Seedbeds or boxes should be arranged in such a way that people working can walk freely and can reach any part of the seedbed. Paths of one metre are wide enough between rows of seedlings which should also be about one metre wide and as long as is necessary.

To keep off rodents and domestic animals, a nursery should have a fence. A hedge, where appropriate, should be grown and a gate should be maintained to keep out unauthorised people. It should always be borne in mind that cleanliness is essential to prevent introduction of diseases and pests in the tree nurseries.

In short, then, siting a nursery calls for infrastructure such as water, roads, labour, telephone if possible, and cold storage. It is useful, too, to have other facilities nearby such as schools, a hospital, a market and other essential commodities for people working in the nursery.

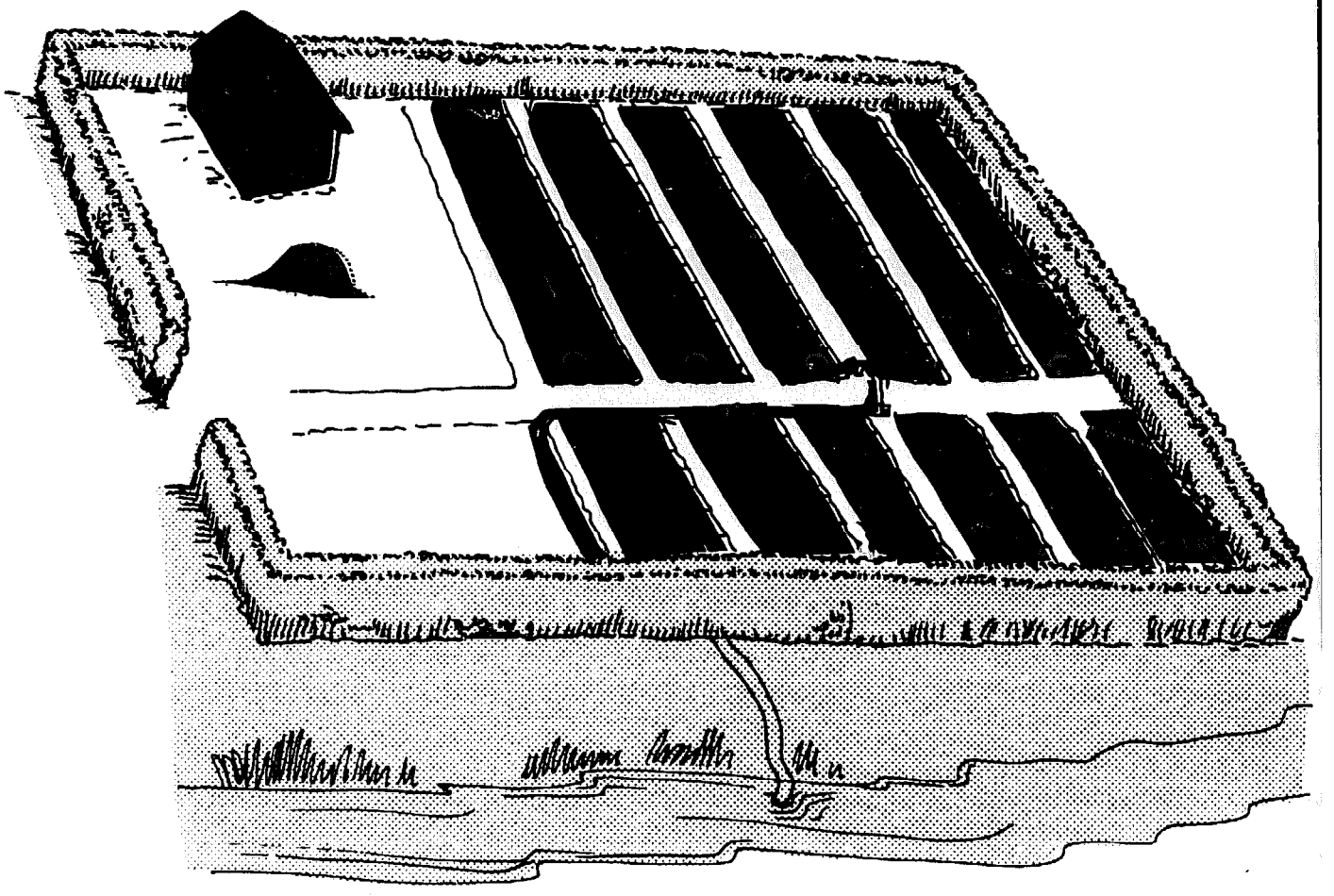


Figure 4: Nursery Layout

SOWING IN NURSERY

Once a nursery site has been chosen, the seed beds laid out, and nursery buildings constructed, the sowing of seeds follows common standard methods in Africa. Generally, the sowing is done either into seedbeds or directly into containers such as polythene tubes in such a way that there is no transplanting into the nursery. Whichever is the case, fertile soil must be made available to give a boost to the seedlings. A typical nursery soil would have the following mixtures:

a) Forest soil;

b) top soil from any vegetated site;

c) some sand or gravel for proper drainage;

d) some cow manure;

e) fertilizer, about 28 grams per 25 litres tin of soil.

Usually forest soil is assumed to be fertile. In some cases it does lack some essential elements, i.e. nitrogen, phosphorous, or potassium. If this deficiency is discovered it is essential then to add some fertilizer. Sufficient care should be maintained as fertilizers are known to drastically lower survival rates when badly applied, particularly nitrogenous fertilizers. But this does not rule out the essential role of fertilizers to seedlings.

The sowing of seeds should be done so that their optimum size (about 25 cm long) will be attained just prior to the planting or rather match the size of seedling to rain. The period seedlings stay in the nursery will obviously depend on climate, as influenced by altitude also. For example, in the moist highlands of East Africa pine requires a total of 13 - 18 months in the nursery. A considerable amount of planning is essential for proper synchronization. Either too small or too big a seedling is not good for planting.

A germinating seedbed should have some sand to facilitate drainage. Experience will show how to sow seed without over-crowding, which often leads to damping off. If in doubt, it is good to mix seeds with, for example, sawdust before broadcasting and this will make an even distribution of seeds. For fast growing seeds, enough soil equal to the shortest diameter of the seeds should cover the seed. For slow germinating seeds. greater depth is needed. In other words, for very small fine seeds, only a thin layer of soil is needed for germination.

Germinating seedlings are usually susceptible to damping off. The disease is caused by *Pythium* species of fungi and if unchecked will kill seedlings. Damping off can be checked by:

a) having a light density of seedlings;

b) avoiding shading seedlings in wet, damp periods;

c) naturally avoiding soil that is heavily infested with *Phythium* fungi whenever possible.

Damping off in spite of the above precautions may occur, in which case an appropriate fungicide such as Peronox can be applied on the seedlings or in the soil.

PRICKING OUT METHODS

Young seedlings are extremely tender and must be handled with care. Even a light pressure of the fingers, especially from inexperienced persons, may crush seedlings and that is why handling is done by the leaves. A dibble is driven below seedlings as shown in Figure 5 and the seedlings are individually picked up for transplanting. Otherwise, pulling them from the soil will also damage their tender roots, besides the possibility of tearing leaves or stems. This is an operation which needs very close supervision and indeed it must

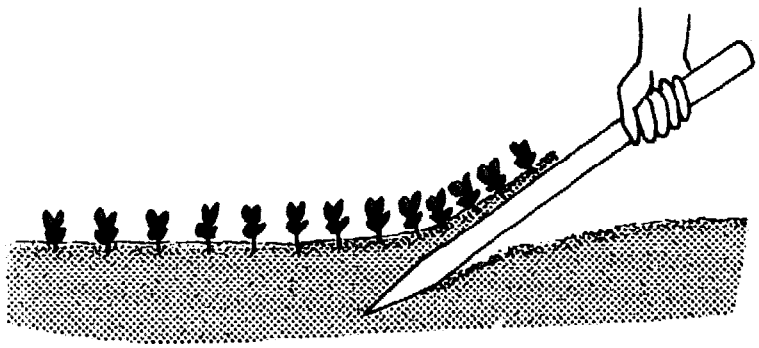


Figure 5: Pricking out method

not be done on task work (i.e. workers should not be told how many seedlings must be pricked out per day). Here, quality rather than quantity is the issue that matters. A good pricker should, however, be able to prick and transplant betwee 750 and 1000 seedlings per eight hour day.

The other important precaution is to ensure that seedlings are not dehydrated. As they are normally bare rooted, some people keep young seedlings temporarily in water or slightly wet. They must, however, be transplanted immediately to avoid the seedling dying. Staff experienced in pricking and transplanting should be maintainted in the same job as long as possible to take advantage of accrued experience.

It is not advisable to prick seedlings individually as this might injure the tender plant. When a dibble is pushed under seedlings, as shown above, the whole block of soil will fall apart and one can pick the young seedlings for transplanting. On transplanting, they should be planted at the same level they were on the germinating bed, or sometimes a little lower but never higher.

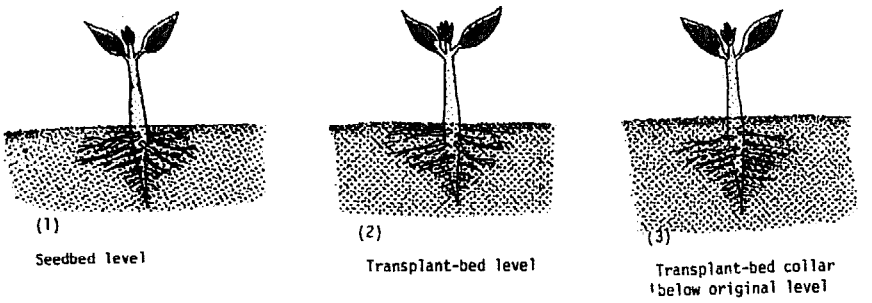


Figure 6: Levels at which seedlings should be planted

It is advisable to cut the tip of the root if it is too long, to allow better transplanting. The holes for transplanting may be made by a dibble or by a mould prepared for this purpose may be as shown in Figure 7. Again, seedlings should not be handled by their stems but rather they should be handled gently by their leaves.

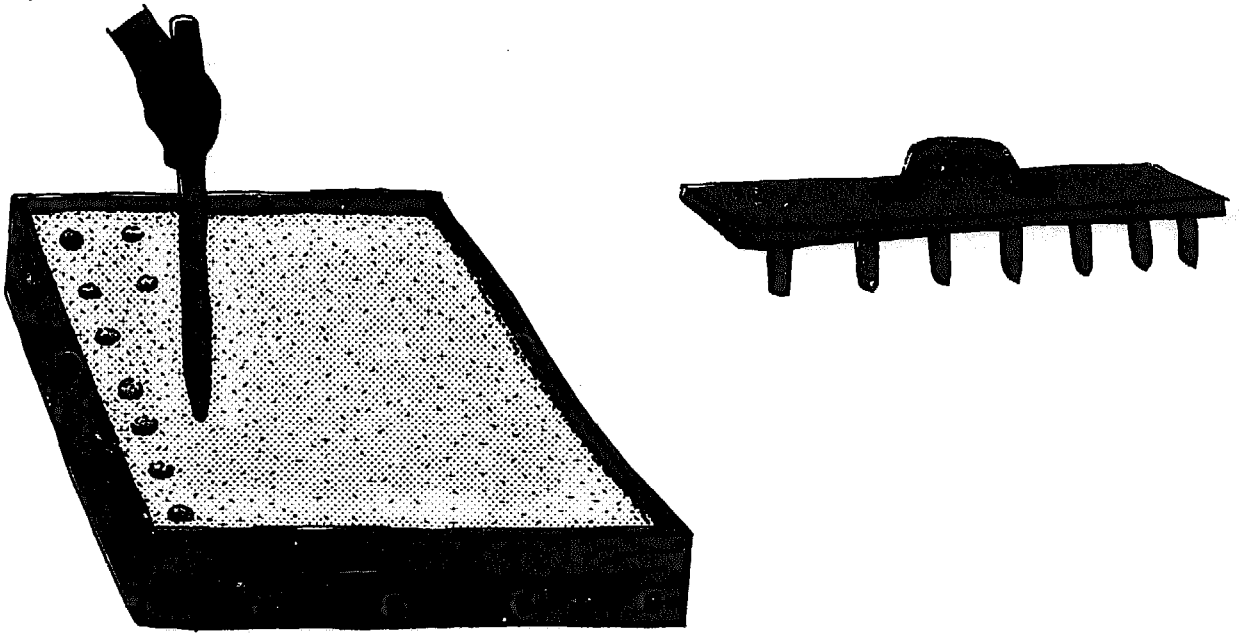


Figure 7: Making holes in Box by Dibble and Mould

WATERING AND SHADING

After carefully placing seedlings into the hole, however prepared, soil should be firmed gently around the seedlings. It is advisable to give seedlings plenty of water and, if it is a very hot place with overhead sun, some light shading is recommended. Watering twice a day results in better survival and growth than watering

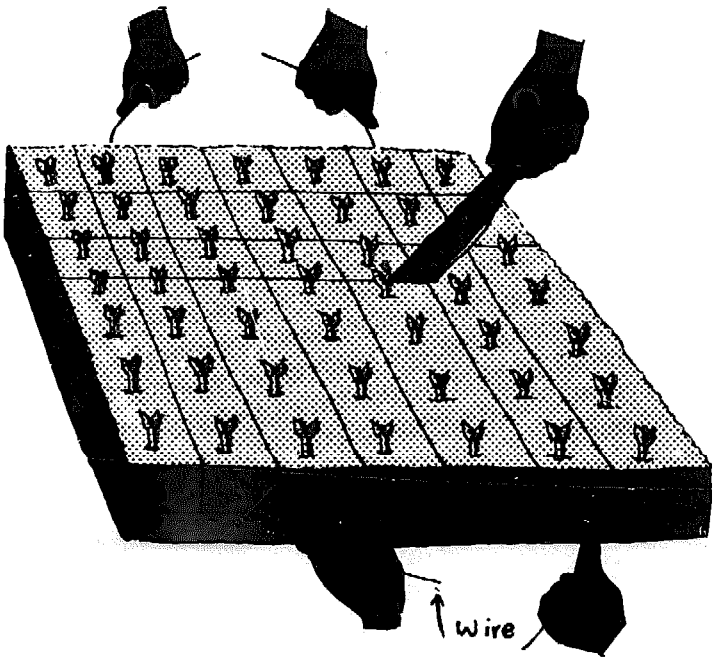
every other day (Dolberg & Lysholm). Some seedlings such as *Araucaria* and *Pterocarpus* require light shade most of the time they are in the nursery (FAO). In Kenya it was also observed that shading, whether constant or only in the middle of the day, is very beneficial for survival and height growth of *Pinus Oocarpa* and *Pinus caribaea* (Solberg and Lysholm). In most cases, however, there is no need to continue shading once the seedlings have passed the shock of transplanting.

ROOT PRUNING

Whether the transplants are in boxes (in East Africa boxes are made to contain 50 seedlings and this has been found to be very convenient for handling) or on seedbeds (popularly known as Swaziland beds because of the historical fact of origin of the method in Swaziland), it is absolutely necessary to prune roots. Pruning of roots stimulates growth of fibrous root systems, ideal for feeding. It is known that for success of a tree, of more importance than root depth is the root length density, that is, length of root per cubic metre of soil (Leyton); fibrous roots have a higher density than unpruned roots. Pruning is done by passing a fine wire below seedbed or below a box, while cutting between seedlings is done by a sharp knife. This prevents too much root intermingling and, consequently, at the time of planting, a neat seedling with its soil can be separated.

A seedling with its own compact ball of soil has better chances of survival than a seedling which, in the course of being detached from the box of seedbed, loses most of its soil. In fact, where a seedling is uprooted without root pruning, considerable damage is done to roots and hence such seedlings take much longer to establish themselves once transplanted. (see figures 8a and 8b).

Wire being drawn two ways to avoid leaving some roots bent down.



A ball of soil from a well root pruned stock

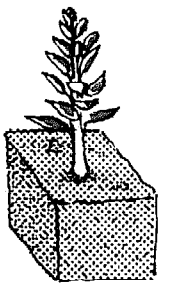


Figure 8a: Root Pruning

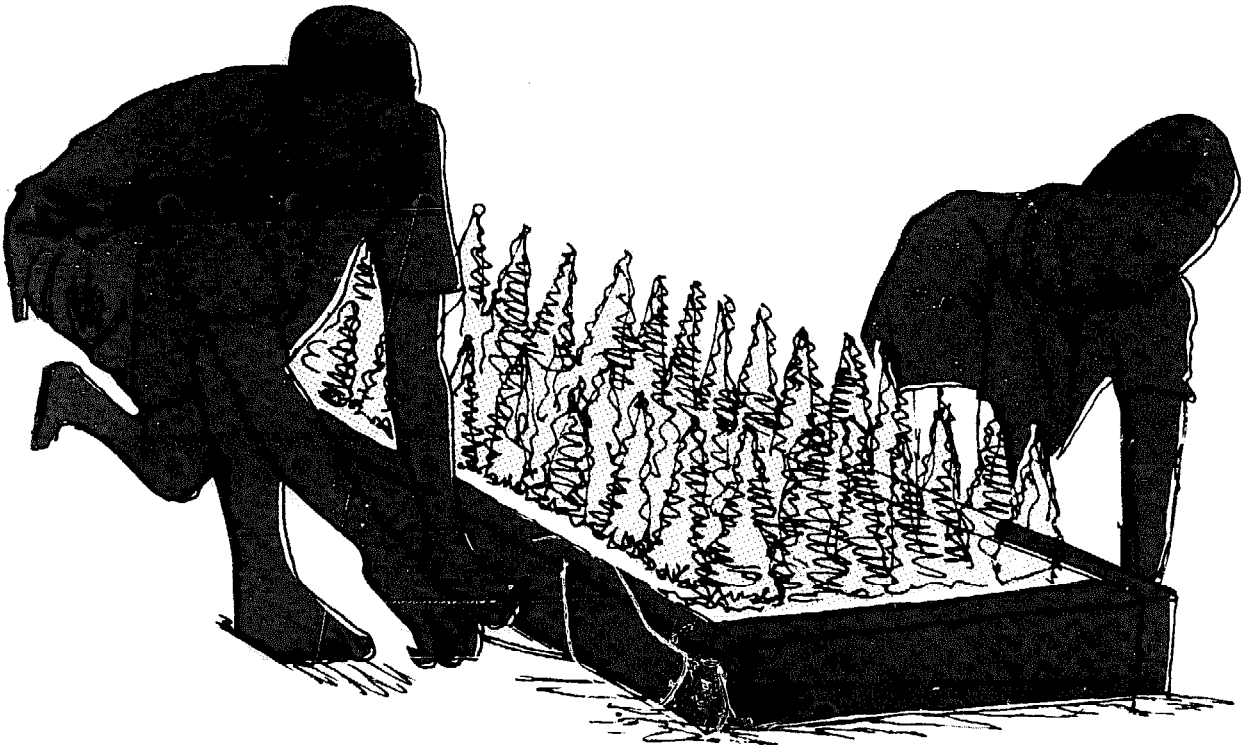


Figure 8b: Root Pruning of Seedlings in Swaziland Bed

Carelessness in root pruning or neglect leads to roots being badly bent on planting and this has been known to lead to the tree stangling itself. (Konuche, Kenya silviculturist on Turbo afforestation - Personal communication).

SUBSEQUENT WATERING AND PLANT HARDENING

Besides pruning, the essence of nursery care is to ensure seedlings can be watered. Fine rows of water sprays are much better than one big jet of water. Also, in hot places one good watering is better than several small bits of watering which tend to be evaporated immediately. Watering should be done in the morning and evening for more effective use by plants. Watering in the morning or evening only has been demonstrated to be better for mean height and survival rate (Solberg & Lysholm).

Particularly in dry areas, there is an issue of hardening seedlings. Seedlings should have their water ration reduced progressively as this prepares them for the eventual shock of being planted in the field. Water is reduced gradually until the plant starts wilting and then it is given some water. It is recommended that, immediately before planting, seedlings should be given a good final watering.

Besides watering, small seedlings need some shading but not when it is wet and misty. If shading is done under those conditions, damping off may be accelerated.

QUALITY CONTROL OF SEEDLINGS

In nursery management it is extremely important to plant only the good stock because planting defective stock can be very expensive. It is therefore important to cull good stock. This is especially true in large government nurseries like those managed by various agencies responsible for forestry. In a private nursery there may be less culling because in many cases an individual person who is planting trees for firewood may rightly not be worried about the form of the tree.

When planting in the field, seedlings from a nursery are available mainly in three forms. There are the seedlings from a seedbed which would be called 'naked root tree planting'. Here a seedling may only have a very small amount of soil in the roots and at times there may be no soil. They are recommended in exceptionally wet conditions. There are also seedlings from boxes. If the root pruning has been done well between the rows at the right angles, seedlings come out of the box with a mat of soil. They can stand longer transporation than naked root seedlings. There are also potted seedlings in any convenient container. Usually one seedling per pot is the case. The pots may be compact soil ball, polythene tubes, bamboo tubes, banana box or indeed a metal or wooden box. These potted seedlings are recommended for dry areas where transportation is fairly long.

Seedlings should have enough soil and moisture to overcome deficiencies at the site of planting. The point in quality control is that since any blunder in tree planting is expensive, only healthy and vigorously growing seedlings should be planted

Figure 9: Different Containers for Seeds

Selecting Sites for Tree Planting

THREE major factors determine suitability of a site for tree planting, and these are: climatic conditions, soil quality, and the ecology of a particular area. These factors should be carefully considered when selecting sites for tree planting. Site analysis is important especially since ecological factors differ from one place to another. Even on an acre of land differences in soil quality could vary considerably from one specific site to another. These variations should be given careful consideration.

CULTIVATED SITE

A cultivated site will yield better results than an uncultivated one. Cultivation loosens the soil and improves the texture, a factor which promotes plant growth. Prior to the planting of trees, the chosen site should be cleared of weeds and tilled to loosen the soil. Cultivated sites formerly utilized for crops should be given priority in choosing sites for tree planting.

ROCKY OR STONY SITE

If planting of trees has to be done in rocky areas, then the selection of the right type of tree species is important. Some tree species such as *Pinus Kesiya* have roots that are able to penetrate through hard layers of laterite soil and hence manage to reach moist soil below the rocky pan. Species which do not have deep penetrating roots would easily die if planted in rocky sites. If an area must be planted, as in the case of home and school compounds, then the rocky layer has to be broken through before planting takes place. In such a situation, the spot where the tree is to be planted should be well covered with soil collected from elsewhere.

UNDERSTOCKED SITE

An area is understocked if it has a comparatively lower percentage of tree cover than it should have under normal circumstances. Such an area could be cleared of existing vegetation to allow for fresh tree planting or "enriched" by planting with additional tree species. If enrichment planting is carried out in partially forested sites, then the newly planted tree seedlings will be subjected to competition for nutrients by existing well established roots of older trees. Enrichment planting is however, preferable to clear felling, in view of the desirability to conserve soil and water. Clear felling of a forested site should be discouraged unless deemed absolutely necessary and if replanting will be done.

GRASSLAND SITE

In East Africa especially there is more area under grass than forest. Grassland sites can be forested by proper land preparation prior to the planting of trees. The choice of species able to withstand competition with grass is of utmost necessity. Certain species of *Acacia* do well in East African grasslands or the savannah.

WATERLOGGED SITE

Waterlogged sites should be drained prior to planting of trees. In such areas, deep rooted species of trees that drain soil should be utilized. Certain species of *Eucalyptus* (blue gum) have proved suitable to waterlogged sites. Mangroves and other water tolerant species do well in swampy coastal areas.

Selection of Species

THE choice of species to plant will depend mainly on utility and adaptability to environmental conditions. Before planting, the right type of species should be carefully selected. Information regarding utility and suitability of species should be obtained at the nearest local forestry office, taking into consideration the factors outlined below:

a) Adaptability of Species

In selecting species for planting, preference should be given to the existing indigenous species available in the locality. Alternatively, species which have proved successful under similar ecological conditions should be given higher priority to any unproven type. Species imported from other regions with different climatic conditions should be subjected to experimental planting before mass planting in new localities. For example, Africa has 115 species of *Acacia*, adapted to different ecological zones of the region.

b) Utility

The characteristics of a tree will determine its suitability for various roles, as outlined briefly below:

i) Fuelwood: In selecting species for fuelwood, factors such as ability to grow rapidly, withstand drought and degraded soil, and exposure to wind should be considered. Most suitable are those termed as "pioneer" species which, in nature, colonise deforested areas, withstanding grazing, cutting and fires. These are usually well-known and available locally (National Academy of Sciences).

ii) Ornamental: Form, size, colour and texture of the crown are important qualities in determining the aesthetic value of a tree.

iii) Nutritional value: Various species of trees are planted for their nutritional value to both human beings and herbiverous animals.

Nutritional products like oil, fruits and fodder are obtained from numerous tree species. In the Kalahari, for example, pods of *Acacia Aerioloba* are gathered for feeding cattle during the long dry seasons.

iv) Soil quality: Apart from the direct benefits accruing from trees, various species of the leguminosae family have nitrogen fixing ability which helps maintain a steady supply of nitrates to the soil. Tree roots help to hold soil particles together, hence increasing soil stability.

BELOW IS AN OUTLINE OF SOME COMMON SPECIES INDICATING VERY BRIEFLY THE SITE REQUIREMENTS, POSSIBLE OR COMMON USE AND METHODS OF PLANTING THE RESPECTIVE SPECIES

Species	Site requirement	Use	Methods of planting
cia albida	Will grow in fairly dry areas.	Fuel, fodder as it is evergreen in dry period. Shade for sorgum and tobacc	Direct sowing on prepared land. Seeds should be soaked in water before planting
cia nilotica	Will grow in dry areas even when inundated with water.	Fuel, and tanning from pods, bark and leaves.	Direct sowing
cia Senegal	Does well in fairly dry areas	Gum arabic and fuel	Direct sowing
cia tortilis	Early colonizer of dry areas and last surviver in desert. Favours alkaline soil and can grow in rocky or sandy areas.	Fodder, fuel, shade and shelter.	Direct sowing easily propagated by animal after passing through alimentary canal.
ocarpus axinifolius	moist areas and deep soils	Fuel and timber	Transplants from nursery
ucaria nninghamii	Requires high to average rainfall.	Pulpwood and timber	Difficult to germinate. Seeds must be planted soon, within a few weeks of ripening. Raised in nursery boxes, pots or polythene tubes. Fertile soil and *mycorrhizal* inoculation produce good results.

ecies	Site requirement	Use	Methods of planting
achta	Likes humid warm sites minimum moisture about 450 mm, pH of over 6 is required.	Firewood, shade as it is evergreen, poles, and timber.	Poor germinative capacity and viability of seeds shortlived. Large transplants used for planting.
is glauca	Moist zones but will grow in slightly dry zones.	Grown for timber	Tansplants in trays, boxes or pots.
siamea	Does not do well in dry area. Shallow rooted species with advantage of being termite proof	Good for fuel and timber	Direct sowing and also stump planting is recommended.
ina ifoloa	Dry tropical and semi-humid tropical	Shade and poles	Transplants from boxes, polythene tubes and boxes. Naked roots planting also possible in high rainfall areas.
hola	Moist forest savannah	Sawn wood; excellent timber. When in association with other species it is picked first as superior timber	Germinative capacity good when seeds are freshly extracted. Planting of large stumps and striplings usually recommended.
arpus	Requires high average rainfall	Pulpwood and timber. Fast growth.	Direct sowing due to large seeds.

Species	Site requirement	Use	Methods of planting
Cuppresus lusitanica	Moist highlands, over 1000 mm of rainfall. An exotic species which has done well in East African Highlands.	Good timber and high growth rate.	Sowing seeds in nursery and then planting transplants from boxes, Swaziland bed, or polythene tubes. In high rainfall areas, naked root planting has proved successful.
Dalbergia sissoo	Survives in dry sandy soils, alluvial and riverbeds.	Excellent fuel quality poles, furniture, fodder.	Direct sowing, stumps or root suckers all recommended; sensitive to weed competition initially.
Eucalyptus camadulensis	Ability to survive in dry areas.	Poles and firewood.	Transplant from boxes, polythene tubes in high rainfall area; in swamps naked root planting has been successful. Proper spreading in broadcasting seeds in nursery bed to avoid overcrowding.
Eucalyptus grandis	Moist areas	Firewood and timber. Has fast growth	Transplant from Swaziland bed, boxes or polythene tubes. Small seeds need proper broadcasting.
Eucalyptus microtheca	Drought resistant	Poles and firewood	Transplant from nursery. Like other eucalyptus, very small seeds. Potted plants.
Eucalyptus tereticornis	Drought resistant	Poles and firewood	Transplant from nursery, small seeds.

Species	Site requirement	Use	Methods of planting
Gmelina arborea	Optimum rainfall about 1800 mm. Deep well in drained soils.	Excellent pulpwood, plywood, good timber.	Direct sowing and if seeds are scarce six months stumps can be used. Seeds are fairly large about 2 or 3 seeds per fruit and has high germinative capacity.
Grevillea robusta	Moist highlands	Fuelwood and timber polareling is done It is popular tree in agroforestry system. It is a nursing tree.	Transplants from boxes, pots or Swaziland bed. Sowing must be done quickly after ripening to avoid loss of viability. Storage period should be less than three months. The tree does not coppice well but when branches are cut, new ones sprout quickly.
Jacaranda actifolia	Arid and semi-arid areas	Ornamental and fuelwood	Transplants from nursery. Easy to handle and if wet, bare root stock will grow well. Fast growing species.
Juniperus procera	Moist savannah	Easy-to-work timber. Cedar wood oil and cosy timber. Pencil slats and flooring.	Transplants from nursery. Potted plants are ideal. Pure plantations have not done as well as cedar species found growing naturally in association with other species.
Khaya ivorensis	Moist areas	Sawn timber of good quality	Stumps or striplings, and it is a shade intolerant species.
Leucaena leucocephala	Fast growing in moist areas but fairly drought resistant. Low elevation species.	Excellent fodder and fuelwood, and poles	Direct seeding and also potted transplants from nursery. Can be a nuisance weed.

Species	Site requirement	Use	Method of planting
Lovea Klaineana	Moist areas	Good timber	Stumps or striplings. Fairly shade tolerant when young.
Pinus Kesiya	Moist highlands; can penetrate laterite soil	Good pulp material	From transplants either from Swaziland bed, boxes or polythene tubes.
Pinus patula	Moist highlands, over 1000 mm of rainfall	Sawn timber and pulp material	Transplants either naked roots in fairly wet places or in boxes or polythene tubes.
Prosopis Juliflora	Drought resistant. Becomes serious weed in good climate. Deep rooted species.	Fuel, fodder. The pulp of fruit has high content of carbohydrate. Nitrogen fixing in soil.	Transplants in boxes or polythene tubes. Direct sowing also possible due to rapid taproot.
Pterocarpus angolensis	Rain forest to dry open savannah.	Timber of outstanding value. Cabinet wood.	Stump planting recommended. Seed fairly difficult to extract and good germination is obtained if one edge of the fruit is chopped off. Slow growth, but young tree coppice. Regeneration is good in cleared or burnt areas.
Schinus molle	Moist to dry savannah	Shade tree.	Transplants potted or in boxes. Good germinative capacity when fresh.

Species	Site requirement	Use	Method of planting
marix *ticulata*	Salt tolerant and drought resistant	Fuelwood and sand dune fixation	Cuttings can suffice
ctona *andis*	Moist forest but also savannah	Excellent timber, teak poles, fuel and sand dune fixation. Due to heavy leaf fall, it enriches site well.	Stumps about 25 mm in diameter. Some direct seeding can succeed. The species has outstandingly big leaves.

Land Preparation

LAND preparation is extremely important in tree planting, as it is in agricultural work. It has been said that in budgeting for tree planting, as much as 95% should go to tree planting processes and 5% of the budget should go to the cost of the tree itself (Thompson). Planting in unprepared land is asking for very costly losses. The main objects of land preparation are:-

a) to reduce grass and weed competition;

b) to improve soil structure;

c) to conserve moisture;

d) as a fire protection; and

e) to facilitate later mechanization.

If one is planting in a forest area, the first logical step is to clear-cut trees followed by the removal of stumps; in some cases, if an additional crop is wanted, removing stumps is essential, especially for species that coppice freely, because such stumps have already well-established root systems which will compete with new crops. After removing stumps, ploughing to remove small weeds may be done for better results.

Staking and pitting is another category of activity which normally falls under land preparation. In grassland, one may plough before staking and pitting for better growth; or staking can be done with or without spot hoeing. Ploughing in a grassland site is done to reduce competition in the early stages.

In dry areas, land must be brought to good tilth. Usually holes are dug about 25% larger than the soil-ball holding the plants (in dry areas, potted tree-planting is strongly recommended). The aim here is to reduce weed competition and to improve soil structure. It is recommended that, when holes are dug in advance, soil should be returned to the hole to avoid dessication of the walls of the hole. Just before planting, the soil can be removed again to allow a few showers to soak the bottom and the banks of the hole.

In sloping areas, terracing is recommended - again the main point being to prepare land in such a way as to allow moisture to be held for as long as possible. It cannot be stressed too much that moisture is the critical factor for tree growth in dry areas and this must be kept in mind when preparing the land for planting.

On sloping areas, other soil conservation measures, such as making cut-off lines, should be undertaken to avoid excessive erosion, as the washing away of top-soil through erosion is bad for tree planting.

In gravelly sites, again, soil structure improvement is of prime consideration. A much bigger hole is required in gravelly areas than in areas with good soil. If all soil on the site is bad gravel, for example, one should then import good soil. Even where soil is fairly good, it is helpful to keep soil in two heaps when digging a hole; top soil should be kept on one side and bottom soil on the other side, as shown in figure 10.

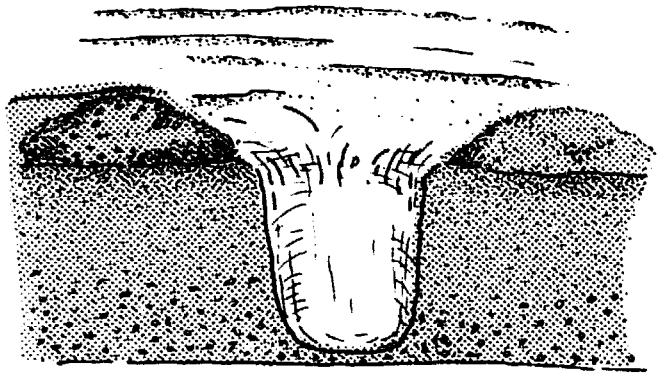


Figure 10: Separation of soil when digging holes to plant

Figure 11 shows tied ridging more applicable to dry areas, which is done by preparing soil in some kind of box; planting is then done on top soil of the ridges where there is enough soil, while some water is held in a kind of microcatchment at the bottom of the box.

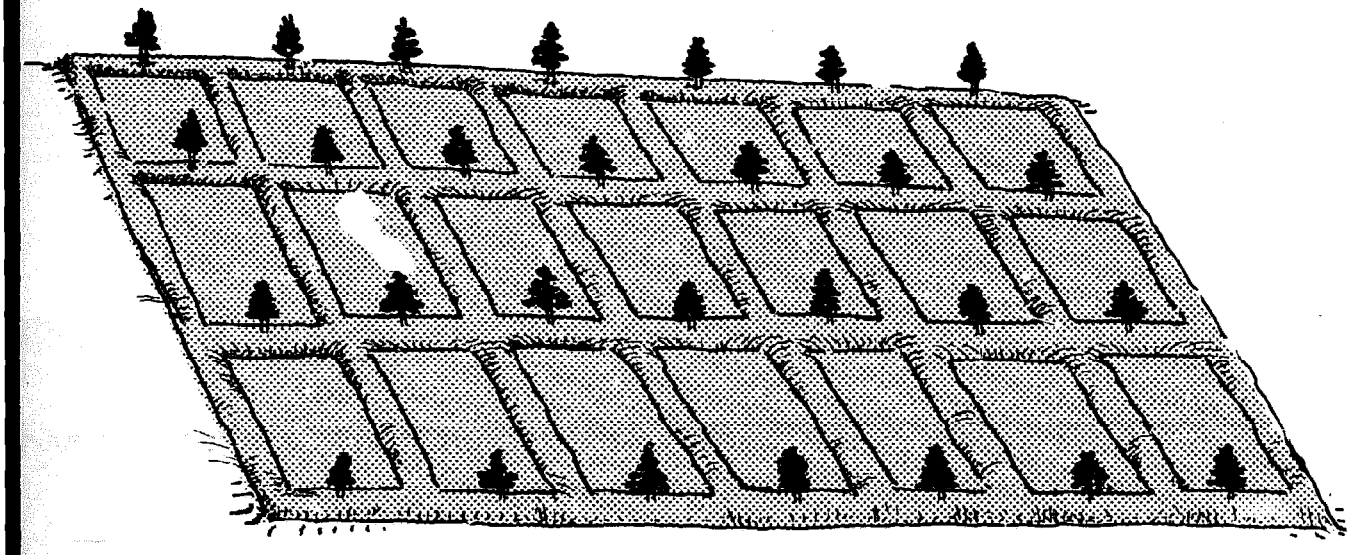


Figure 11: Tied ridging for trapping moisture

Transportation and Distribution of Planting Material

PROXIMITY OF a nursery to the area under tree planting is recommended to reduce the cost of transportation and, equally important, to avoid a potentially high casualty rate in the course of transportation. Young seedlings are very vulnerable and can die due to mishandling. Seedlings can be transported in the form of:

a) naked root stock;

b) stock in boxes which carry more than one seedling (in East Africa a box usually contains 49 seedlings); and

c) potted stock (which means one plant per container).

TRANSPORT OF NAKED ROOT STOCK

In transporting naked root seedlings, care must be taken to ensure no damage is done to roots by, for example, blazing the skin off, as this can easily lead to diseases. The other important precaution is to ensure that the plant does not become dehydrated. A plant is always transpiring water and unless roots are also getting water, it will dehydrate and die. To avoid dehydration, therefore, roots must be kept wet or, alternatively transpiration should be minimized. To avoid dehydration, wet roots can be bundled in polythene tubes during transportation.

It is important to note that transporting naked root stock should be avoided where possible, and planting of such material should be confined to nearby wet areas. Once the stock has reached the planting site, it is still necessary to keep planting stock wet. One can place roots in moist sawdust or use other moisture-holding material like moss. Naturally, roots should not be kept permanently in contact with water, although an occasional flash would not do any harm. When it is a wet day, bundles of seedlings can be transported fairly far. In such misty or wet weather there is less transpiration and, consequently, fewer chances of dehydration.

TRANSPORT OF SEEDLINGS IN BOXES

Transportation of seedlings in boxes is a much easier method. Provided boxes have enough moisture, the stock can be transported long distances. Care must be taken to ensure that soil is not shaken from seedling roots for this would lead to dehydration and subsequent death of the seedling. When carrying seedlings in a lorry, platforms should be made into which boxes are slotted. For short distances, boxes can be piled on top of

one another. In fact, even if seedlings are bent, they will grow as soon as they are released. Once at the planting site, boxes should be kept in the vicinity of water and should be watered regularly. A temporary nursery would be ideal and it should be located in a frost-free zone.

TRANSPORT OF POTTED PLANTS

Transportation of potted seedlings is not complex but it is very expensive, considering cost per plant. There are, however, other advantages over transportation; potted plants are very easy to establish. This type of planting stock can stand longer transportation distances than any other. Moisture in pots usually lasts a long time and the soil is usually compact with a network of root systems. However, handling with care - to avoid the disintegration of soil - cannot be over-emphasized.

Especially for parks, or for areas where instant forest is desired, large trees may have to be transported after uprooting them in the forest. These large trees are very sensitive to transportation and extra care must be taken, otherwise the optimum soil will fall off or roots will be damaged. A tree which has been growing on a site by itself will stand longer transportation and will have a better chance of survival than a tree uprooted from among many other trees.

Planting

AFTER ALL the necessary preliminary work has been completed, the time comes when a tree is ready to be put into the soil to grow. Planting is usually done by hand in Africa but, no doubt, mechanized planting can be done in some areas where land is prepared, as when an agricultural crop is being planted. Essentially, planting a tree is a simple thing; however, care should be taken when placing a tree in the soil to ensure that its roots can spread as much in their natural position as possible. Folding of the roots may lead to strangling of the mother tree or to drastically interfering with the feeding habit of the tree, which could lead to slow growth. (See Figure 12 on correct and incorrect methods of handling roots.)

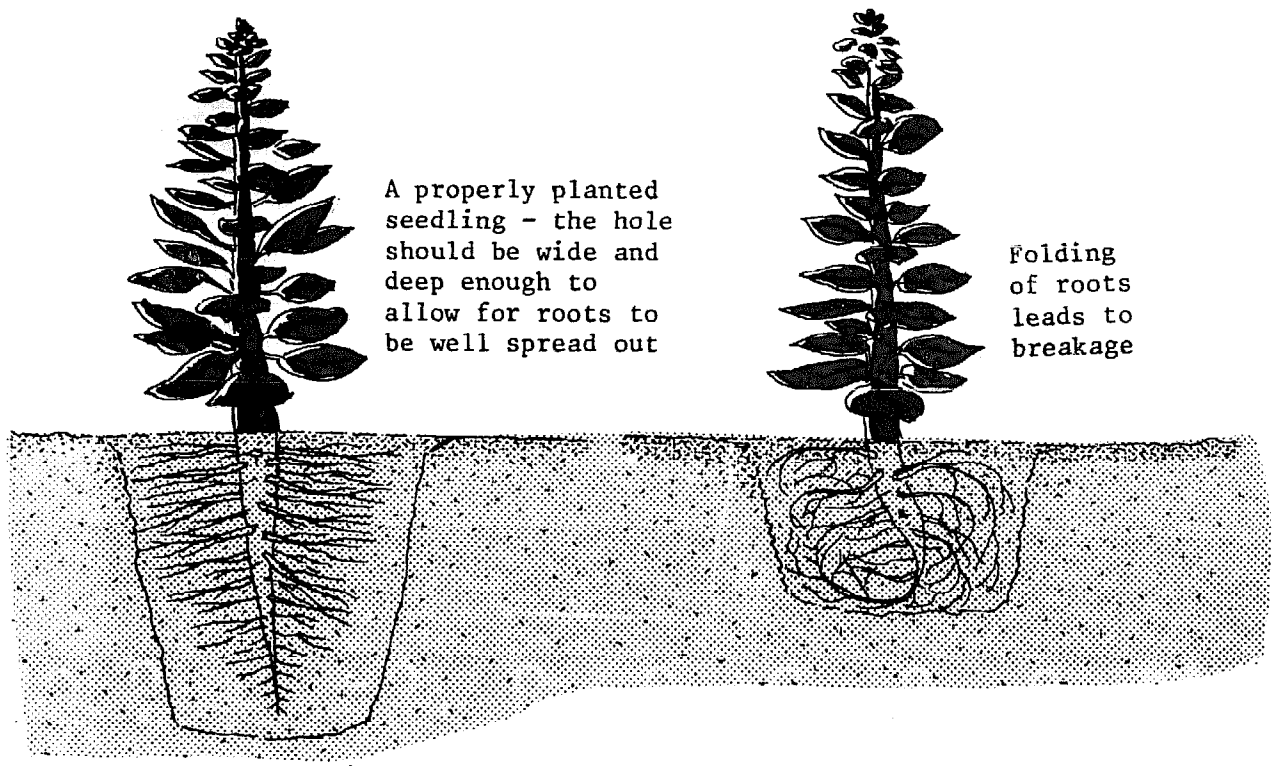


Figure 12: Planting Methods

The other major precaution is to ensure that after planting, the soil around the tree is firmed; this is important to avoid air pockets. Root hairs cannot feed when suspended in space and such space can also become filled with water, both of which are undesirable for the tree's growth. One can gently tap the tree if the soil is very loose, and this will make it sit more firmly.

On average, a man should be able to plant 500 seedlings per day. The job needs close supervision and people should not be given unrealistic targets, otherwise they will do a shoddy job with the loss of many seedlings. Planting has been described as an "emergency operation" because the opportunity of favourable weather must be seized and planting must be done from dawn to dusk in large scale planting programmes. For small scale planting in farms there is no urgency, but the job must be done well. A small difference in the timing of planting may make all the difference in survival of planted stock.

HAND PLANTING

Some people like using a hoe for planting, others a small sword-like tool of sharp metal ("Panga" in Kenya), and others a spade in soft soil. Using a spade or a bar, a person can plant about 600 plants per day on well prepared land. It is again emphasized, however, that haste does not pay and it is better to do a good job and avoid high rates of mortality.

Hand planting can be improved considerably by using a long tube-like tool, popularly known as "pottiputki" in Finland. Using this tool, especially when plants are in polythene tubes, one can plant twice as many as when using a spade or a bar. At least on well prepared land, it is possible to plant 1200 seedlings per day (Seppala, personal communication). (See Figure 13.)

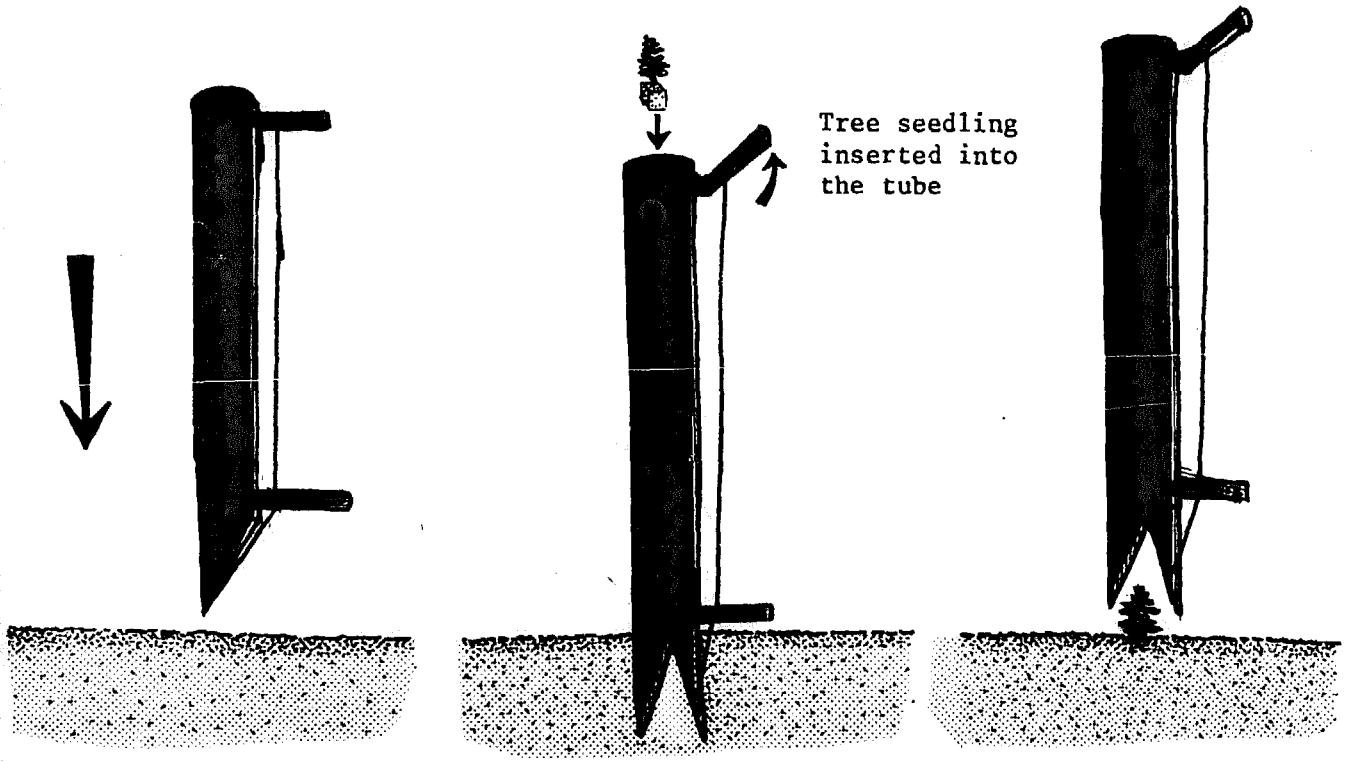


Figure 13: "Pottiputki" Planting Tube

Planting

Planting is a fairly tiresome job, especially when large scale plantation is contemplated. Use of such hand devices, now also widely used in USSR, can improve the rate of plantation. The advantage of the device is that one does the planting while standing erect. The tube is pressed into the soil, using the foot; the bottom of the tube is then withdrawn.

If an area is both wet and soft, a bar can also be used with success in planting. With a bar and a sharp sword, the roots of seedlings are pressed, but since they are not folded, they easily spread out later. (See Figure 14)

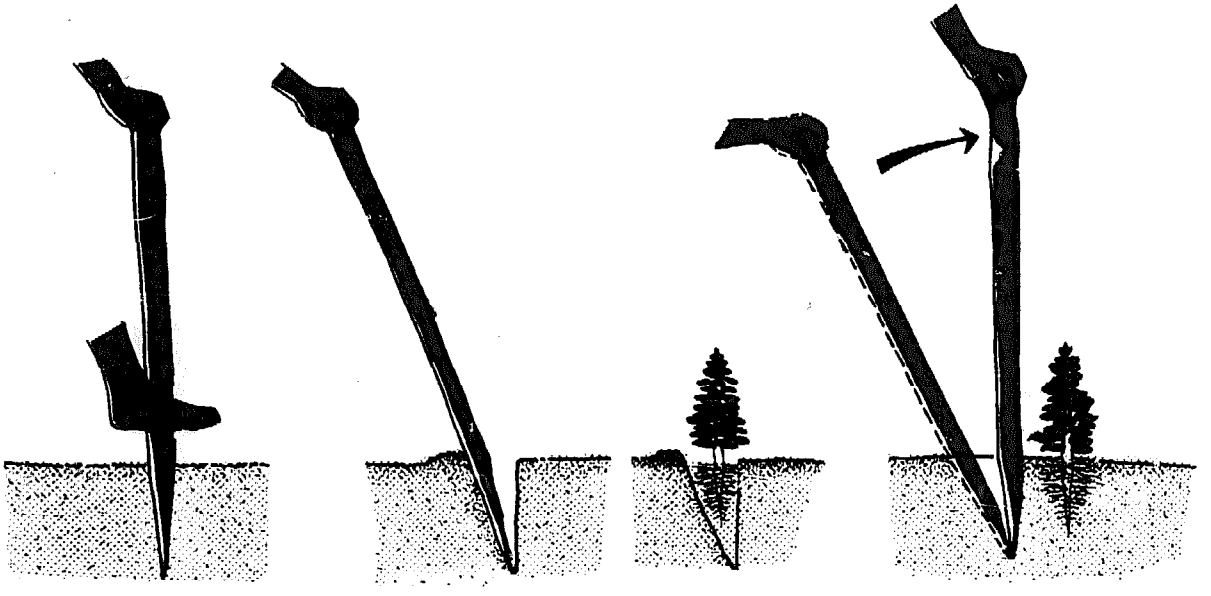


Figure 14: Planting with a Bar

Especially on grassland sites, a better job can be done by one man going ahead of his crew, digging holes with a hoe or a mattock; people behind him then place the seedling and make the soil firm around it. Even on cultivated sites this method may be speedier. Digging holes in advance has the advantage of improving the aeration and the permeability of soil to water. Such disturbed soil also forms a good base from which the roots of seedlings can establish themselves. Normally, young tender roots, especially after suffering transplantation shock, are not in a very good condition to strike out and penetrate hard and pressed soil; therefore, digging planting pits simply avoids this eventuality.

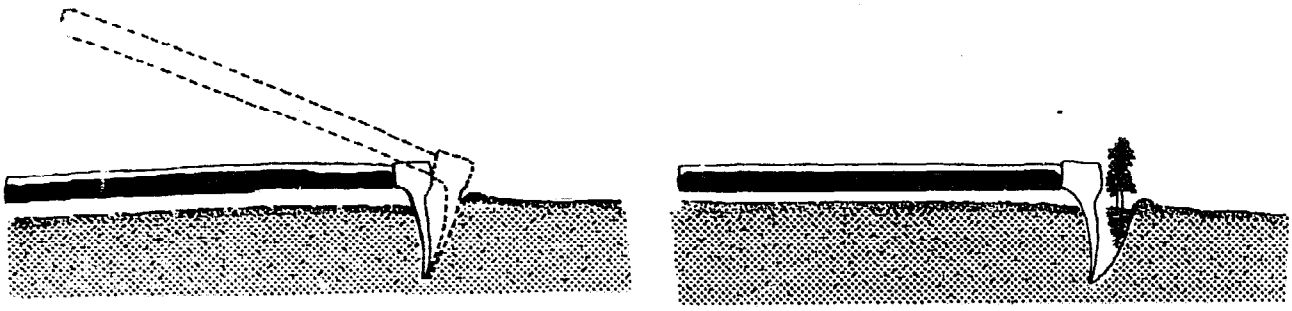


Figure 15: Planting in light, soft soil

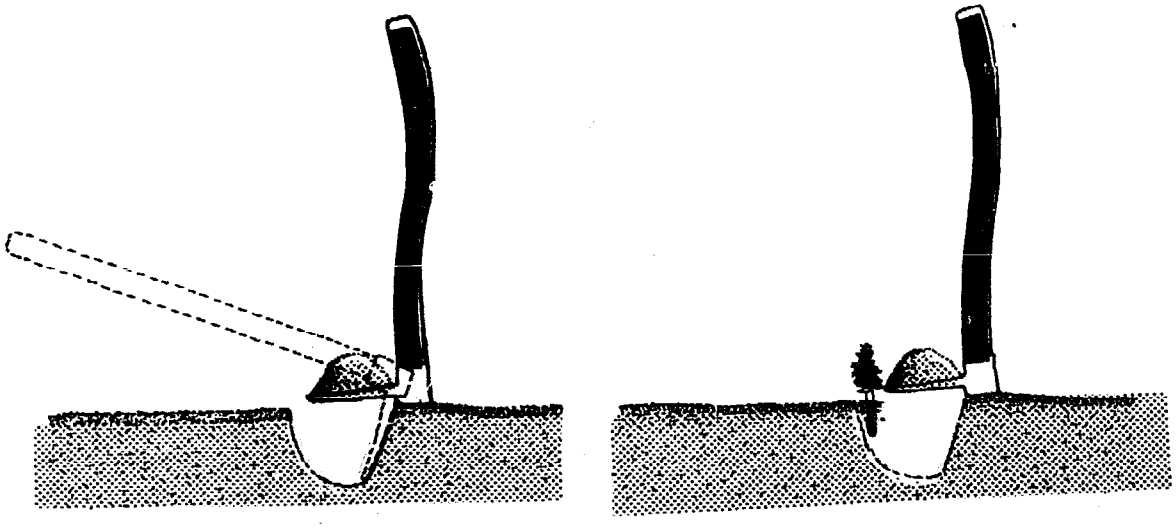


Figure 16: Planting in heavier or grassland soil

Whatever instrument is used, there is always a face which is next to the sharp end and on the opposite face there is the compacted portion of soil formed by tilting the planting instrument. The compacted portion should be loosened after planting. (See Figure 17).

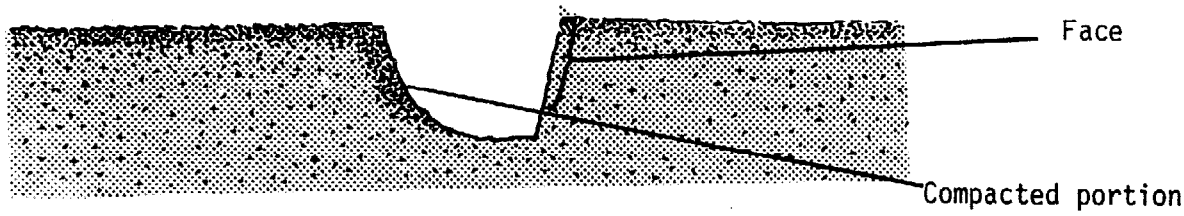


Figure 17: Structure of hole thus dug out

MACHINE PLANTING

Machine planting is obviously quicker, but the work may not be of higher quality than hand planting. Machine planting is ideal for land without obstacles, but the method is not so applicable in small-holdings where the number of seedlings to be planted is not the major consideration. Machine planting is usually done by an ordinary tractor mounted with implements for planting trees. One man mounts the tractor and keeps on slotting seedlings on catches which embed the seedling in the soil as it rotates. In farms and in woodlots planting is a small job, in view of the number of seedlings to be planted, therefore hand planting is recommended.

ESPACEMENT

Espacement of trees when planting usually depends on the final crop and also on the zone in which trees are being planted. There is an optimum espacement for maximum dry matter production: too wide espacement will mean land is not being utilized fully and hence will produce less volume; too close espacement means undue competition for light, water and nutrients. A balance is the aim in planting. As a general rule, similar species compete more severely than a mixture of species. As a corollary to this, different species can stand closer espacement than similar species. Also if some trees are surface feeders while others are deep feeders, there is less competition and hence closer espacement might be recommended.

In most forest planting, espacement has been 2.5 metres by 2.5 metres for exotic species, with much variation in different localities. In West Africa, hardwood is planted in espacement of 4 metres by 4 metres. In agri-silviculture systems the espacement may be too close when canopy closure is wanted immediately. When agricultural crops are to be retained long, wide espacement is practised. For example in Ghana, when planting *Terminalia ivorensis* and *Cedrela mexicana* in conjunction with coco-yam, an espacement of 5.5 metres by 5 metres of tree species is made with some success (King). *Acacia senegal* has been found to do well at a density of 600 trees per hectare. In range-land, scattering of trees at 25-50 trees per hectare has been found to improve the growth of grass in South Africa (Timberlake).

In East Africa, for exotic species such as pines and cypress, starting plantations at 1600 stems per hectare has been found practical, considering the four thinnings done for sawlogs. Review of optimum espacement is still under way. In agroforesty systems, arrangement of seedlings or espacement is of critical importance. In fact, the major objection to tree planting in agroforestry is the competition they represent to agricultural crops. Therefore, wide espacement to avoid both light and nutrient/water competition should be a guiding principle. In some inaccessible corners of land, even closer espacement may be made to compensate for wide espacement elsewhere on the farm. Use of small striplings for building or fuelwood may also call for even closer espacement in some corners of the farm. Optimum espacement is a fairly complex target but, stated simply, espacement depends on the species used, the purpose for which it is grown, moisture availability at the critical periods and tolerance of weed competition.

INTERCROPPING

Planting in agricultural land presents no major problem, considering the fact that soil is under cultivation and hence of good texture. The point to note is that planting is done in such a way that there is minimum disturbance. In high potential areas, trees are interplanted with coffee, tea or bananas. In Zaire, to keep weeds down in banana plantations, *Terminalia superba* is introduced and does better when interplanted with agricultural crops than when planted in a plantation. In Northern Nigeria, growing of ground nuts, beans and millet among tree crops resulted in markedly superior growth compared to that of adjoining farmland devoid of trees and crops certainly seemed better in colour and growth (King).

PLANTING IN COMMUNAL LAND

Establishing Community Woodlots by utilizing communally owned land requires a well planned programme especially in areas where land is not officially adjudicated.

For tree-planting in communally owned land to succeed, prior planning and decision-making must involve the affected community. The community has to be consulted and involved at every stage of the process. It is important for the members of the community to realize the value of tree-planting and the necessity of taking care of them.

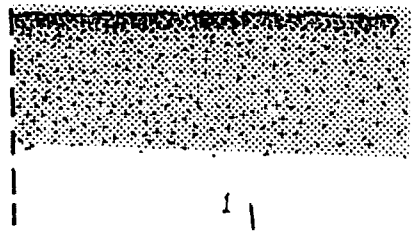
Communal tree-planting programmes fail mainly because local participation in planning and decision making is not sought. Trees planted in communal land through such careless approaches are liable to destruction by grazing domestic animals due to lack of concern by the people. In Niger, for example, a World Bank-financed project lost 500 hectares of woodlot because a community, which was not properly consulted, grazed and uprooted the trees.

PLANTING TECHNIQUES FOR ARID AREAS

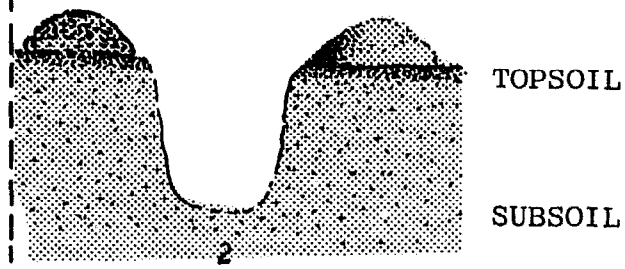
Planting trees in arid and semi-arid zones requires more attention and care than under normal conditions. Due to high rates of transpiration potted seedlings should be given priority to open-rooted stocks. Various techniques have been developed for dry land planting (VITA); the steps outlined below represent a standard procedure where an open-rooted stock has to be planted. Remember to keep the seedling moist throughout until it is planted.

PLANTING STEPS FOR OPEN AND ROOTED STOCK

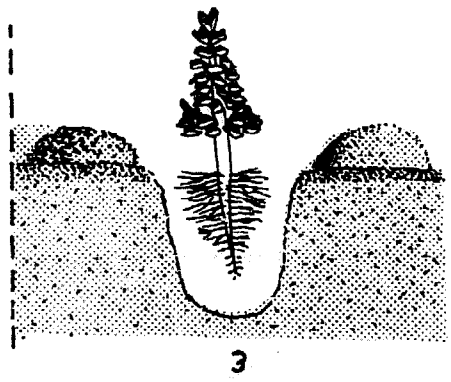
Select and clear site of all weed



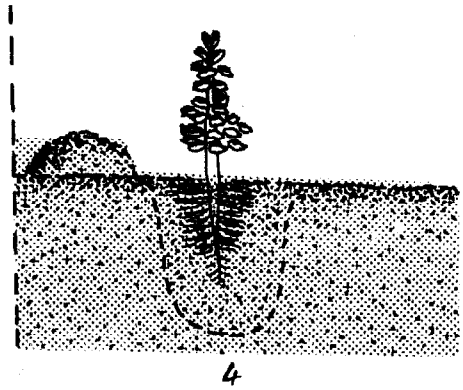
Dig a hole one foot deep placing subsoil on one side and topsoil on the other side. Pour water into the hole if possible.



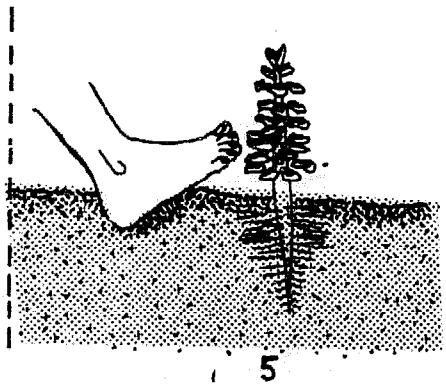
Hold seedling slighly above the bottom of the hole to avoid crumpling of roots.



Cover the rooted stock with topsoil and finally subsoil.



Use your heel to make a depression next to the seedling to remove air pockets.



Firmly but gently press the soil with the palm of the hand around the stem to hold the seedling firm in the soil. Water the seedling.

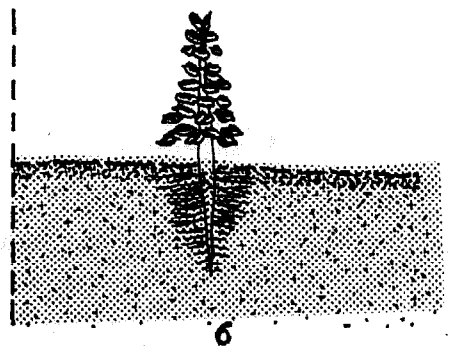


Figure 18 : Planting steps

After planting, mulching should be done using pebbles. Mulching helps conserve moisture in the soil, a very important factor in dry areas.

POTTED STOCK

If a potted stock is to be planted then it is important to remove the polythene tube covering before planting as briefly outlined below:

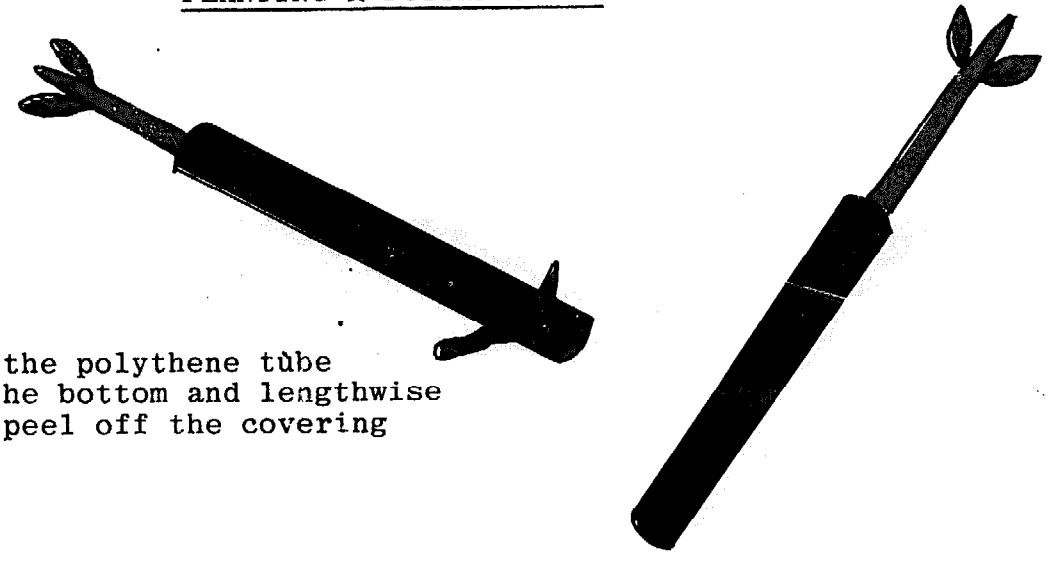
(1) Cut the tube at the bottom with a sharp knife

(2) Make another slit lengthwise from the bottom

(3) Place the plant stock into a prepared hole (as described above)

(4) Slightly cover the stock with soil and then remove the polythene covering exposing the soil around the roots.

PLANTING A POTTED STOCK



Cut the polythene tube at the bottom and lengthwise and peel off the covering

Figure 19: Removing the container

In Algeria a system known as "*Potet masque*" has been evolved (Douglas & Hart). This is an ingenious way of conserving water: when a tree is planted, as explained previously a rim of top soil is removed. Then some dry vegetation cut in the spring for this purpose is packed around the plant. Some stones are then placed

on top and the plant given 2 litres of water. The mulch of vegetation acts as a sponge and evaporation is completely minimized by stones on top which do not at the same time inhibit flow of moisture that may fall. The system has been used by Algerians with some success.

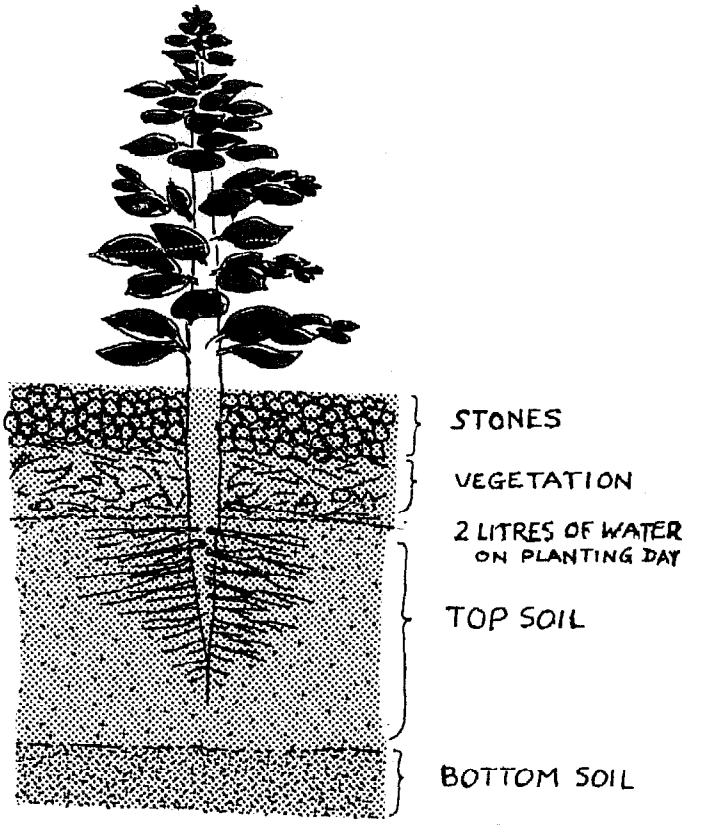


Figure 20 : Planting Techniques in Drv areas

PLANTING IN AREAS PRONE TO EROSION

In dry areas, finding suitable soil in which to plant trees can be quite a problem. In Tunisia, Berbers build dry stone dams across erosion gullies. After some erosion, silt accumulates behind the stones and is more suitable for planting trees than the ordinary soil. Olive trees have been planted in such silt.

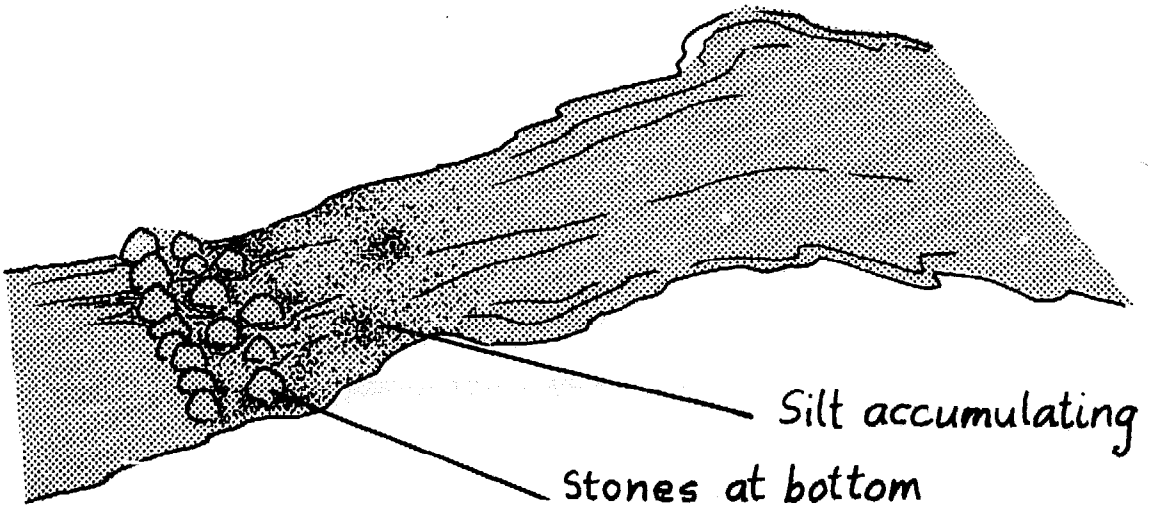


Figure 21: Blocking Erosion gullies to build up silt

Use of Micro Catchment: Another method of planting trees in a dry area is to prepare the soil in such a way that there is micro-catchment serving each tree. Using natural depressions is also a recommended and successful method of tree planting. Where there is no rainfall, planting is only possible on riverbanks, swampy areas or seepage zones. These areas should be identified. Irrigation is also a possibility though expensive. It is usually justified in the early stages during the critical period of the tree's establishment. Drip irrigation or watering only where the tree is growing also means less weed competition since the unwatered parts usually remain weed free.

Alkalinisation Problem: The other problem associated with planting in dry areas is that of alkalinisation. There are few trees which can stand a relatively high concentration of salts. *Tamarix* and *Prosopis* species can stand some alkalinity and, of course, the mangrove species. Because many valuable species cannot tolerate a high concentration of salts, a method of desalinization has been attempted with some success. When a tree is planted porous earthen pots can be put around the tree in the soil. They are filled with soil and some manure. When they are watered daily, some water flows to the plant and decreases salt concentration. The method is expensive but for a valuable tree, for example in the compound, the method might be worthwhile.

PLANTING IN WET AREAS

Unlike planting in dry areas, where moisture is the limiting factor, the problem of planting in wet areas is that of weed competition. There can be spot hoeing to reduce weed competition, in which case there will be no need to prepare holes in advance. There can however, be a problem of leaching nutrients beyond the reach of tree crops, especially at the early stage. It is common knowledge that trees grow quickly where there are ashes, from previously burned trees, because of the nutrients released. A method which has been used is to pile slash in lines and then to burn it; planting is then done along the line of ashes and good results are obtained. Weed competition is greatly reduced, at least at the beginning - an important consideration in wet areas, while the minerals consequent upon burning wood are necessary for growth.

CUTTINGS

Tree planting occasionally involves raising species which are not good producers of seeds. Where genetic conservation is of prime importance, raising trees by vegetative methods is a surer way of

avoiding contamination than the normal process of raising trees by seeds. Most trees can produce roots if induced; there are, however, some species easily established from cuttings while others are obstinate. Some of the species which can easily be propagated asexually are:

Commiphora species
Euphorbia species
Millingtonia
Ficus thornningii
Delonix elata
Pterocarpus indicus
Poplar species

In most cases it is wise to grow cuttings initially in a green house and then transplant them after they have developed enough roots.

The method of producing cuttings is simple. From a healthy branch or a shoot, usually a year old and rarely two years, a neat cut at an angle of 45^{o} should be made on a node or just below the node. The stem thus severed from the parent material should have three to four eyes or buds. It is necessary to use young material from healthy and vigorously growing trees. For equal thickness, intermediate cuttings are more successful than cutting from terminal shoots or the base of a stem. (See Figure 22)

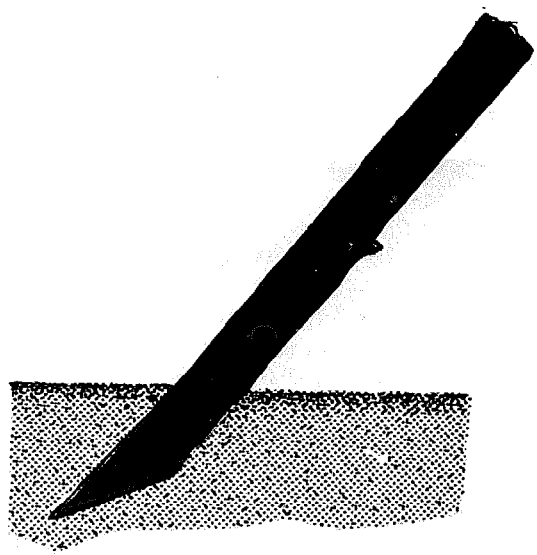


Figure 23: Use of cutting

When the cutting is put under the soil, slanting as shown in Figure 22, the soil is pressed around it. If soil is not firmed around the cutting, the small roots will not be able to get food and the cutting will die. The stem must be planted in constant contact with soil. Two thirds or one half of cuttings should be above the ground. Tips might dry out but can be removed or be left to rot. In case of doubt as to whether a tree will root, some rooting

hormones can be applied. Besides cutting, propagation can be done by suckers, buds or root suckers. For example *Acacia melanoxylon*, *Dalbergia sissoo*, *Ocotea usambarensis* and *Poplar* species can be propagated by root suckers. When a root sucker is used. for example, quicker establishment can be obtained than when raising a tree from seeds. It is therefore important to keep in mind this method of tree planting especially where fast afforestation is wanted. Nursery management may also mean some grafting and budding work. Healthy stock should be used with equally healthy scion, that means similar growth vigour. Growth of fission can only take place when there is direct contact of cambium.

PLANTING ORNAMENTAL TREES

Planting practices for ornamental trees are similar to planting trees for other purposes. The variation, however, occurs when large tree stock must be planted. As a general rule, the bigger a tree is, the more difficult it is to transplant, all other factors being equal. Since ornamental trees are the most permanent feature of a landscape, success is essential. Permanency of features of a landscape is usually better obtained with slower growing species which last longer than fast growing species. For example, most of the African hardwood will last more than 200 years while most exotic species start dying at the age of 30 years or slightly more.

One can plant nursery stock or wildings. One principle is that since a bigger stock suffers bigger transplanting shock, trees should be transplanted when they are dormant or when their growth is relatively slow. Tress planted during a period of rapid growth are likely to suffer damage unless care is taken when handling them; leaves need water all the time because high metabolism means more transpiration.

The other major consideration is the rooting system. Different species have different rooting systems: some have compact fibrous roots while others have sparse roots or a root system with a major tap root. Depending on environmental factors some species may have a different pattern. For successful transplanting, a compact, tight, and fibrous root system is better and, at times, root prunning in the nursery is necessary for the purpose of inducing a fibrous root system.

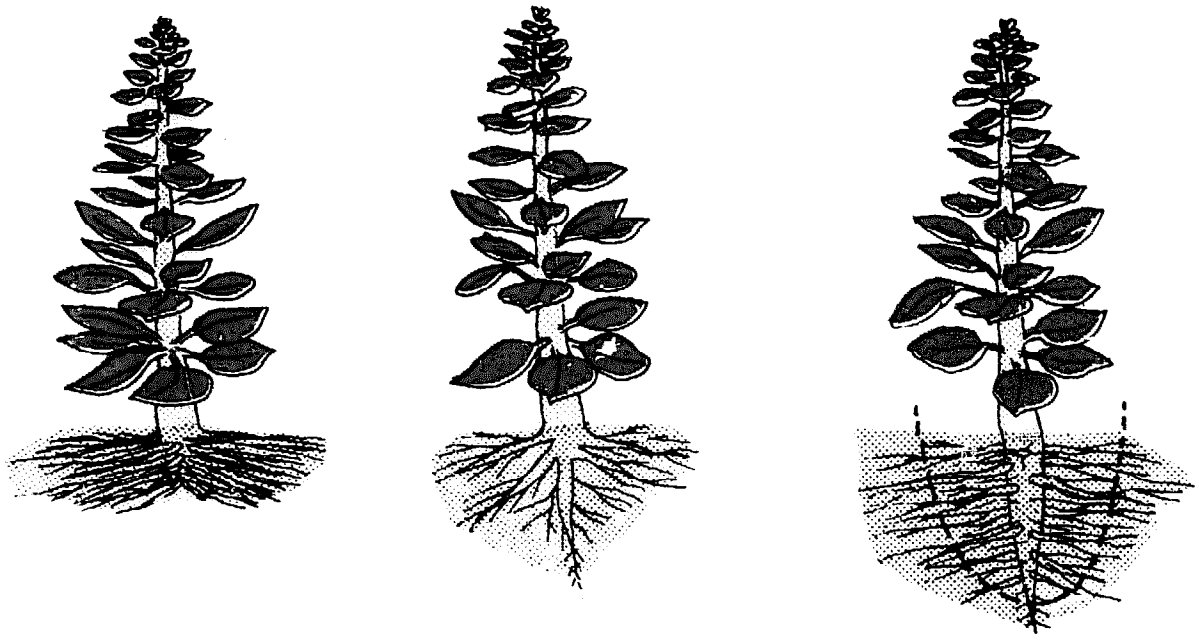


Figure 23: Forms of root systems

When wildings are used, they should be dug out with a considerable amount of soil. Holes for large stock should be dug in advance. When there is poor soil, bigger holes should be dug and more imported soil used. In a number of agroforestry systems, planting of wildings is more common than planting stock from nurseries. This is also the way a number of species have been propagated discriminately in agroforestry systems. Planting of wildings has the advantage of skipping the costly nursery operation and, in most cases, due to the proximity of such wildings, transport costs are minimized. The point to note in planting wildings is that they should be planted as soon as possible after uprooting. In the course of transporting, they should be kept moist. If it is not possible to plant them immediately, an intermediate depository in the form of nursery can be made. In bundles or individually, such plants can be stored by keeping their roots in the soil and moist until one is ready to plant them.

When planting large stock it is necessary to provide mechanical support before the roots are established. As soon as a plant is strong enough, such mechanical support is not necessary except in cases where animals may lean on the tree. Mechanical support simply involves driving a piece of wood into the ground and the guying the tree thus planted to the support.

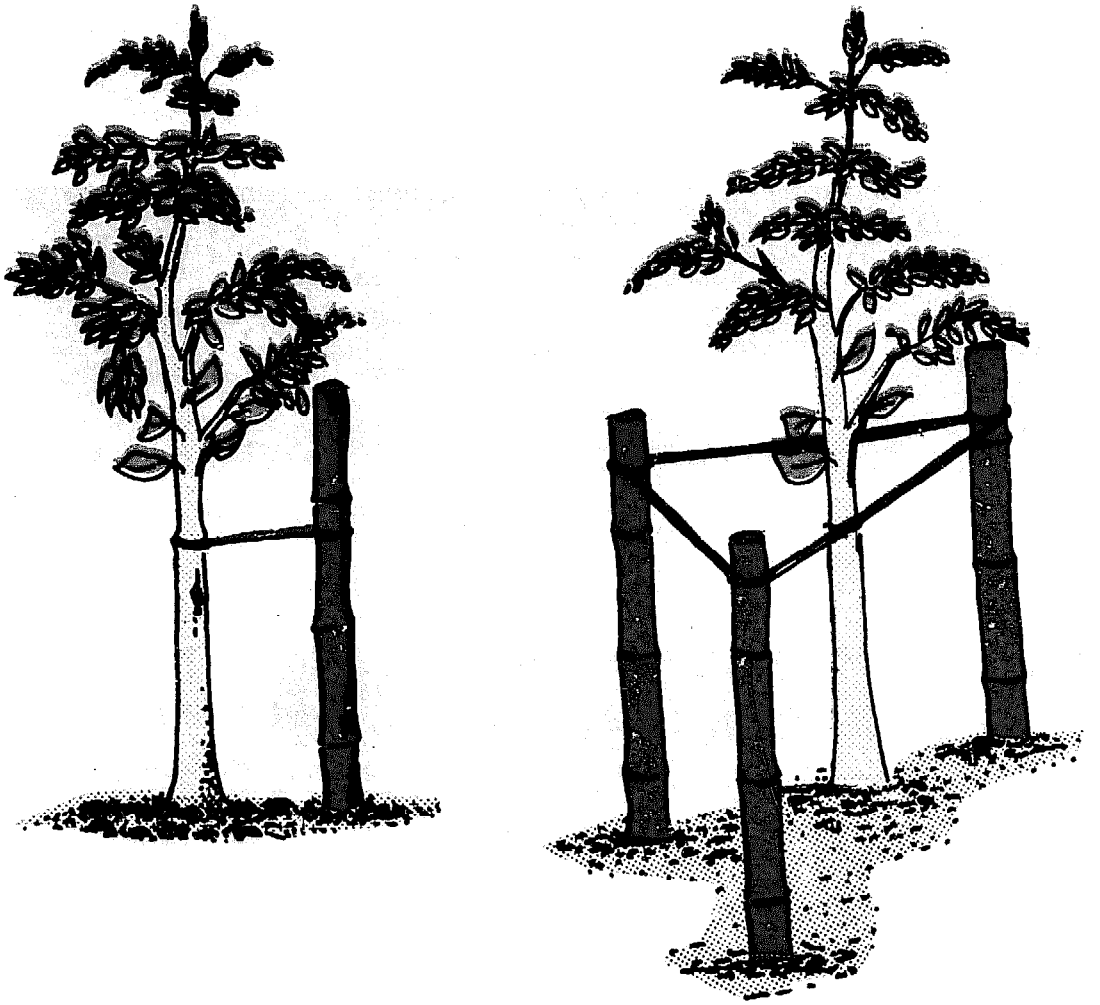
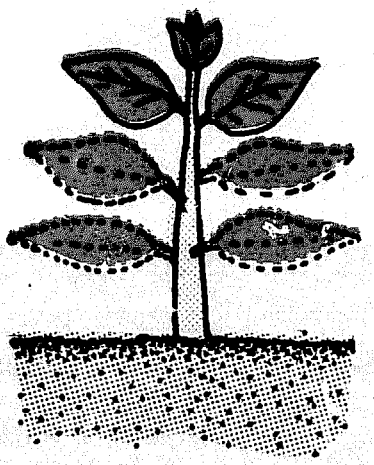


Figure 24: Mechanical support of tall planting stock

STRIPLING AND STUMP PLANTING

In stripling planting, where leaves demand a great deal of water, one can remove all the leaves except the terminal bud with two or three leaves near it (Weber). *Azadirachta indica* and *Kahya senegalensis* do well with leaves thus stripped.



Leaves removed

Figure 25: Removal of some leaves

In other cases, plants do even better when planted as stumps. Nursery stock or wildings can have their tops completely cut about 10 cm above the collar and then the bottom part can be transplanted.

Weber has found in West Africa that *Cassia* and *Gmelina* species do better when planted as stumps. In addition to cutting off the top part of the tree, roots are also cleanly cut about 15 cm below collar. One advantage of planting stumps is that relatively more plants can be transported long distances at much lower cost. Other species which can be planted as stumps are:

Conocarpus lancifolius
Chlorophora excelsa
Cassia regia
Dalbergia sissoo
Tectona grandis

The general rule is to plant fairly small stock with a diameter less than the thumb but bigger than a pencil.

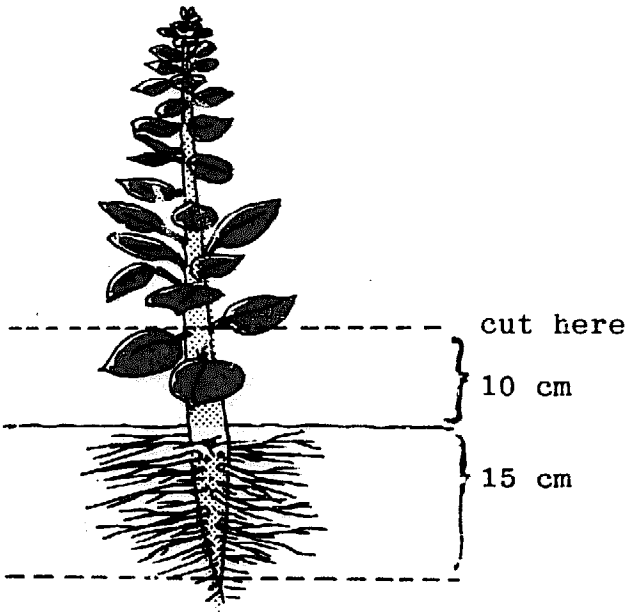


Figure 26: Preparation of planting stumps

Protection

IT IS evident from the foregoing that tree planting can be a very expensive operation. Cost analysis of various operations has not been considered here because it is felt that costs differ greatly from one locality to another. It is usual to indicate relative costs by man-days, but again such expressions need qualification because in some cases labour is expensive and in other cases (especially where opportunity cost of a labourer is almost zero) labour costs can be very low.

In the sense that costs are incurred in planting trees, some extra cost for protection is justifiable. When tree planting in an area fails, due to lack of protection, as often happens in Africa, one cannot really say such an area is unsuitable for trees. Such failure should be attributed to lack of proper planning.

In tree planting, protection is usually required against:

a) heat;
b) loss of moisture via evaporation;
c) overgrazing;
d) burning;
e) diseases; and
f) pests.

Occasionally some direct heat can be lethal to the very young seedlings in which case some light shading is recommended.

EXCESSIVE LOSS OF WATER

Loss of moisture by evaporation can leave plants without enough water. Where water is of critical importance mulching is recommended and some considerable difference in tree growth is realized. There is little that can be done to stop excessive transpiration. Watering is, of course, also recommended even when it is not extremely hot; mornings and evenings are good times to water plants.

OVERGRAZING

Overgrazing and trampling are major problems to the survival of young trees in many parts of Africa. Both domestic animals and wildlife cause damage to planted trees. Goats and animals that browse rather than graze are particularly harmful. In Kenya game moats have been used to keep wild animals from plantations. The grazing problem is solved by keeping animals away from areas planted at least until plants are above browsing height.

Fencing of an area, or of individual trees, is the usual practice but it can be expensive. Coating plants with unpalatable substances can promote selective grazing. Another method to avoiding overgrazing is to reduce the number of animals in the area.

Expert opinions agree that environmental degradation in Africa is due mainly to overgrazing, particularly of domestic animals on which the nomadic economy is based all over the continent. Quite often destructive exploitation in the form of overgrazing is justified on the basis of a philosophical belief that man has a God-given right over land and animals therein (McKell). But more animals feed on shrubs and trees in semi-arid areas than on true grass (Douglas & Bodgan).

BURNING

Burning is indeed another practice against which plants must be protected. In most cases burning goes along with grazing. People want succulent grass to come out after a long drought and burning is usually done before rains. This is harmful as it leaves bare baked soil vulnerable to erosion when rain falls. Burning is also done to control ticks. To avoid this harmful practice it is necessary to educate people on the damages associated with uncontrolled fires.

The construction of fire breaks is sometimes the only effective way of stopping bush and grassland fires. Fire is also caused by people in the course of preparing land for agricultural work. The method of cutting and burning slash also leads to fires spreading to planted trees. Community participation in control of fires can minimize the problem of burning.

DISEASES

Diseases are not usually a threat to tree planting. Damping-off, however, is a common and serious disease which is caused by more than fifty different fungi (Goor and Barney). The disease attacks seeds when germination is starting and other fungi attack germinated seedlings. Proper nursery management should ensure that mortality from damping off is minimized. The favourable conditions for damping off are:

a) High humidity;

b) cloudy weather;

c) too much shade;

d) high density of seedlings;

e) organic matter in soil;

f) high nitrogen;

g) alkaline condition in soil; and

h) heavy soil.

Protection is really to avoid the above conditions as much as possible. One cannot do anything about weather but can, for example, avoid shading during cloudy weather. To inhibit fungi, soil can be sterilized; (treated with chemicals); other chemical measures are soil acidification and treatment of seeds with appropriate chemicals (formaldehyde and methyl bromide). The recommended dosage of methyl bromide is 50 to 100 gm per M^3 (Goor & Barney) applied as vapour. Dosage of formaldehyde is 80 cc per 5 litres of water per square metre applied 7 - 10 days before sowing seeds.

Besides reducing the incidence of damping off the two chemicals provide some control of nematode and weeds. Fungicides are also chemicals that are toxic to fungi but not to seedlings. Peronox, Thiram and Captan are examples of effective fungicides.

Armilarria melea is a root disease that can attack a broad spectrum of species. It attacks *Acrochpus fraxinifolius, Araucaria cunninghamii, Cassia siamea, Chlorophola excelsa, Eucalyptus citriodor Tectona grandis, Gmelina arborea,* etc. Some agricultural crops accelerate spread of *Armillaria melea.* For example, severe *Armillaria melea* attacks were observed on *Pinus elliotti* grown in conjunction with cassava (King). Rubber plantations in mid-western Nigeria had similar fungal attack from a cassave plantation. It is not a very serious disease and healthy plants can be protected by uprooting and burning affected trees. Other diseases such as *Diplodia pinea, Dothistroma* and *cankers* are not usually a threat to tree planting but care should be taken to make sure there is no epidemic.

PESTS

The major pests that attack trees are:

a) Insects;

b) cutworms;

c) nematodes; and

d) rodents.

In Africa, termites are perhaps the most serious threats to tree planting. Termites usually attack the weak trees but some species are more susceptible to attack than others. One can say that *Eucalyptus* are more susceptible to termite attack. Species which are resistant to termites are: *Cassia, Acaciae, Albizia lebbek, Jacaranda, Gmelina, Callitris,* and highland species such as pines and *Acacia melanoxylon.*

Termites are not always a foe in tree planting. Some trees do better in termite molds and generally termites have a role in soil formation by assisting in decomposition of organic matter. Appropriate pesticides can be used to prevent termite attacks. If possible avoid the use of Dieldrin or Aldrin, which can be absorbed through the skin, and is extremely poisonous to man and domestic animals. Putting ash below a tree is reported to keep off termite attacks. This practice has been effective at a farm near Kibwezi in Kenya, an area where trees are very susceptible to termite attack.

Besides termites there is *Oemida ghani* which attacks cypress. The best protection is to avoid leaving exposed scars too long. If scars do not heal (occlude) quickly they should be coated with appropriate available chemicals. Also *Eucalyptus globulis* is easily attacked by *Gonipterus scutellatus* and luckily biological control is possible because a parasitic wasp (*Anaphoidea nitens*) does flourish on the snout beetle. Other *Eucalyptus* species attacked by the snout beetle are: *E. viminalis, Eucalyptus camadulensis* and *E. tereticornis* species. These species are drought resistant and fortunately not very susceptible to attack by the snout beetle. *Chlorophora excelsa* is attacked by gall fly (*phytolyma lata*) and mahogany family is generally attacked by shoot borer (*Hypsipyla robusta*).

The point to note is that besides climatic limitations tree planting can fail if protection measures against the various destructive agents are not properly planned and executed at the right time. The motto should be "Trees Planted Must Survive".

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