TREES IN EROSION AND SOIL CONSERVATION IN KENYA

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TREES IN EROSION AND SOIL CONSERVATION

by
Carl G Wenner 8.11.1980
Farm Managemant Branch
Project Management and Evaluation Division
Ministry of Agriculture
Nairobi

(this picture is from Kenya's National Report to the United Nations on the human environment)

Paper produced to the Kenya National Seminar on Agroforestry
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Other publications from the Soil Conservation Extension Unit

1) "Soil Conservation in Kenya, especially in small-scale farming in high potential areas using labour intensive methods".
Handout in 250 pages for teaching agricultural staff ("the blue book").
Annual editions 1975-1980.

2) "An outline of soil conservation in Kenya".
Handbook in 60 pages for agricultural and administrative staff as well as for school teachers and educated farmers ("the red book").
Two editions in 1980.

3) "Soil erosion and soil conservation".
Booklet with 17 coloured pictures + text for people in common ("the green book").
First edition in English 1980.

4) "Pocket book for technical assistants".
Giving tables and figures needed during field work, 24 pages ("the yellow book").
Printed 1980.

5) "Text to be read out by chiefs".
This paper provides chiefs with information for barazas with farmers.
English edition of 1975.
Swahili edition of 1976.

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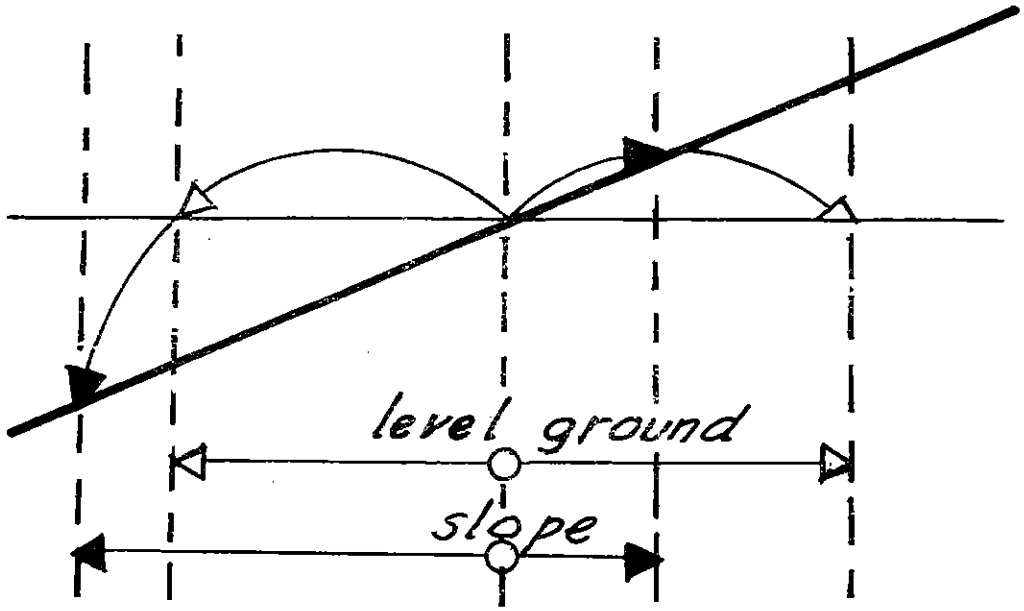

level ground
slope

Fig. 1

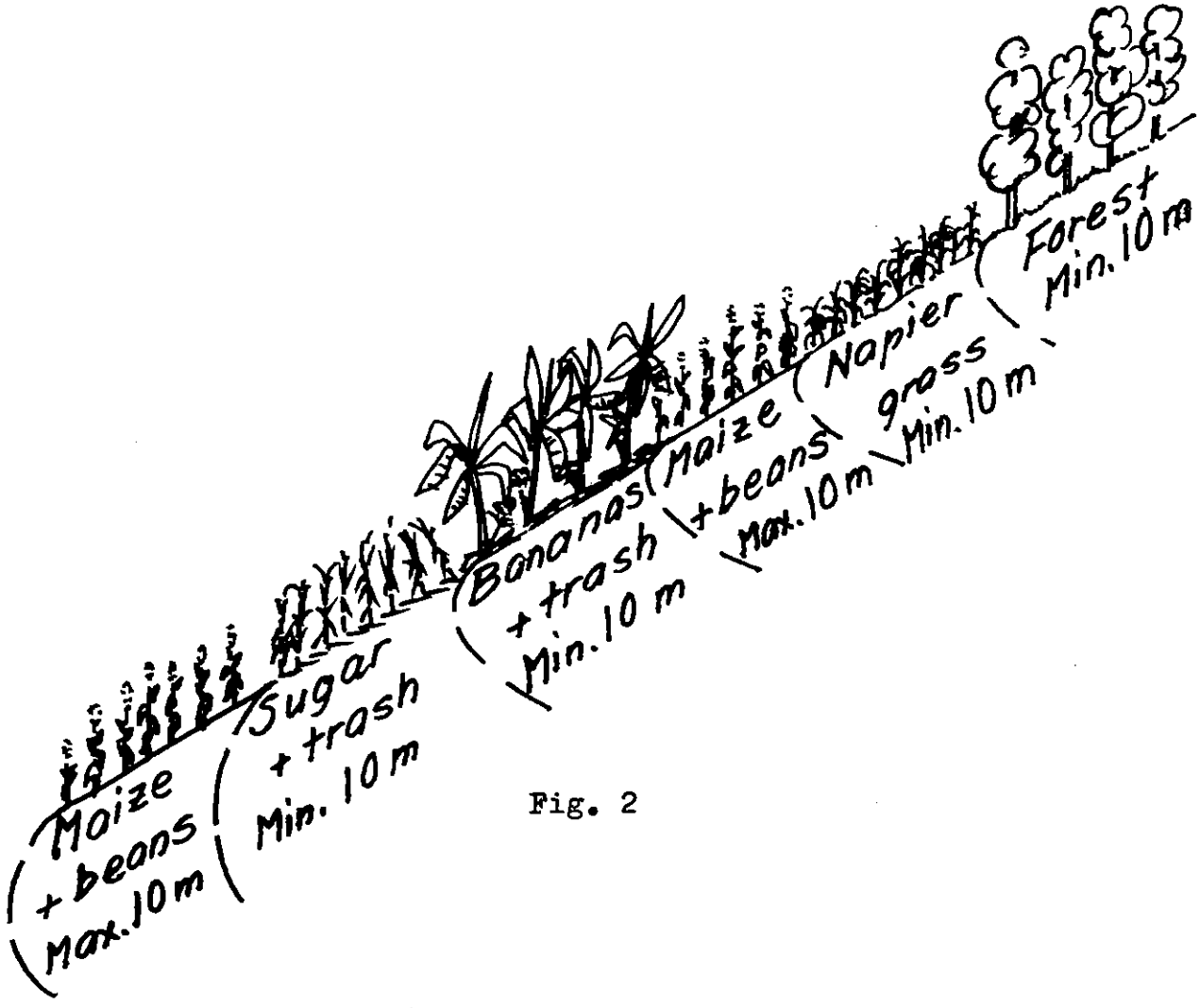

Maize + beans Max. 10 m
Sugar + trash Min. 10 m
Bananas + trash Min. 10 m
Maize + beans Max. 10 m
Napier grass Min. 10 m
Forest Min. 10 m

Fig. 2

1. TREES IN EROSION PROCESSES

The erosion processes causing soil erosion are:

1. raindrop erosion (splash erosion)
2. flowing water in: a) rill erosion
   b) gully erosion
   c) river erosion
3. solifluction (earth flow)) mass movement
4. landslides) mass movement
5. wind erosion

1.1 Raindrop erosion

Nowadays we know that raindrop erosion is the most important erosion process on slopes with no or poor vegetation cover.
During skybursts big and heavy raindrops bombard the soil, detaching soil particles and splashing them to the sides. As shown in the drawing (Fig.1) soil particles jump further downslope than upslope.

The canopies of trees break the energy of the raindrops. They are split up in many small drops, falling to the ground from a low height. Consequently tree canopies close to each other will reduce erosion (e.g. on a tea field with trees some years old).
Trees reduce erosion also because the soil properties below the canopies are improved (e.g. litter on the ground and higher amount of humus).

1.2 Flowing water

1.2.1 Rill erosion

Overland flow will appear, when the ground is saturated. This overland flow will concentrate into rills. In the old East African literature it is mentioned that bushes planted as wash stops on cultivated slopes can increase erosion on slopes steeper than 6 - 20 % (Beckley 1935). I think the reason is that a bush stem can collect water and cause a rill starting at the stem.

Trees or bananas can decrease rill erosion on slopes, if they are planted in wide strips (e.g. tree strips should alternate with grass strips or strips with crops). This is a kind of strip cropping. The idea is that rills on the slope should be infiltrated into the ground of the tree strips (Fig. 2 a and b).

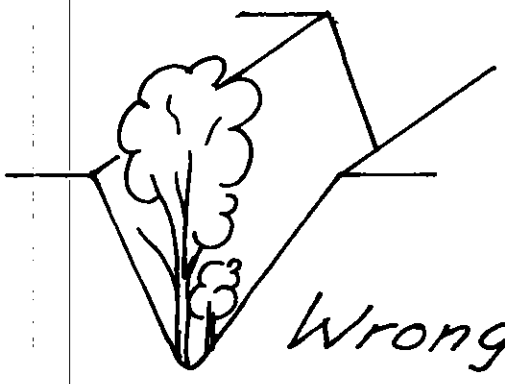


Fig. 3

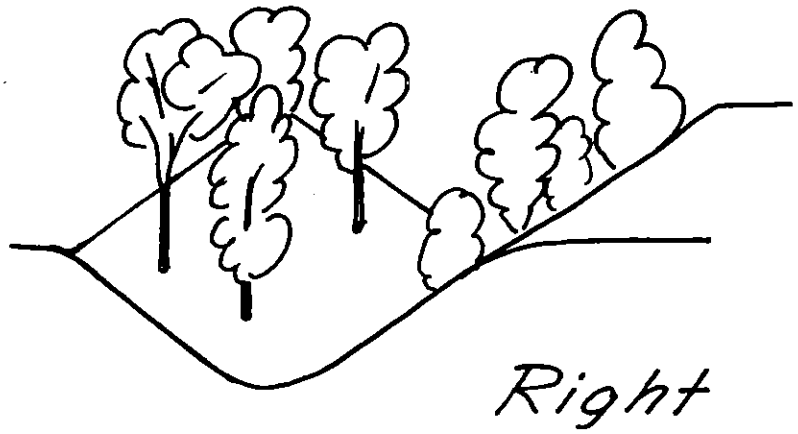
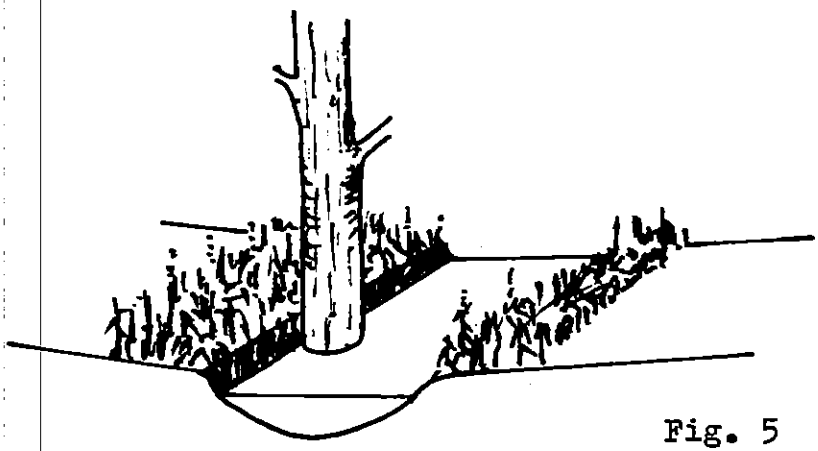


Fig. 4



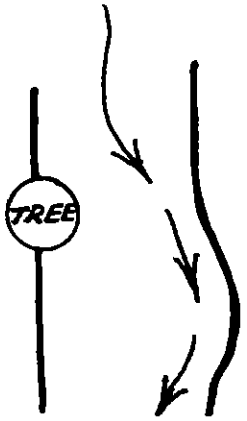


Fig. 5

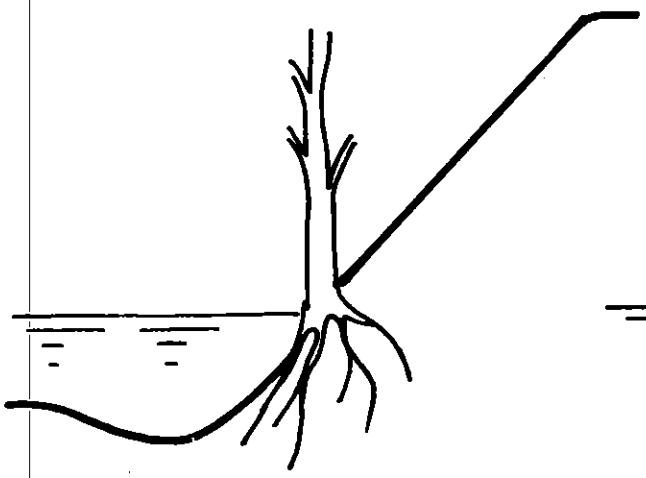


Fig. 6

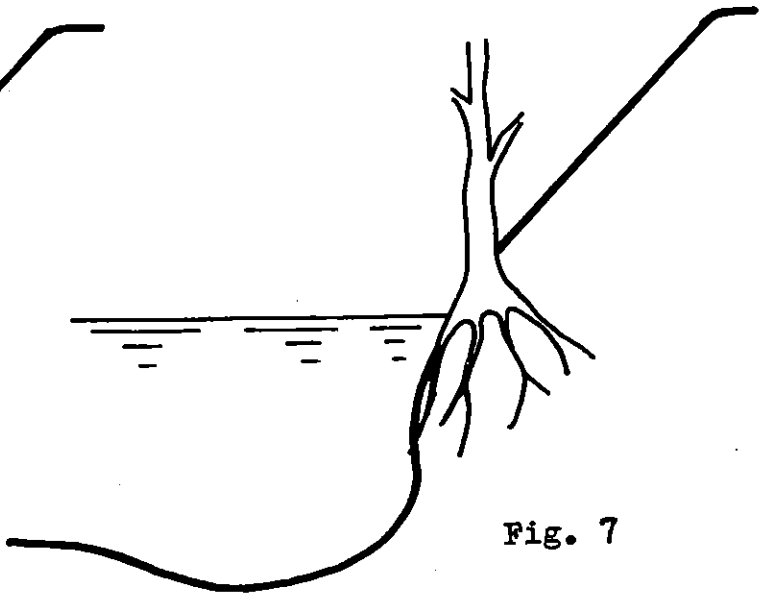


Fig. 7

1.2.2 Gully erosion

Trees or bananas should not be planted on the floor of eroding and narrow gullies, because the stems will decrease the cross-section of streaming water, thus increasing the velocity of streaming water. The stems can also divert the stream to the sides of a gully, thus causing an undermining erosion of the gully sides (Fig. 3).

When the sides of a gully valley have an inclination of about 1:1 or steps on the sides, trees should be planted on the gully walls (Fig.4). Trees will facilitate the stabilization of the gully and will increase the value of the eroded land.

1.2.3 River erosion

When viewing the use of trees in river erosion, the size of the river must be considered.

There is no need to plant trees along small rivers (brooks). A tree stem can divert the stream to the bank of the channel(Fig.5) thus creating erosion. During the dry season many large trees can desiccate a small waterflow.

On the banks of medium-sized rivers the root systems of trees can prevent or delay excavating erosion in the river bed. Consequently a row of trees should be planted along the bends of a medium-sized watercourse. Even if the river bank is eroded to be very steep, the root systems will prevent or delay slumping of the river bank (Fig.6).

In large and deep rivers the excavating erosion in the river bed will occur below the root systems, thus undermining the bank below the root systems. Such a river bank will collapse with or without trees (Fig.7). Trees falling down into the river can divert the water to the opposite river bank, thus causing new erosion.

In large but shallow rivers with high floods trees on the banks will reduce the velocity of the water and prevent erosion. Artificial levees along rivers can be protected through planting of trees (FAO Forestry Paper No.12, 1978).

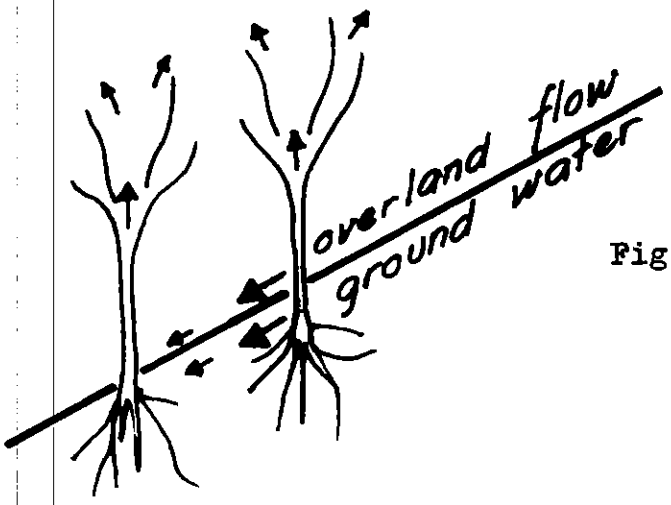
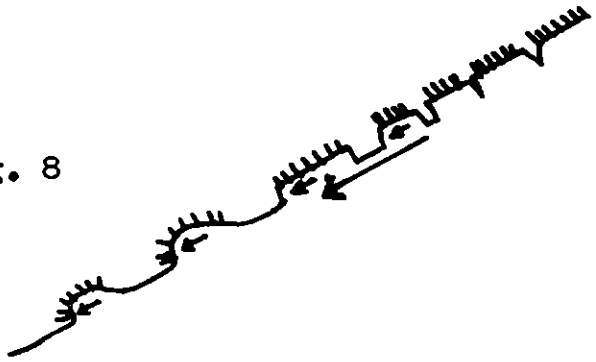


Fig. 8



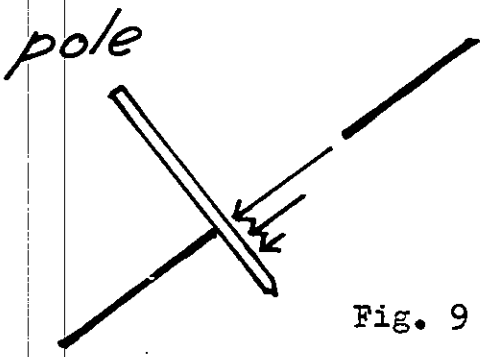


Fig. 9

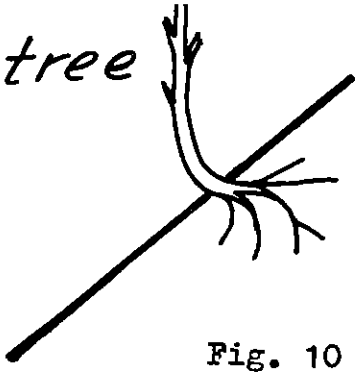


Fig. 10

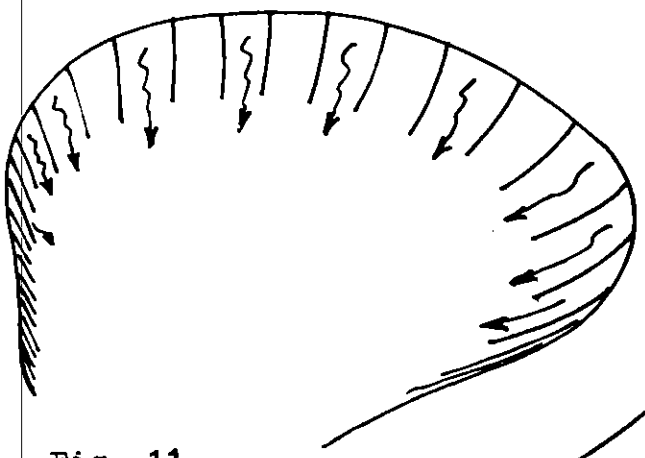


Fig. 11

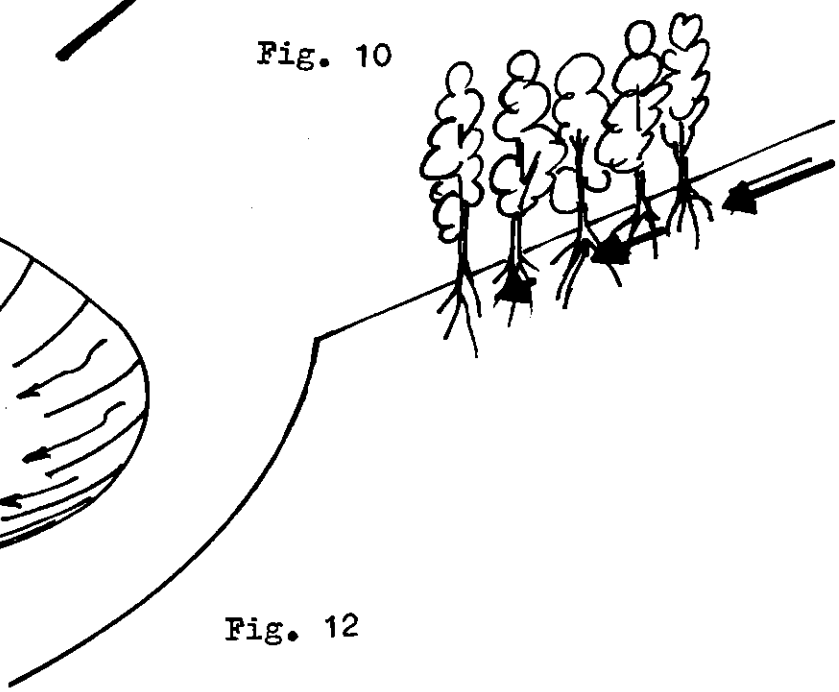
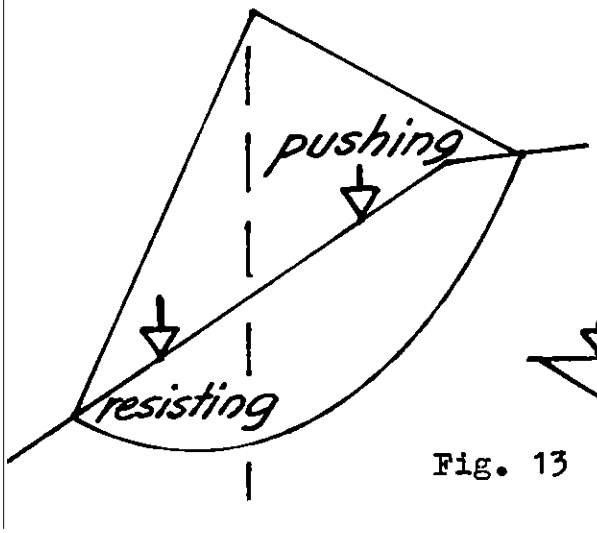


Fig. 12



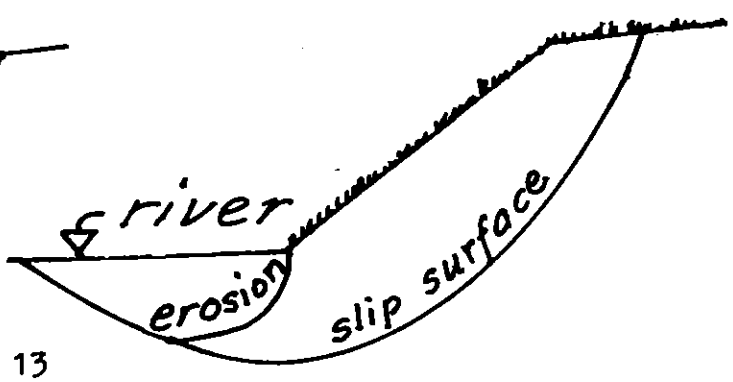


Fig. 13

1.3 Solifluction

The slopes in nature have usually been stabilized at a certain inclination (e.g. a slope with forest can be steeper than a slope without vegetation). If forest is removed, there will not be any transpiration of water by trees. Consequently there will be a surplus of water resulting in increased runoff, as overland flow as well as ground water. The latter will create a water pressure, and especially during rainy seasons the soil will have such a loose consistency, that it can flow down the slope (Fig.8).

As the friction is larger with increased depth, the soil of the surface of the ground will move faster than deeper in the ground. This will result in moving sticks and poles from their original vertical position to a leaning position (Fig.9). Living plants, however, will not have such an inclination. Because of phototropism they grow straight up. Consequently stems of plants, bushes and trees will have a bend near the ground indicating that solifluction is going on (Fig.10).

On slopes with soils sensitive to solifluction this process can create large semicircular excavations growing up the slope some metres every year. On a slope in Olkalau, Nyandarua District, the erosion is increasing at a rate of 4 - 6 m per year. Another example of a solifluction area is the Kikuyu loam on both sides of the main road Nanyuki-Meru. Ground water is often collected on a layer just below the ground surface. Typically, water and erosion is spread over a surface, working backwards into the slope on a broad front (Fig.11).

The anti-erosion measure is to remove the excess of ground water. The first method to be tested is to plant at least 4-6 rows of trees above the solifluction pit as shown in the picture (Fig.12).

1.4 Landslides

A landslide means that a large portion of ground plus earth beneath has slid down a slope, when the stability of the slope is changed.

The most common slides are those in bends of rivers, where erosion is undermining the bank (Fig.13). Another example is roads cut into a steep slope, where water is led to the road bank creating a ground water pressure and a slide. In such a case trees cannot be used to prevent landslides. But there is another common situation to be regarded (e.g. on steep slopes, preferably steeper than 30°, where forest has been removed). Increased water pressure in the slope is decreasing the

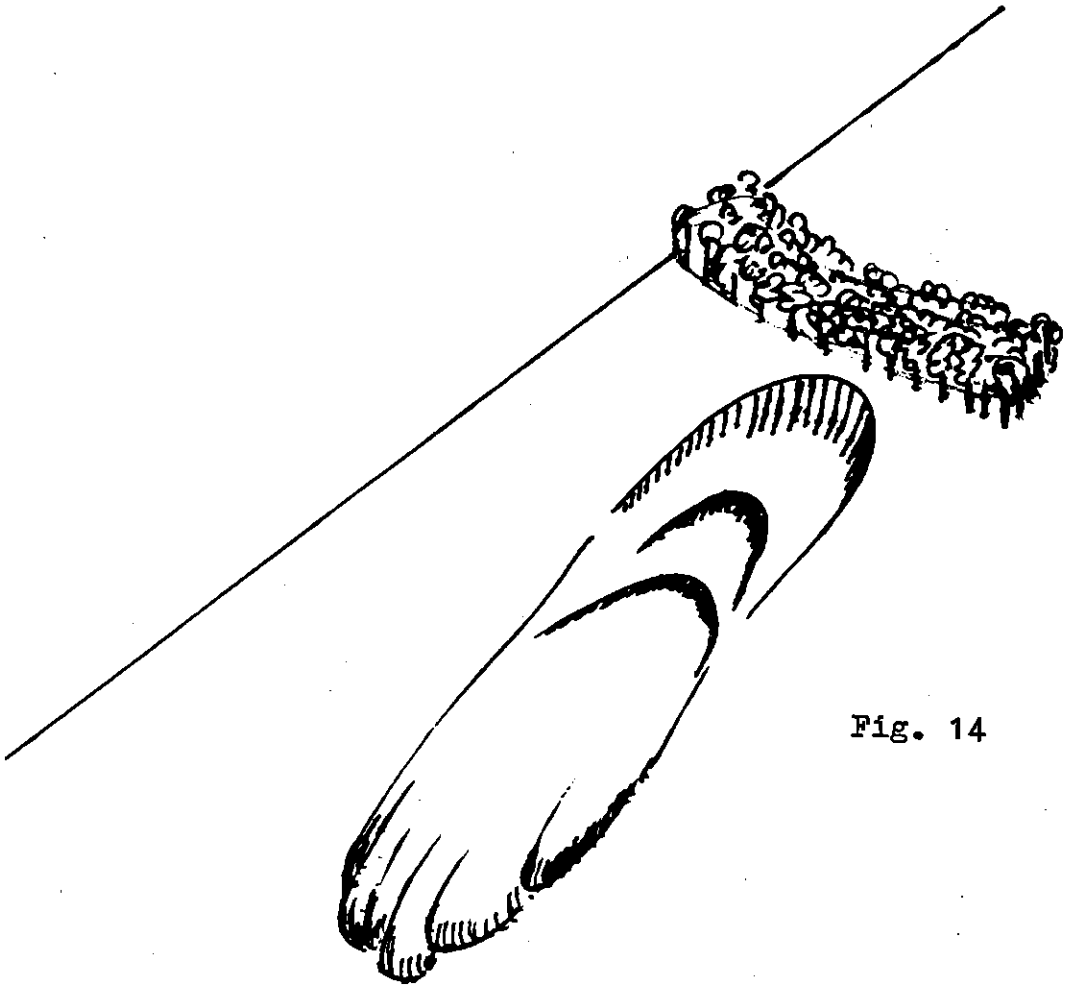


Fig. 14

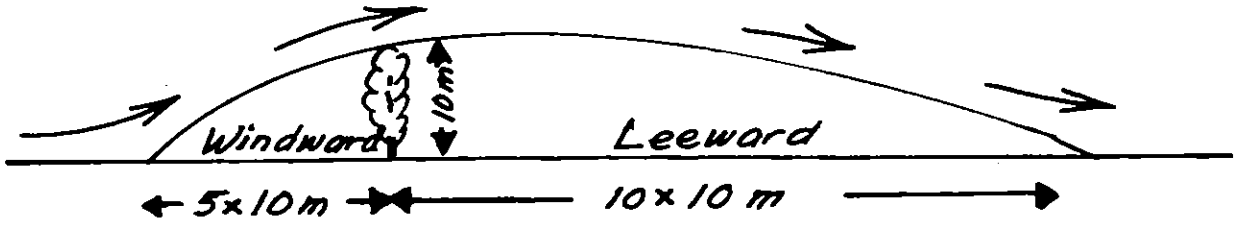


Fig. 15

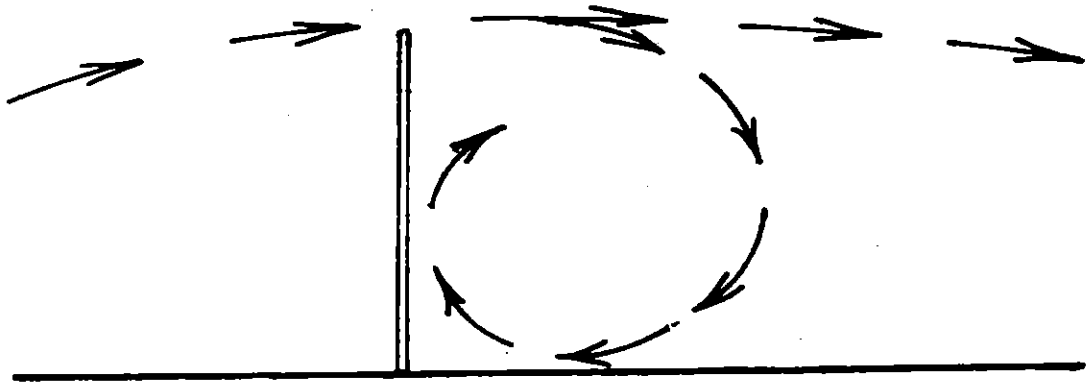


Fig. 16

strength of the earth, so the slope will not be stable any more.

Landslides can kill people and cattle as well as damage houses and roads. In some parts of Kenya several percent of the land area is lost through large landslides (e.g. on the escarpment of northern Elgeyo Marakwet District). Once a slide has happend, it can continue to grow upwards the slope as new slides, one after the other.

A total reforestation is not needed to prevent landslides. It is sufficent to create forest belts at least 6–10 m wide, along the contour and at an interval depending on the local conditions (Fig.14).

1.5 Wind erosion

Wind can transport sand along the ground and deposit it as dunes. Trees or bushes can be used to stabilize dunes, e.g. Casuarina equisetifolia can be planted on the coastal dunes of northern Kenya.

Turbulent and strong wind can lift and transport particles smaller than sand under the following conditions:

1) the soil is bare and dry, and the particles are detached from each other
2) the size of these grains is of fine sand, silt and loam grade (0.1 – 0.5 mm and the percentage of this grain size is more than 60 %)
3) the velocity of the wind 1 ft above the ground is exceeding 6 m/s (i.e. a flag can be stretched or big branches of a tree moved).

Especially in dry areas, all the top soil and a varying depth of the subsoil has been swept away by the wind.

Trees can prevent erosion on windswept plains and hills. They should be planted perpendicular to the prevailing direction of strong winds in rows as windbreaks or as shelterbelts. The velocity of the wind will be reduced not only on the leeward side of the windbreak but also on the windward side (Fig.15).

A windbreak of one row of trees should not have any gaps, because the velocity of the wind will increase in such gaps. On the other hand a windbreak should not be dense as a wall, because such a wall will create an eroding eddy on the leeward side of the wall (Fig.16). The interval between windbreaks should be 15 – 20 times the height of the windbreak. The tree species of windbreak should have a well developed canopy from the top of the tree to the ground. Examples of such trees used in Kenya are Conocarpus lancifolius, Cupressus lusitanica, Eucalyptus camaldulensis, Cassia siamea and on the coast Anacardium occidentale.

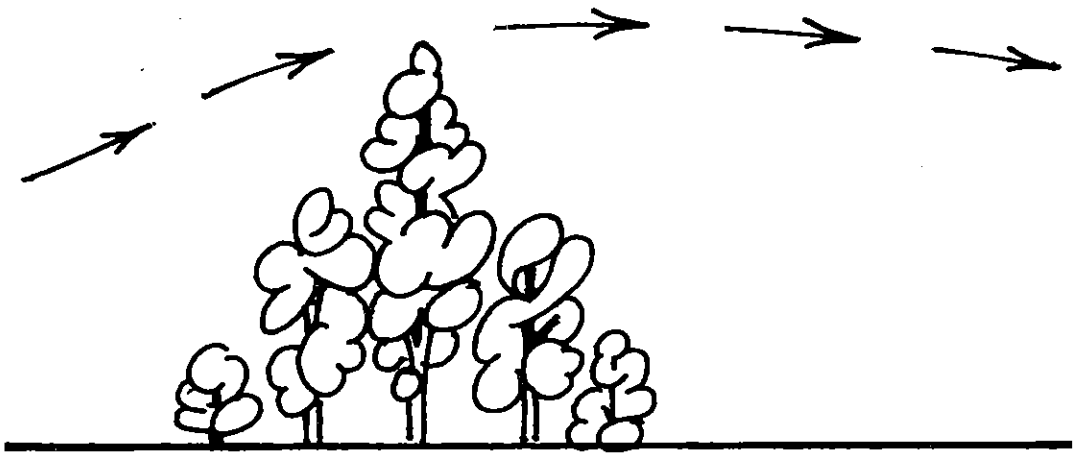


Fig. 17

If there is space for more than one row of trees, the windbreak will be more efficient (e.g. at Eldoret Large Scale Farmers Training Centre there is one row of high trees combined with a row of Nandi Flame Tree).

If there is plenty of space you can have several rows of trees of the same species or combine trees and bushes of various heights. I will give examples of both.

On the windswept plains of northern Cameroon (300 - 350 m above sea-level, annual rainfall 645 - 914 mm) windbreaks have been planted testing various species (Cassia siamea, Dalbergia sissoo, Anacardium occidentale, Azadirachta indica) as well as various numbers of rows of trees (1,2,4 and 6 rows). It was found out after 6 years that Cassia siamea planted in four rows with spacing 3 m is a good solution (Guiscafré 1961). Cassia is resistant to termites. If single trees die, the windbreak will still be efficient. When the trees have grown up, the rows of trees can be harvested and replanted one by one.

If various bushes and trees are used, they should be arranged in a triangular cross-section (Fig.17). Such a shelter-belt, requiring a strip of land 17 m wide, has been proposed as follows (Wimbush 1942):

1) 2 rows of tall trees, 3.5 m apart. Examples of medium-tall trees for areas with different annual rainfalls:

more than	1,000 mm	Cupressus macrocarpa (Monterey cypress)
	875 mm	Cupressus torulosa (Himalaya cypress)
	750 mm	Grevillea robusta (Silky oak)
less than	750 mm	Casuarina cunninghamiana (River oak)
		Schinus molle (Pepper tree)

2) 2 rows of medium-tall trees, 3 m apart, then a space of 4.5 - 6 m.

3) 2 rows of a hedge, planted 0.6 m apart, then a space of 3 m.

A good shelterbelt decreases the evaporation and can increase yields in dry areas by 10 - 20 %, and during years of drought by 50 - 60 %. In the Liaoning Province of China research has shown (FAO Forest Report No. 12, 1970):

	1 row of trees, 20 m high	4 rows of trees, 20 m high
Wind speed reduction	14 - 30 %	58 %
Evaporation reduction	12 - 25 %	38 %
Grain yield increase	13 - 17 %	30 - 50 %

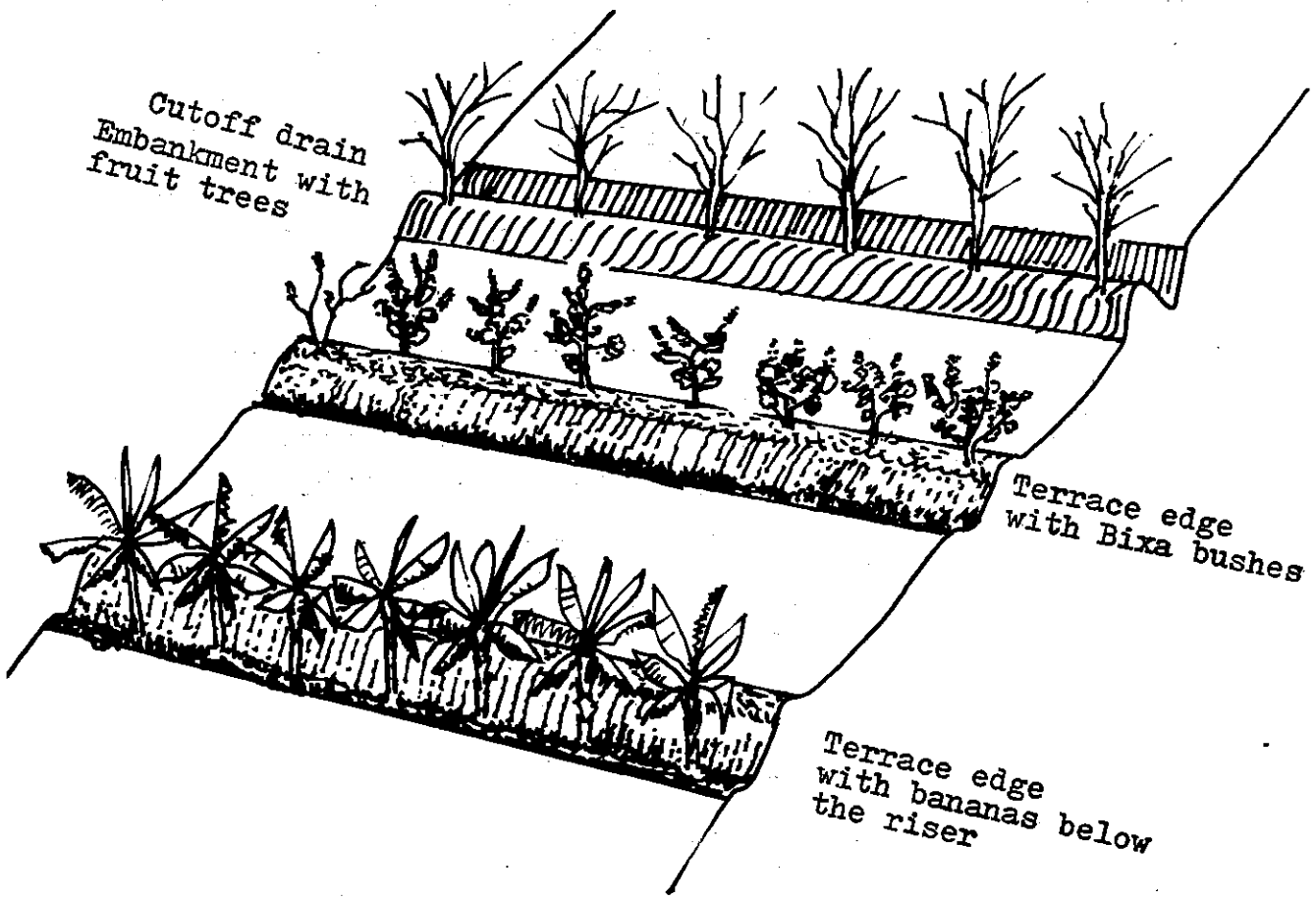

Cutoff drain
Embankment with
fruit trees
Terrace edge
with Bixa bushes
Terrace edge
with bananas below
the riser

Fig. 18

Farm yards often need some trees as shelter against the wind, at the same time as shade trees and for ornamental purposes.
Examples: Cassia (below 1,300 above m sea-level), Camel's Foot (Bauhinia, below 1,900 m), Nandi Flame (Spathodea nilotica, below 2,300 m) and Jacaranda (below 2,300 m). More pronounced shade trees are Croton megalocarpus, Schinus molle and Ficus species.

2. TREES IN TERRACING

2.1 In general

In the nation-wide soil conservation programme of Kenya soil conservation does not only mean terracing. It means a spear head to improved agriculture.

Developed bench terraces and grass strips will retain moisture and nutrients, thus increasing the yields, in dry areas of Machakos and Kwale Districts by 50 %. Terrace edges with a high productive fodder grass, e.g. napier or bana-grass, can permit a farmer to have cattle without owning any grazing land. The cattle will provide manure, increasing the crop yields. Embankments of cutoff drains and terrace edges can also be planted with trees.

Such planting of trees on slopes has the following advantages:

1) increasing the yield and the income of the farmer
2) providing permanent contour cultivation even if the slope should be used as pasture for some time
3) stabilizing the risers of bench terraces and the embankments of cutoff drains
4) preventing people and cattle from using the terrace edges and the embankments as foot paths, the trampling decreasing the infiltration rate
5) acting as "nutrient pumps", bringing nutrients from large depths to the canopies and from there to the ground, improving topsoil and fertility, and
6) preventing or decreasing raindrop erosion during heavy rainfalls.

Trees along terraces might have the following disadvantages:

1) competition between the rootsystems of the ground crop and those of the trees, resulting in decrased crop yield
2) shade effect preventing vegetation on the ground
3) rainfall below the canopies will be too small and the ground too dry, and

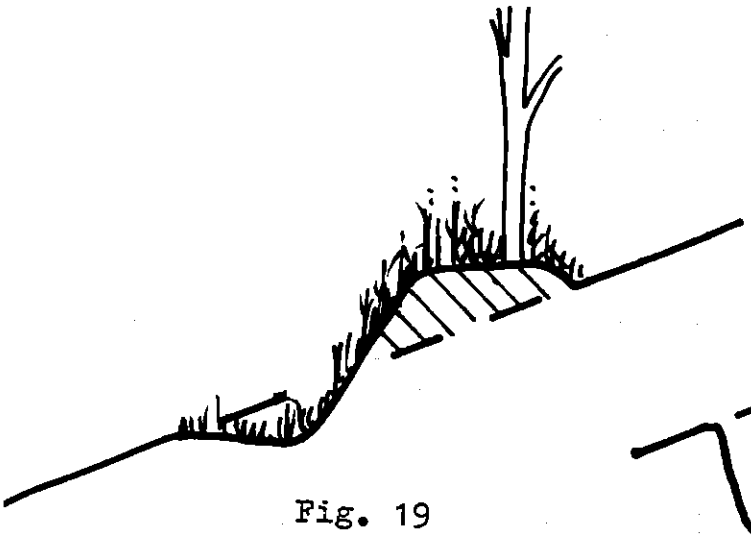


Fig. 19

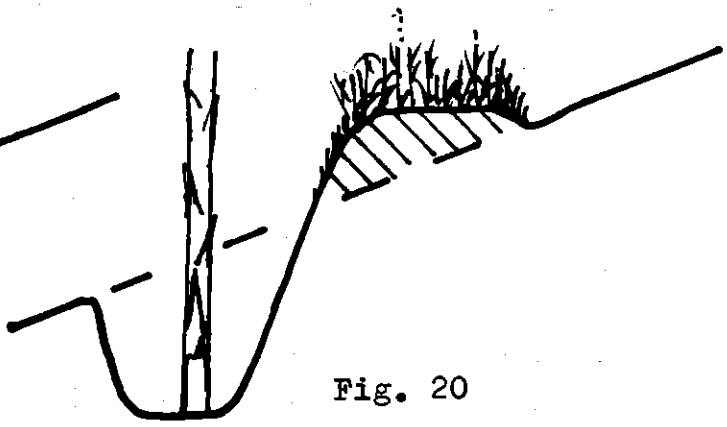


Fig. 20

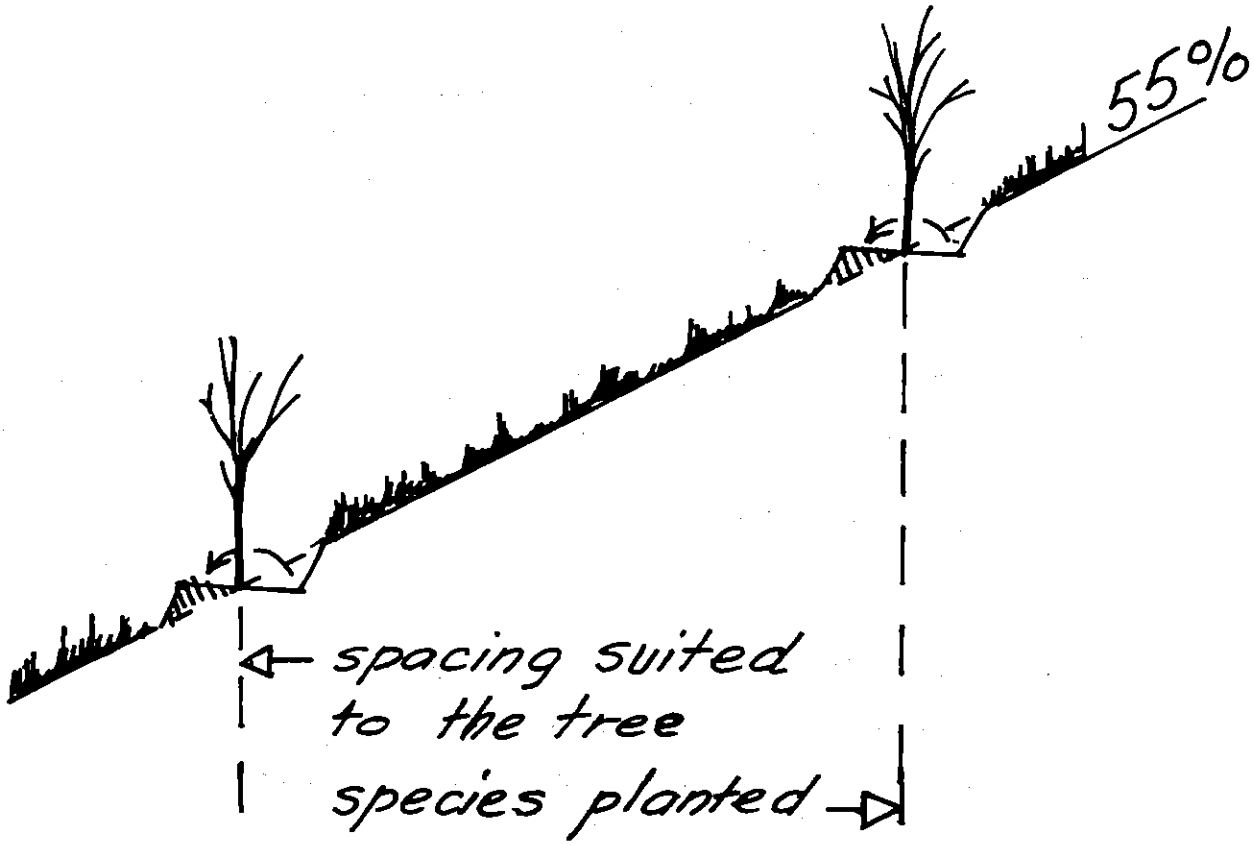


Fig. 21

4) trampling round the trees during harvesting fruits or fodder will compact the soil, decreasing infiltration and increasing eroding overland flow.

Of course trees can reduce the nearby yield of crop but it is the summarized yields of trees plus ground crops, which should be considered. Regarding influence on shade and rain, this can be reduced by cutting the lower branches of the trees. Our present knowledge on all these matters is poor. We need to gain more experience from existing cases, and scientific research is needed on experimental basis.

2.2 Where to plant trees

The following cases will be considered: 1) cutoff drains, 2) terrace edges, 3) steep slopes.

The embankments of cutoff drains should be planted with trees. These are normally planted along the top of the embankment or along the lower foot of the embankment (especially bananas). Trees planted along the top will prevent people and cattle from walking along the embankment.
As to terraces the trees are usually planted on the upper side of the embankment or on the upper side of a grass strip (Fig.19).
Experience shows that a terrace riser will move into the slope.
If trees or bushes are planted too near a terrace edge, the root system will grow into open air.

Bananas must be planted below the risers, especially in dry areas (Fig.20). The root system is not wide and will not decrease the yield of ground crop. A disadvantage is that the banana stem will prevent excess water passing a riser to be drained away along the foot of the riser.

Considering this, every terrace should not be planted with bananas on long slopes or on slopes below hills. Every second or third terrace should be planted with trees above the riser, so diversion ditches can be arranged for excess water, if any.

Steep slopes, i.e. between 25 % and 55 % (14°–29°) and even very steep slopes, i.e. more than 55 %, can be used for cultivation of trees on modified bench terraces. These are ledges cut into the slope, 1 – 3 feet wide. The interval of modified bench terraces is that recommended as spacing for the tree species used.

The idea of ledges is to minimize erosion during the establishment of trees and the establishment of a cover of grass on the slope (Fig.21).

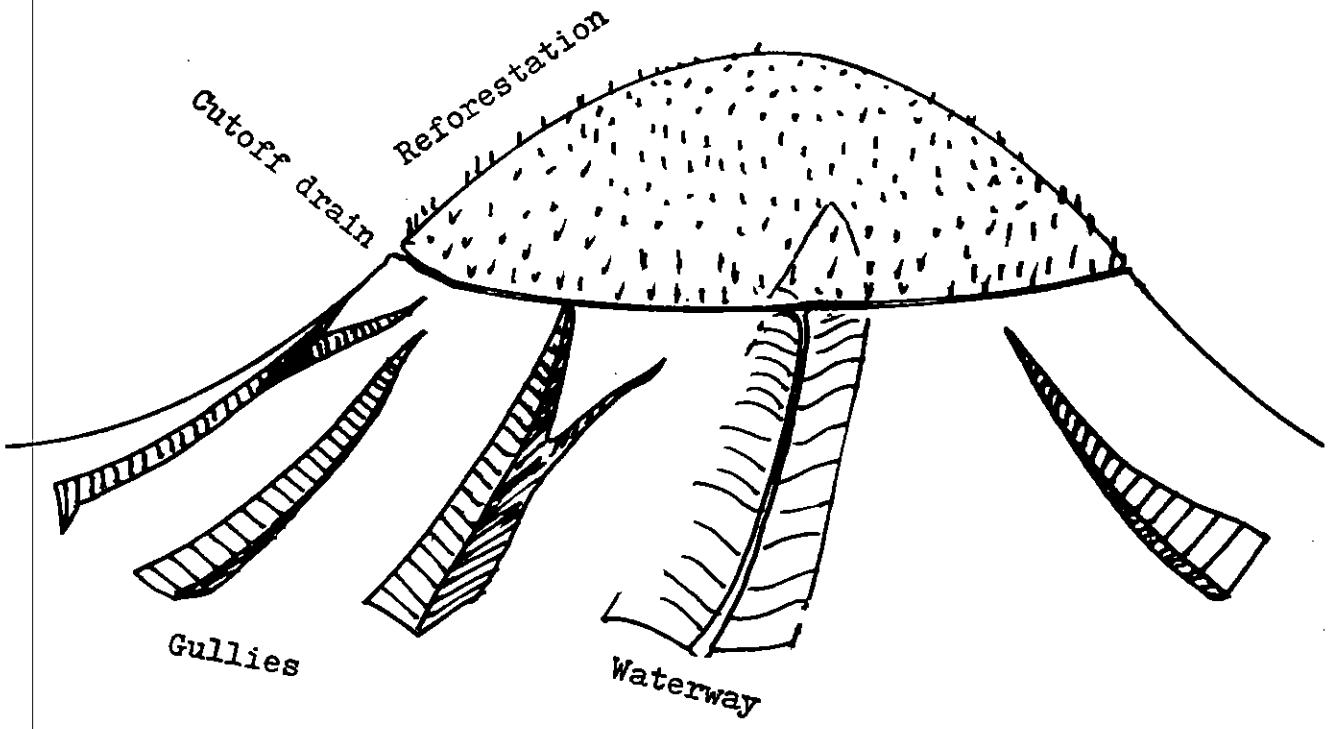


Fig. 22

2.3 Tree species

Trees or bushes used in terracing should have deep tap roots or rootsystems which will not compete with the surrounding crop. In addition to this point of view the following should be considered for selection of tree species to be used in terracing:

1) availability of tree seedlings in the area
2) need of wood or fruits on the farm and marketing facilities
3) altitude above sea-level and climate (ecozone), and
4) soil type and depth of the earth layer above the rock.

Among timber trees Grevillea robusta and Casurarina equisetifolia can be used, but Cupressus and Eucalyptus are not as suitable. I have seen maize influenced by a row of Cupressus at a distance of 4 - 6 m but bana grass was not.

Among fruit trees the following species have been planted along terraces in Kenya:

1) in the temperate zone: peaches and plums
2) in the coffee zone: peaches, oranges, mulberry, papaya, castor, bixa
3) in the cotton zone: papaya and coconuts.

I have also seen guava, mangoes (with lower branches removed), cashew nut and macadamia, but in these cases further experience is needed.

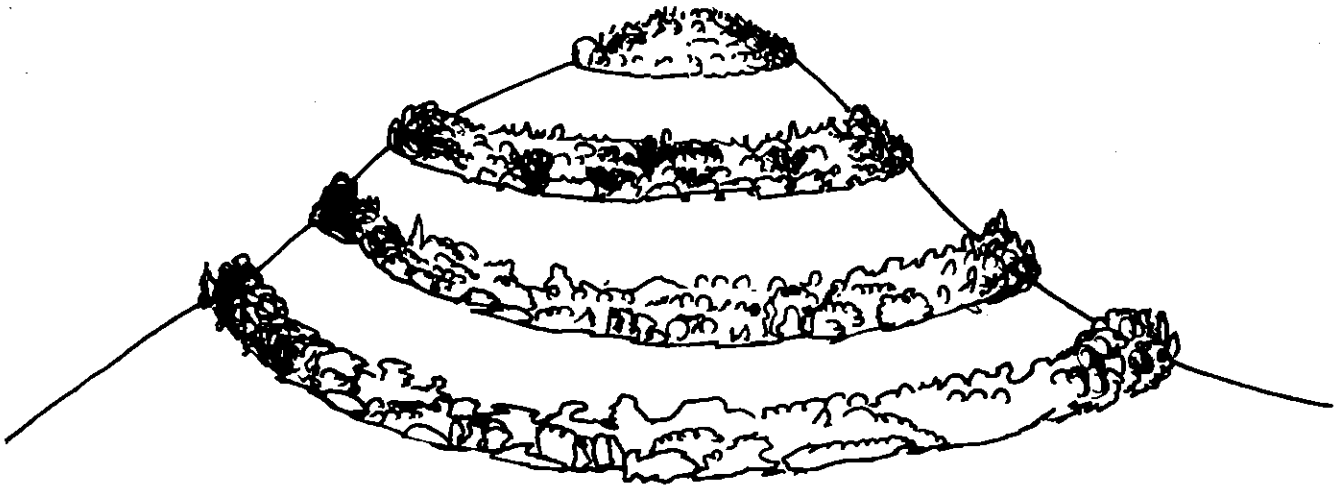
3. TREES IN RECLAMATION OF DENUDED LAND

3.1 Hills and escarpments in semi-arid areas

There are many hundreds of overgrazed hills in the semi-arid areas, where erosion is devastating the normally rather thin soil layers. These hills can be brought into production as pastures or forests. Very little has been done to date. In a few districts some tentative activities have started, e.g. in Machakos and Meru Districts.

A big cutoff drain is dug on the slope around the hill. The water is discharged through a natural waterway, which has reached the bedrock. Above this cutoff drain forest trees are planted, if the farmers do not need the hill for grazing. The slopes below the cutoff drain can be cultivated, if terraces are established. Most of the crops have deep roots and are not so dependant on a topsoil as in more humid areas.

If the slopes are so dissected by gully erosion, that they cannot be cultivated, bana grass is planted on the areas between the gullies and trees on the gully slopes (Fig.22).



Reforestation
as regular forest belts

Reforestation
where ever possible

Fig. 23

The bana grass will compensate the farmers for the pasture they have lost.

The first measure to be taken, however, is always closing the hill from grazing to establish a grass cover and to protect the seedlings planted. After, cutoff drains can be dug.

It is not absolutely necessary that all the hill is covered with forest. Patches with good soil can still be cultivated, especially if they are longer along the contour than down the slope (Fig.23). Russian investigations have shown that the overland flow is infiltrated on a hill, if forest belts along the contour cover 30 - 40 % of the surface of the hill (Pereira 1973).

Trees so far used for reforestation of hills are Cassia, Eucalyptus, Grevillea and the Neem tree.

3.2 Farms with denuded slopes

Desertification is often described as the southern border of the North African desert moving to the south. However, in Kenyas semi-arid areas there is desertification of almost every farm.
The farms are rather large, often 10 - 20 acres, and only the upper and smaller part of the farm is cultivated. Most of the farm has been used as pasture and is usually overgrazed and denuded. The ground is bare, dry and compacted. Gully erosion is accelerating. Those areas could definitely be better used and should be rehabilitated before they are totally dissected by gully erosion.

The first measure to be taken is closing from grazing. Grass can come in by itself or can be seeded. For the establishment of grass, ploughing along the contour is recommended with an interval of 1 - 4 m between the plough furrows, the width depending on the slope and the severeness of the erosion.
If labour is available on the farm, the slopes can alternatively be cultivated, if terraces are established. The best type of terracing for these areas is the Fanya Juu terrace, because trash and grass strips can be eaten by termites.

Whether the rehabilitation of the denuded slopes aims at grazing or cultivation, it can be combined with planting of trees. Such cultivation patterns are known from long ago. The Maya Indians of Central America combined Leucaena trees with maize on terraces.
People in the Niger area of Africa increased the yields of millet, if the cultivation was done under trees of Acacia albida. In North Africa carob trees have supplied fodder for cattle during dry seasons.

Trees for dry lowlands (firewood, charcoal, poles, timber and fodder)

Species	Ecozones	Max. altitude above sea-level, metres	Soil	Can withstand inundation	Cultivation pattern
Acacia albida	IV + V	1,800 but preferably 1,200	most soils but preferably deep sandy soils	yes	evenly distributed, with ground crop
Leucaena leucocephala (Lucena)	IV + V	1,800 but preferably 500	most soils but preferably not very acid soils	no	evenly distributed or in rows, with ground crop
Prosopos (Algaroba)	IV + V	1,500	most soils but preferably heavy soils		evenly distributed, on grassland
Cassia siamea	IV	1,300	most soils	no	in rows, on grassland
Eucalyptus camaldulensis	IV	600	poor growth on dry sandy and alcaline soils	only seasonal	evenly distributed or in rows, on grassland

There is no reason why similar methods could not be used in the dry parts of Kenya. I don't know what happened to the trials of fodder trees more than 40 years ago (Maher 1939).

The Soil Conservation Project has supplied its tree nurseries with seed of reclamation trees since September 1979, concentrating on five species. To help the Agriculture staff to select tree species for their reclamation work, some data have been put together in the table on the opposite page.

The reasons for using trees in land reclamation are to improve the micro climate, restore soil fertility and decrease erosion. The shade and the reduced wind will increase humidity. Decreased ground temperature will favour moisture and preservation of humus. The trees will "pump" nutrients from great depths and return them to the ground litter. The topsoil will show an increase especially in nitrogen, phosphorus and exchangeable calcium. The canopies of the trees will reduce raindrop erosion, and below the canopies the infiltration rate and absorbtion of water is increased. The trees also reduce wind erosion.

The farmers show tremendous interest in planting trees, as these will provide fodder during the dry season, fuel, food and timber for consumption on the farm or for sale.

The biggest constraint is the protection of the seedlings from grazing during the first 2 - 8 years.

Appendix

PRESENTATION OF FIVE TREES FOR LAND RECLAMATION

ACACIA ALBIDA

Altitude: Up to 1800 m above sea-level but normally below 1200 m.

Annual rainfall: Preferring 650 mm but can withstand 300 mm.

Soils: Prefers deep sandy soil (as for millet) but does not grow well on lateritic soils. Can withstand occasional waterlogging.

Height: Up to 20-25 m.

Uses:
- Good soil conservation tree (can lead to higher yields of crops planted beneath), at least 15 trees per acre to maintain soil ferlility.
- Pods and leaves are good for cattle feed (tree retaining leaves during dry seasons but dropping them during wet seasons).
- Branches for fences.
- Firewood, charcoal.
- Wood for carving.

Cultivation:
- Fast growing during the first years, little mortality during the following years.
- The tree can reach a height of 2 to 4 m after 3 to 4 years and can produce pods in 5 to 8 years.
- The trees should be evenly distributed when planted, 10 m apart (48 trees/acre).
- Young trees are difficult to protect. The young branches and leaves are enjoyed by animals; so they must be protected for 5-8 years from planting.
- Suitable for dryland farming. Because roots are unusually deep, they do not affect the ground crop. Yields are actually increased. Can be planted together with millet, sorghum, cotton, groundnuts, cowpeas, and grasses. On eroded ground Acacia albida can be planted together with Eucalyptus sp.
- It is grown in a scattered fashion and never in close plantation.
- After planting, height growth is negligible to start, but the root system rapidly develops. By the third year when the roots have reached subsoil water, the tree grows vigorously.

CASSIA SIAMEA

Altitude: Below 1300 m, sometimes higher.

Annual rainfall: 500-1500 mm.

Soils: Most kinds of soils but requiring good drainage.

Height: 12 m.

Usage:
- Timber (resistant to termites). Poles not durable.
- Reforestation.
- Shade, ornamental.
- Good dense windbreak with no undergrowth.

Cultivation:
- Good for reforestation as shelterbelts on plains, in rows with spacing of 3 m between seedlings, 4 rows deep.
- Suitable for strips along contours but it effects the crop growth negatively on both sides of planting as does Azadirachta, Eucalyptus and Prosopis.

EUCALYPTUS CAMALDULENSIS

Altitude: Best on lowland (below 600 m above sea-level).

Annual rainfall: 635 mm average.

Soils: Heavy or rocky soils. Poor growth on sandy and alkaline soils. Better along river banks and on valley floor than on slopes.
It can tolerate seasonal flooding but not long - term waterlogging.

Height: 18 to 45 m, sometimes higher.

Usage:
- Hard and durable timber.
- Fencing poles.
- Firewood, charcoal.

Cultivation:
- Can reach a height of more than 10 m in 6 years.
- Planting is beneficial along river banks to prevent erosion.
- It's roots are very widespread.
- Reforestation of hills. Shelterbelts on plains.

LEUCAENA LEUCOCEPHALA (LUCENA)

Altitude: Below 1800 m, preferably below 500 m.

Rainfall: 600 to 1700 mm. Possible at 250 mm.

Soils: Flourishes in deep, red latosolic soils. ph 5 to 8, best 6.5 to 8. Requires good drainage and cannot withstand flooding. Ideal on the sea coast of Kenya.

Height: 4 to 6 m, sometimes higher.

Usage:
- Firewood, charcoal.
- Timber.

- Windbreak.
- Forage.

Can produce pods 8 months after planting. Produces a large amount of vegetation during drought periods. If leaves are cut 6 to 8 weeks, after it reaches a harvestable size, Leucaena can produce 100 tons/ ha/year of palatable green fodder. It can be grazed at a height of 0.8 to 1 m.

Cultivation
- To establish Leucaena as forage, sow seed between growing maize plants.
- Can be planted in rows spaced at 0.3 m within rows and 1 m between rows. Can be harvested at 2 to 4 months intervals.
- Can be cultivated as shelter belt against wind erosion, and as contour hedges on slopes.
- Useful for reclamation of semi-arid land because it can grow on bare ground, steep slopes and in marginal soils. The roots are very deep. Can reach 2 m in two years and 5 m at five years.
- Can be intercropped with vegetables, root crops, grain crops, bananas and grasses.
- Early growth is slow, but later, there is little effect from competition by grass or weeds.

PROSOPIS (ALGAROBA)

Altitude: Below 1500 m above sea-level.

Rainfall: 250 to 1250 mm, good below 600 mm.

Soil: Prefers rich heavy soil (clay) but also on light sandy and rocky soils. Can afford some salty soils.

Height: 9 m or higher.

Usage:
- Pods and leaves as fodder.
- Timber, fence poles.
- Shade. Windbreak. Stabilizing sand.

Pods are a high protein cattle food (up to 6 to 7 tons/ha/year, producing beans after only two years). Sweet beans edible by humans without cooking.

Cultivation:
- Can be a planted as seedling tree or from stump of two year seedling.
- Tree requires pruning to a single stem and to such a height that cattle can graze below the canopies.
- Fast growing on good soils.
- Foresting of dry areas. Algaroba increases the nutrient content of the soil below the canopy, but it might effect the growth of ground crops because of the wide and shallow root system.
- Can be a weed in humid areas and on good soils.

SEED AVAILABLE FOR SOIL CONSERVATION TREE NURSERIES

Forest trees	Altitude above sea-level m	Annual rainfall mm	Soil etc
Azadirachta indica (Neem)	Below 1,200	Above 300	Porous well draines soils
Cassia siamea (Ironwood)	Below 1,300	500-1,500	Most soils, good drainage
Casuarina equisetifolia (She-Oak, Muinji)	Below 1,800	700-2,000	Sandy soils, river banks
Croton megalocarpus (Musine, Mukinduri)	1,300-2,100	1,000-1,900	
Cupressus lusitanica (Mexican Cypress)	1,200-3,000	Above 900	Well aerated soils
Eucalyptus camaldulensis (Red River Gum)	Lowland	Average 635	Heavy or rocky soils
Eucalyptus saligna (Sydney Blue Gum)	Mainly highland	900-1,300	Preferably loamy soils
Grevillea robusta (Silky Oak)	1,200-2,300	1,000-1,500	Best on deep sandy loam
Pinus patula (Mexican Pine)	1,800-2,700	1,000-1,500	Well drained sandy loam
Fodder trees			
Acacia albida (Apple Ring Acacia)	Below 1,200 (1,800)	250-900, best 650	Clay to sand, best deep sand
Conocarpus lancifolius (Somali Tree)	Below 400	Low	Deep soils, heavy clay
Gmelina arborea (Melina)	Below 1,200	Above 750	Sandy soils, good drainage
Leucena leucocephala (Lucena)	Below 1,800	Above 250	Not strongly acid soils
Prosopis (Algaroba)	Below 1,500	250-1,250	Also sandy rocky soils

Fruit trees

The Soil Conservation Extension Unit will also help to raise the following seedlings for "soil conservation farmers".

Temperate zone

apples, peaches, pears, plums

Coffee zone

avocados, bananas, custard apple, guavas, limes, loquats, macadamia, mangoes, mulberry, oranges, papaya, peaches

Cotton zone

cashew nuts, coco nuts, macadamia, mangoes, papaya.

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In addition a large number of publications have been used for the Appendix.