Agrodok 11

# Erosion control in the tropics

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# Foreword

## Foreword to second revised edition

This is a revised version of the first edition of this Agrodok. Hopefully it is a useful introduction to the erosion problem and its control. We want to thank Mr. Eppink from the Agricultural University of Wageningen for his remarks and corrections, and Hensen Trenning for the illustrations.

The authors,

Hil Kuypers
Anne Mollema
Egger Topper

Wageningen, 1987

## Foreword to the fourth revised edition

We have experienced that this Agrodok on Erosion control is quite popular. Due to this we have to reprint regularly. For this fourth edition we have improved the layout and the pictures, and incorporated improvements in the text.

We are very grateful to Arend Kortenhorst who has taken care of the lay out with great patience and a good eye for details.

Agromisa welcomes readers to send us suggestions which could help us to improve the contents of the publication.

Marg Leijdens
Coordinator Agrodok Publications

Wageningen, 1999

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# 1 Introduction

Agromisa's Question and Answer Service receives many questions about erosion and its control. In reply to the very specific questions, an equally direct answer can usually be given. However, general questions come in as well, such as: "What can be done against erosion in this area?". Obviously, such a question can only be answered if a number of counter-questions are asked, for example:

- What are the erosion characteristics?
- What is the rainfall distribution?
- What sort of crops are grown there?
- Are you situated in a hilly area?
- etc.

Only then would we be able to give the most important facts about soil conservation. This Agrodok may be considered as an extensive reply to such questions. At the same time it is an introduction to erosion control.

With only this booklet at hand, you will not be in a position to lay out a number of terraces straight away; for this, other books are available (see the section 'Further Reading'). Yet, we have tried to write a book which will be useful for people who are confronted with the practical aspects of erosion.

## 1.1 Objectives of this Agrodok

In compiling the booklet we have kept the following objectives in mind:

- To emphasize the seriousness of the erosion problem. Erosion is not always recognized in time, and certainly not when it takes place surreptitiously.

- To give an insight into the causes and the course of the erosion process, by stating the factors which influence the mechanism of erosion and how these factors are linked up.

- To clarify the relation between erosion and the farming system. The farming system (land-use) largely determines whether erosion will occur; erosion in its turn again imposes limitations on agriculture.

- To enumerate the most important soil conservation measures and the principles on which they are based, at the same time indicating how they can be applied. How erosion can be prevented will be discussed at length here too.

For clarity, we have restricted ourselves to erosion caused by water. In doing so, the connection between the causes of erosion and the principles of erosion control measures will always be kept in mind. The so-called mass movements (earthquakes, mud streams etc.) will also be discussed briefly because these phenomena are often related to water erosion and the causes of it. The seriousness of wind erosion cannot be underestimated but this is beyond the scope of this booklet.

To keep this booklet accessible for everybody we have not assumed a previous knowledge. Therefore, you may well read things you already know. Some technical terms will have to be used too, necessary to prevent misunderstandings. The same terms will crop up anyway when reading other literature. The explanation or the definition of the relevant difficult terms can be found in the Glossary in the back.

If you find it difficult to get an overview of all the information, you could refer to Chapter 10 in which the connection between the various chapters is briefly given.

## 1.2 What is soil erosion

Since there are several different definitions of erosion, we will first clarify what we mean by erosion here. There are really two types of erosion, natural and accelerated erosion, also called man-made erosion.

- Natural erosion is going on all the time; the weathering of mountains, hills etc. caused by the influences of nature. New landscapes are formed, but the process is very slow.

- Man-made erosion occurs when people cause the soil to become susceptible to be carried away by rain or wind. Cutting trees and burning vegetation are examples of practices that destroy the natural protection of the soil. This book is about man-made water erosion.

Another important factor is soil degradation, that is the decline of soil quality as a consequence of people using the land. Soil degradation and erosion overlap. Soil degradation is a wider term, erosion being but one form of soil degradation, others are: pollution, salination, etc.

## 1.3 The seriousness of the erosion problem

Every minute, an estimated 10 hectares of agricultural land is lost to erosion throughout the world. In some areas, very little occurs, in others more than 200 tons of soil disappears every year from 1 hectare...... (i.e. 20 lorry loads!). On average about 50 tons of soil per hectare are lost each year. The soil lost is the top layer, which is the most fertile part of the soil.

The rivers in which these soils are transported change into a brown gushing stream in the rainy season. They occasionally flood the low lying areas. The fish in these rivers are at the mercy of that dirty water. If the water is used for irrigation, then ditches silt up, at best maintenance costs rise alarmingly. Sometimes all the soil ends up in a dam reservoir, as in the Shinen reservoir in Taiwan for example, which was half full of silt within five years, whereas a life duration of 70 years had been estimated.

These problems could be fatal and forces the governments to face up to the seriousness of the erosion problem. A government can oblige farmers to carry out erosion control (soil conservation) measures as reafforestation and terracing. The farmers should then be compensated with loans in these schemes. Many farmers are so badly in need of their plot of land that any restricting regulation would mean starvation.

If the threat of erosion is not yet as fatal as mentioned above, individual farmers or groups of farmers can carry out erosion control measures in order to protect their land and food security.

It seems that the seriousness of the erosion problem can be measured by the amount of soil lost from one hectare. This is not always so simple. Especially in hilly areas the depth of the fertile top soil may vary considerably from one place to another within short distances. There is no cause for alarm if the depth of soil is a few meters, but if there are only a few centimetres before reaching the subsoil or bare rocks, this must be safeguarded at all cost.

It can be concluded that the seriousness of the erosion problem differs not only on a worldwide scale, but locally as well. For two farmers living on the same mountain slope, the situation may be quite different. It is usually the poorest section of the community that is hardest hit by the effects of erosion. In the light of this, it is not surprising that in the U.N. report of 1984, erosion is considered to be the greatest threat to mankind.

# 2 How to recognize erosion

The previous chapter explained how erosion can impede development of large areas and even whole countries. Now an attempt will be made to illustrate the ways in which a farmer is confronted with the physical characteristics of erosion in the daily work. For this, it is important to know how to recognize erosion in the field.

Always keep the course of the erosion process in mind when looking for signs of erosion in the field. When a certain characteristic is noticed, one should ask oneself just why it should occur in that particular place, and why it has that appearance.

More attention will then perhaps be given to the causes of erosion and the more subtle characteristics of erosion will be observed. An important rule of thumb is always to work upstream, in the same way as when looking for water. So: 'I am now standing in a gully where water has accumulated. Where did this water come from? That is where erosion is likely to be. Up the hill I go again'. Keep in mind though that there might always be other causes for the erosion, which are not easily seen.

## 2.1 Symptoms of erosion

This section lists the symptoms that can arise from erosion. Of course, several symptoms can manifest themselves at the same time.

### Gullies

Gullies are deep fissures occurring in the soil and being caused by large quantities of water that have to be transported in a short time. Gullies are sometimes many meters deep (see figure 1).

### Developing gully

A developing gully is less deep than a gully. If a number of these gullies are more or less parallel and close together, then a whole gully-system has formed.

**Rills**
Rills are fissures in the soil that resemble a small gully (to about 30 cm deep). A rill may run into a gully. A system is formed which tends to expand in an upslope direction.

**Bad lands**
A bad land is an area being made inaccessible by a very close system of gullies. This is especially a problem when using agricultural machines.

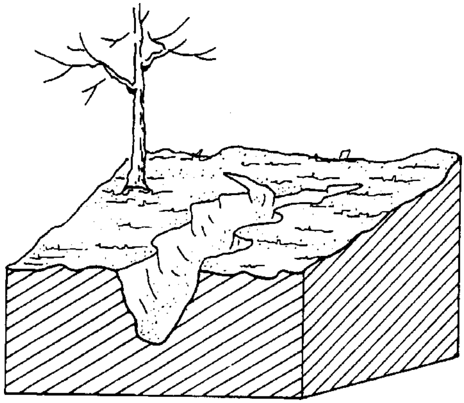

*Figure 1: Gully*

**Exposed root system**
Root systems of plants have the ability to retain soil. In trees, the fine ramifications of the root system are important for this. If the top soil layer is washed away, then the roots are exposed. Thus for annual crops we can determine roughly how much soil is washed away in a growing season (see figure 2).

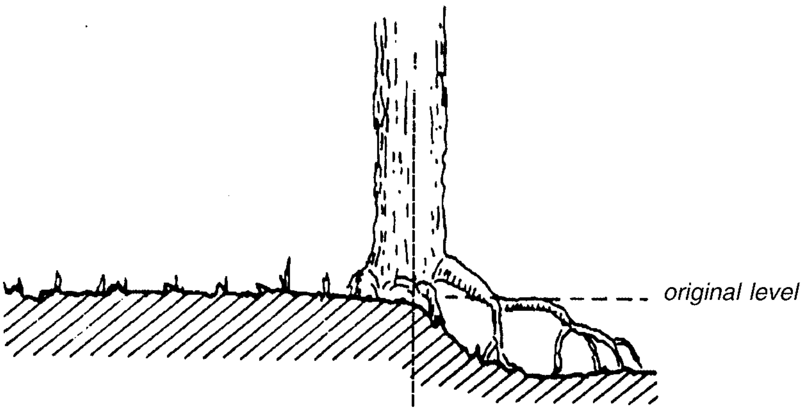


*Figure 2: Exposed root system*

**Pedestal**

Pedestals are seen when soil under grass clumps, roots and small stones is staying in place while the soil in between is washed away. Stones and the like protect the soil against the erosive force of the rainfall and eventually come to lie on a little mound of soil (see figure 3). Pedestals are particularly found under the drip area of leaves (mainly trees).

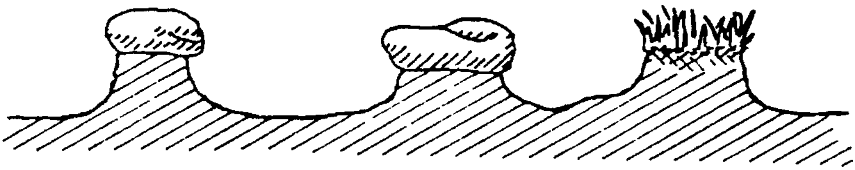

*Figure 3: Pedestals*

**Stones on the surface**

If a whole layer of soil is washed away stones will often remain behind. The force of the water is not strong enough to carry the stones away. The finer particles are removed. If the soil is very shallow, bare bedrock may become exposed; the loose soil is washed away.

**Mud-coloured water**

If muddy water (yellow, red or brown colour) is noticed in a stream or in a river, this indicates that soil is being carried along with the water. You can show this by taking a sample of the water in a glass from different places in the stream and leave it to stand. It can then roughly be seen how much sediment has been transported. Especially the finer particles in the sediment have absorbed nutrients and the water should be left to stand for a while before these particles settle (see figure 4).

**Layers of soil**

A fine layer of soil is often noticed in the lower lying parts of the field. This has been deposited by water that flows more slowly or has stopped flowing altogether. This can be observed too in irrigation furrows and is almost certain to have come from the field in question.

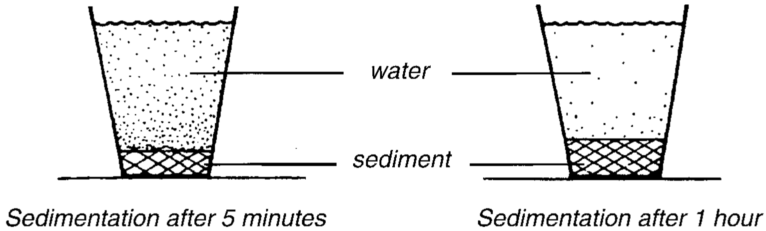


*Figure 4: Mud-coloured water*

It is a sign that a form of erosion is going on in which as yet no great quantity of soil is being transported over a long distance. Erosion is probably still in a preliminary stage. Yet, this fine layer of soil material may be 10 to 30 centimetres deep in places and may cover the emerging crop over dozens of square metres (see figure 5).

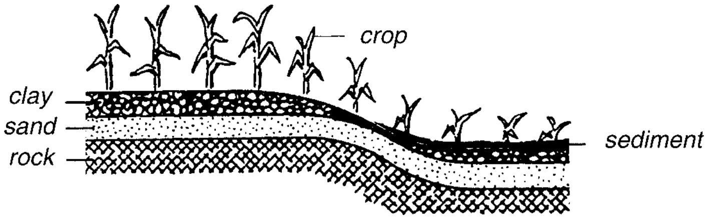


*Figure 5: Sedimentation of soil material*

When thin layers of soil are eroded away evenly from the field, this is known as 'sheet erosion'. This sediment is found in watercourses, culverts and the like. Irrigation and drainage canals often silt up completely.

**Landslides**

In areas with steep slopes, landslides may occur, for example along cattle tracks. For various reasons the stability of a soil can be lost and a large amount of soil slides down the slope. The phenomenon can be observed too if the walls of a gully are undermined by the water stream. In road building too, steep side slopes often collapse in heavy rainfall.

The above examples all indicate that soil displacement has taken place and this is not always easy to see. Irregularities such as rills can be straightened out with the plough, and the crop hides a lot too. Throughout the seasons different characteristics will catch the eye too.

## 2.2 Other ways to discover erosion

Apart from the soil being transported, there are still other ways to discover what has been going on in a particular place. For instance, you could compare fields situated close by, or different spots within a field. Yet with some experience and a little intelligence, much can be observed. Here are some suggestions.

### Comparing fields

Stand at the boundary of the two plots. There may be a considerable difference between the two plots: sometimes there is even an abrupt transition and one field may lie rather higher than the other (see Figure 6). Has soil been washed away perhaps? Or has it just been washed up to the upper edge of the plot? What does the farmer do for the one field that he would not do for the other?

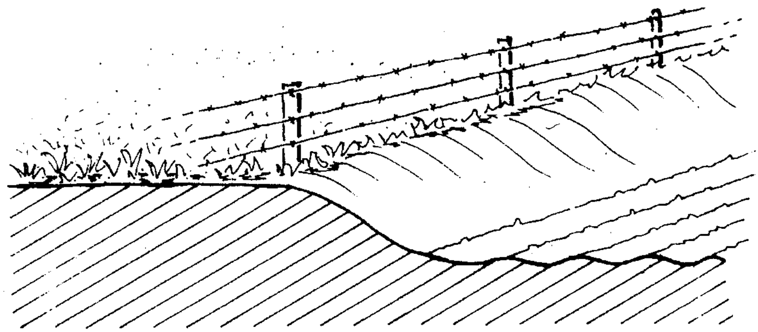

*Figure 6: Difference in level between two plots*

### Comparing soils

From a plot of land that is not used for agriculture, woodland for instance, take some soil from the top layer from various places and do the same from a nearby field. Put them next to each other. The colour, crumbliness, moisture content, amount and composition of plant residues will demonstrate that on the uncultivated part there is much more organic material in the soil. Notice the consequences this has for the moisture retention and the structure of the soil.

### Comparing yields

Different parts of one field may give different yields. Fields often have a few poor patches, but usually the yields are lower on the higher slopes.

This is often the result of erosion, the soil quality at the top of the slope having further deteriorated than that on the lower slopes. It is wise to look at the soil properties here too. If the field is not covered by a crop, it will probably be noticed that the soil on the higher slopes is lighter in colour. This indicates that organic material or clay has disappeared from the profile (see Glossary). The soil is then more susceptible to drought, which can be felt by crumbling some soil from two different places on the slope.

### Failure of crops

As a result of erosion the moisture retention of the soil will decline. Crops, such as maize may continually fail and the farmers would have to switch over to another crop, sorghum for instance, which is more drought resistant.

## 2.3 Symptoms of degeneration of the environment

Finally, to the experienced eye, there are still a number of indications that point to a degeneration of the natural environment:

- There may be a change in the plant composition of the vegetation.
- There may be less plant species because the surroundings impose stricter demands on the plants.

If there is a sudden shortage of firewood in a certain place, this is also a sign that the carrying capacity of that area has been exceeded. When it becomes too time-consuming or too expensive to use firewood then sometimes dung is used as fuel for preparing food. This manure is however indispensable for maintaining soil quality and serious erosion may be the result.

A thorough knowledge of the subject is needed to be able to observe all this and to interpret it. Talking with the local people about such matters is very useful. Often they can tell you about locally well-known plant species and their disappearance.

It is perhaps amusing to relate here that on one occasion we were standing looking at a layer of sediment between the sorghum plants, intrigued by what type of soil it was that had eroded away from further up the slope. A farmer standing nearby politely remarked that this soil came from a flood from a river nearby. So erosion had taken place, but from somewhere quite different from where we had expected it. In our search for erosion we had made it just a bit too easy for ourselves!

We have tried to make clear that when observing the erosion phenomena, the important thing is always to trace the causes of it. In the following chapters we will go more deeply into the erosion process, which may help you to understand the characteristics that you see.

# 3 The erosion process

Some understanding of the way in which the erosion process takes place is needed to appreciate the usefulness of preventive measures. A few factors will be mentioned which together determine how much and what type of erosion is likely to occur.

## 3.1 Splash-erosion and stream-erosion

Within water-erosion there are two types of erosion: splash erosion and stream erosion. Certainly, they do occur at the same time, but for clarity we will discuss them separately.

### Splash erosion

In splash erosion, the falling raindrops break off small parts of the soil aggregates (see Glossary). The loosened small soil particles fill the gaps between the larger particles and a so-called crust is formed (see figure 7). This layer or crust is not easily penetrated by water and air; Water cannot easily infiltrate in the soil, and is not available to the plant- roots; hence crop growth is hindered and the water will run-off.

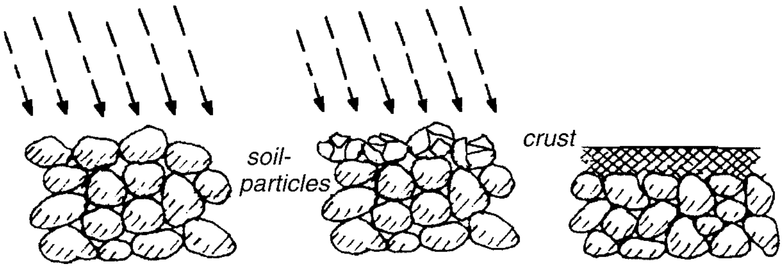


*Figure 7: Splash erosion and crusting*

In splash erosion, the force of the falling raindrops is determined by the size and the falling velocity of the raindrop. Both these factors are of course closely related to the type of rainstorm from which the droplets fall. If the raindrops are first intercepted by a cover crop before falling on the soil their impact will be less. Those falling from a greater height will have more impact.

### Stream erosion

Water that cannot penetrate the soil, runs off to lower lying areas, choosing the path of least resistance. This process causes the danger of stream erosion. In stream erosion, the particles that were loosened by the turbulence in the water are carried away by the streaming water (see figure 8A & B).

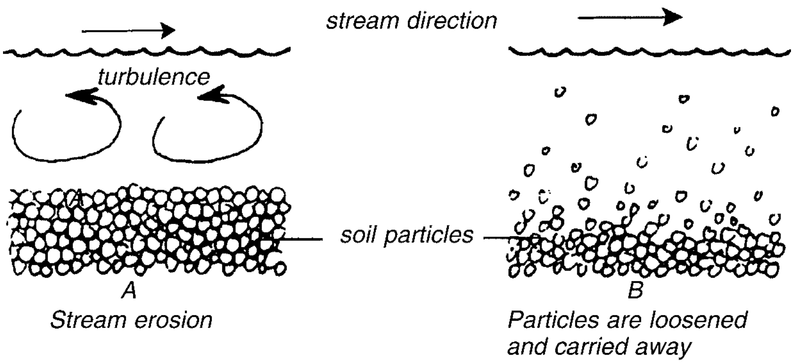


*Figure 8: Stream erosion*

Where the water stream collects, the scouring action of the water is greater and rills may be formed there. These become bigger through collapsing of the sidewalls and scouring until a gully of several metres deep is formed.

The amount of erosion that occurs depends mainly on the force with which the water acts upon the soil and the degree to which the soil can resist this force. The scouring force of the run-off depends mainly on the velocity of the water. The steeper the slope and the deeper the stream, the faster the water will flow. If the slope at a higher level is very long, a lot of water can accumulate and the erosive force may increase even more. The degree in which the soil can resist this force, is handled in Paragraph 3.2.

**Combination of splash- and stream erosion**

The combined action of splash and stream erosion seems to be much more serious than the effect they have individually. Erosion caused by run-off appears to increase considerably when raindrops fall in a water layer of a few millimetres. The water is churned around as it were, loosening still more soil particles which are then washed away (see figure 9).

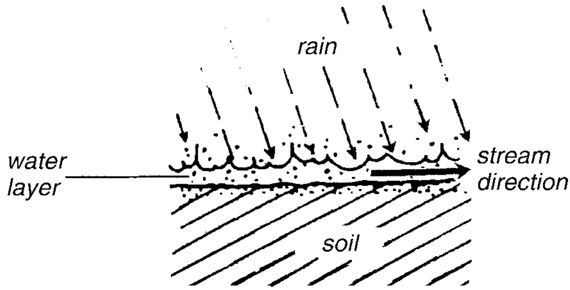


*Figure 9: Combination of splash and stream erosion*

## 3.2 Splash-erosion and soil condition

There obviously is a relation between the type of soil and the susceptibility to erosion. In general the bigger the soil-particles, the greater the resistance. In steep areas only rocks are found. In less steep areas stones and course sands are found. Naturally, the more vulnerable soils are formed on places were the water-force is not strong. These soils are of interest for agriculture. Man-made circumstances (e.g. deforestation), however, can change this.

Looking at the vulnerability of soils: One soil will offer much more resistance to erosion than the other. This resistance mainly depends on:

- the organic matter content of the soil.
- the moisture content
- the type and texture, (the mineral particles which compose the soil, e.g. sand, silt, clay).

**Organic matter content of the soil**

Organic matter probably is the most important factor in binding the soil particles. The better the soil particles stick together, the less easy erosion will occur. As well as organic materials, clay, lime and iron will also binds the soil particles together; hence the clods are less easily broken down by raindrops (see figure 10).

Besides, organic matter is very important for soil fertility and the water holding capacity of the soil. The more water can be absorbed, the less water will run off and cause erosion.

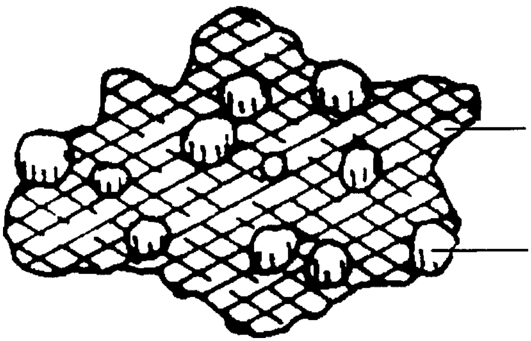


*Figure 10: Adhesion of soil particles*

**Moisture content of the soil**

Depending on the soil type, also the moisture content determines the stability of the soil. Dry soils can be very hard, but because of that, the water will not easily infiltrate and cause great run-off streams once a rainstorm occurs. The moisture content of the soil is not the same throughout the year so at certain times the soil is much more sensitive to stream-erosion than at other times. The soil should be protected as much as possible at these vulnerable times.

When dry, some soils are stone hard and difficult to work. They are then not easily broken up by raindrops. If the moisture content is higher, these soils are more manageable and the clods sometimes break up on their own accord. These periods are usually at the beginning and at the end of the rainy season when there is no protective crop cover. If the soil becomes very fine through tillage operations, the danger of splash-erosion is great. The rain no longer has to break up the clods first, and the soil particles can be quickly carried away by the streaming water, after heavy rains.

If the soil is very wet (in a saturated condition), the resistance to erosion often disappears altogether. The top soil layer is completely disrupted. Just before a shower, sizeable clods are apparent in the field and afterwards the topsoil looks like a muddy pulp, certainly on clayey soils. Different soil types will react differently. So it is advisable to first have a good look around in your surroundings to see how the various soil types react to a number of rain showers. This gives a good idea of the resistance of the soil. A simple manipulation test (see Glossary) is very useful to give an indication of the type of soil concerned.

**Type and texture**

The type of soil is depends for a great part on the texture: The composition of the mineral particles of the soil. This can indicate the vulnerability. However, since the texture of a soil can not be easily changed, this does not offer a possibility for controlling erosion and we will not go into this subject any further.

## 3.3 Stream erosion and the soil

Stream erosion is the ability of streaming water to loosen soil particles and carry them away. In some clay soils it is not even necessary for particles to be loosened, the top layer dissolves, as it were, in the water and is transported is suspended load.

The stream velocity needed to transport this clay suspension is almost nil which can be demonstrated by the length of time it takes before stagnant water loses its muddy colour after a rain shower and becomes really clear. For the same reason the very top layer of sediment material is always very fine in composition.

In practice this can result in the field becoming more stony because the finer particles are slowly washed away. If measures are not taken in time, enormous damage may result from this often strong carrying capacity of the water.

### Rough soil surface

The faster the water runs, the greater the scouring force of the water. The stream velocity increases as the resistance for the runoff declines, that is, for a smooth soil surface. In other words: A rough soil surface can hold back stream erosion. Obstacles such as plant stalks, stones and a mulch also offer more resistance to the streaming water.

Stream erosion is best prevented by seeing that the water doesn't run off. The streaming water should not be allowed to accumulate either, because large quantities of water are potentially dangerous.

Water that does not reach the stage of runoff will not be able to cause stream erosion, but could well be beneficial to plant growth if allowed to infiltrate into the soil. Much more water will infiltrate into a crumbly soil than through a smooth top soil layer. Consider a slight slope with horizontal furrows. A lot of water can be retained here before it eventually runs off (see figure 11).

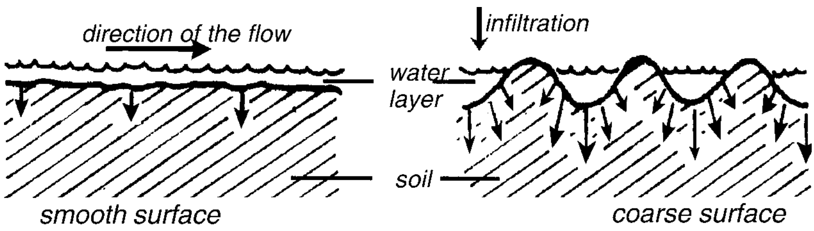


*Figure 11: Run off on smooth surface and infiltration in coarse surface*

Of course, the infiltration capacity (see Glossary) does not depend upon just the coarseness of the soil. The soil texture (sand versus clay), the organic material level and a healthy soil fauna may all encourage infiltration. In general the role of the soil organisms is too little emphasized, but the presence of a healthy soil fauna is an indication that the soil is in good condition too.

## 3.4 An example on how to show the erosion process

To illustrate how splash and stream erosion influence each other, the following example is given:

Imagine an unexpected rain shower. From the shelter of a house the clatter of raindrops can be heard on the roof giving an indication of the force with which it is hitting the soil too. Venturing outside, an interesting comparison can be made. It will of course be noticed that the roof remains impeccably intact owing to the resistance it offers to the force of the rain. This is quite a different story however if the rain is falling on the bare soil. It will become literally washed out which you probably can see happening before your eyes.

The force of the falling raindrops can be made visual at places where rain has dropped from fairly tall height, such as from a roof or for instance a solitary banana palm. A sort of hollow in the soil surface is formed. Look at the stems of plants too (or the side of the house if it is too wet outside). Notice the height to which the soil particles are spattered by the force of the rain. This can be demonstrated by holding up a piece of white paper and seeing how mud-splashed it becomes; of course, if you are not careful the rain will wash it clean again. Sand grains are also noticed on the lower sides of maize leaves up to a height of more than half a metre.

> To illustrate the force of the rain: Look at the water in a puddle of a few millimetres where the rain is beating down. This is reddish or brown, because of the soil particles.

The structure of the soil remains much better in condition if the soil is protected from the direct force of the raindrops (by a crop cover or a stone for example). Water can penetrate more easily into the pores of the soil that have not yet been clogged up by the rain washed particles.

> To illustrate protection of the soil against the erosive force of rainfall:
> During a shower; Put a coin or something like that, on the soil and leave it there for a while. When you look at later, it may be found lying, as it were, on a little mound, of about a few millimetres. Not only have the pores in the surrounding soil become pressed together (which slows down infiltration), but also a quantity of soil will have been transported from the field.
> If the coin cannot be found again this will convince you that erosion costs money!
> Remember that this thin layer of soil, which over the whole field is a considerable amount, disappears as a result of the combined action of splash and stream erosion.

Where water accumulates in furrows or on footpaths, fill a glass in the turbulent water. Keep it upright for a little while to give the soil particles that have become dissolved in it, time to sink. This again gives an idea how much soil is being transported with the water. After a while it will be time to get inside again and go over all the things that you have seen. The most important question is why these phenomena have these particular characteristics.

It is also important to know whether the rain storm that you have just experienced was an exceptionally heavy one. Or can heavier showers be expected which are even more disastrous for the soil, especially at a time that the field lies bare, awaiting the next downpour. It should be added that a heavy rainstorm is just as erosive as rain falling less heavily over a longer period.

## 3.5 The principles of measures against erosion

Knowing the erosion process and how it is related to the condition of the soil, the measures to be taken can be decided upon. To summarize, the principles of these measures are as follows:

- To reduce the force of the rain impact; that means protecting the soil against direct force of rain.

- To improve the stability (the resistance) of the soil to retain its structure in spite of the rain impact.
- To reduce the amount of water which causes run-off, this allows more water to infiltrate into the soil.
- To reduce the speed or to regulate the distribution of the flood water.

In chapter 5,6 and 7 measures against erosion are described. All these measures are based upon the above-mentioned principles.

**Benefit of crops**

The benefit of a crop on the field becomes clear too. In the first place the leaves reduce the force of the rain impact. Secondly the plants reduce the speed of the flowing water. At the same time, a crop increases the stability of the soil and the infiltration of water into it. Organic matter, formed from plant residues plays a leading role here.

**Benefit of organic matter**

- Organic matter plays an important role in the formation of soil aggregates (see figure 10) through which the soil can better withstand the force of the rain and there is less chance of crusting.
- Organic matter stimulates the biological activity in the soil, through which there is a better decomposition of organic material into humus.
- Humus (decomposed organic matter) makes the soil more porous allowing more water and air to infiltrate into the soil, encouraging plant growth. Because of increased infiltration more water becomes available to the plants and surface run off (and erosion) is reduced.
- Humus increases the capacity of the soil to retain the water that has infiltrated. So water will be available for the plants for a longer period.

# 4 How erosion effects agriculture

In Chapter 2 a few examples have been given as to how erosion can be observed in the field. Sooner or later, all the changes observed have consequences for agriculture. To mention one example: small rills, unlike gullies, can still be ploughed by the farmer. If the gully system is very close, then the land may become completely inaccessible (badlands).

By a few examples we will try to show how the farmer in his daily routine on the farm may be confronted with erosion.

## 4.1 Consequences for the soil

When thinking of the effect of erosion on the soil we often have ideas of spectacular gullies in our minds. However, there are less obvious, but just as serious, consequences for crops in the field. We will discuss the two most important of these:

**Limitation of the water retention capacity:**
Because the pores in the soil are disturbed, erosion reduces the infiltration and the water retention capacity of the soil. Less water can then be retained in the soil and after the rains stop there is less water available for the plants.

This results in a shortening of the growing season. Crops with a longer growing period suffer more readily from dry spells. Some drought resistant varieties may give lower yields, others are unable to survive. The farmer has fewer crops to choose from.

**Leaching of nutrients:**
In areas with much rainfall, a decline in moisture retention by the soil, may have other consequences too. Since the water cannot be retained in the soil, part of the water percolates to a deeper level or to the ground water. Through this process nutrients that are dissolved in the soil-moisture, will leach to a deeper level and are out of reach for the

plant roots. Obviously, this will be at the expense of the crop yields. Deep rooting plants are sometimes able to retrieve some of these nutrients. Especially trees fulfil this requirement and by doing so keep a lot of nutrients in circulation (see figure 12). Crop rotation too can prevent leaching of nutrients. First of all the various crops have different rooting depths and by that way leave organic residues of the roots, and secondly they utilize (partly) different or even add nutrients.

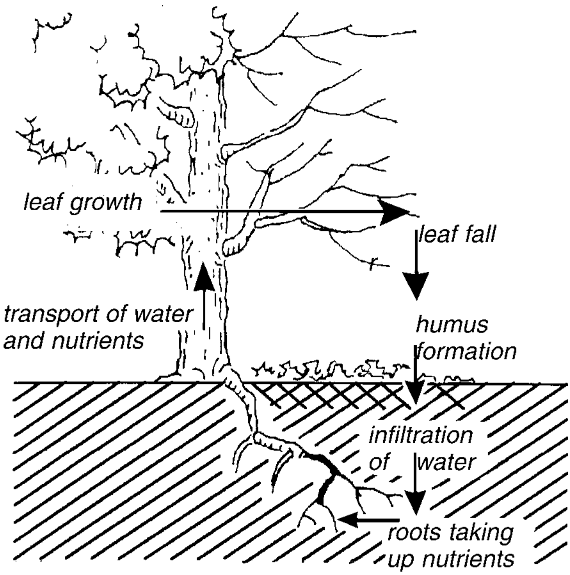


*Figure 12: Nutrient circulation*

## 4.2 Consequences for farm management

The most important effect of erosion on farm management is the decrease of crop yields. However, erosion also increases necessary daily work. These effects of course are not always the same everywhere; on the following pages we will give just a few examples:

### Labour

➢ In the first place the soil which is washed away may, for example, block up diversion drains, cover a crop or cover a path elsewhere.

Removing this soil from the drainage system or the paths adds to the workload of the farmer.

- The reverse applies of course to the field where the soil has been eroded away: exposed roots will have to be covered again; the unwelcome rills or gullies will have to be ploughed up or filled in; if plants have been completely washed away, sowing must be done again (the question then of course is whether the crop will still have enough time to produce a harvest).

- In areas where two successive crops can be grown, another problem arises. If the second crop is not planted in time it will fail. The farmer must then decide what should be given preference: Later sowing of the first (for example food) crop and not expect an income from the second crop in that year (for instance, cotton, with the threat of a broken contract if it is not delivered to the factory). If the farmer chooses to sow the cash crop at the expense of the food crop, then it remains to be seen how much money is left over for food. These factors involve extra costs in the form of seeds and the extra labour required. However, at the so-called labour peaks (usually soil tillage and harvest), there will be no time to organize extra labour and the farmer is obliged to sow up a smaller area for instance.

- When thin layers of soil are continually washed away from the field by erosion, the bigger particles remain and the field will eventually become stonier. Gradually, it becomes more difficult to plough the field and outside labour may have to be hired to get the field prepared in time. If more people are in the same position clearly the cost of labour will rise. In fact some farmers will be unable to afford it.

- Soils can only be well cultivated when at a certain moisture level; when dry they are too hard and if wet they can hardly be worked. Erosion causes soil degradation, dry soils are likely to be an effect of that and more frequently waterlogging is caused. In other words, cultivation becomes harder, the already limited time for tillage and sowing becomes even more scarce .... a smaller area is cultivated, or expensive labour is to be brought in.

It can be concluded that erosion causes the yields to decrease whereas the costs increase. A few possibilities remain for the farmer:

- Look for work elsewhere to supplement the income and the food supply. In practice, however, the effect is that the labour force on the land is lacking just at the essential times (labour peaks) so that food production is threatened.
- Move to the urban areas, where the farmer will have neither land nor job.
- Move to a neighbouring area, where one can start from scratch, until there is hardly any good soil left over.

**Diversification of activities**

If the soil quality is stable, there is a wider choice of crops. This will give a diversification of activities (different growing periods, sowing times etc.). A good example of this is the so-called 'peasant farming system' or home gardens where a wide range of fruits and vegetables are grown, usually by the women. Many hours are spent here between all the other activities and this at least should be sufficient to keep hunger from the door, should the main crop fail.

However, should the fire wood supply become scarce (an almost universal problem) and the women have to spend more time on collecting fuel, their own food supply will be in danger because less time can be spent on the home garden. An alternative to fire wood is to use cow dung. The effect of removing the cow dung on soil fertility is known, but there is barely a choice.

Shortage of fuel has resulted in dung becoming a much sought after commodity and has created a new task for the farmers' wife: to sell this popular product. So we can conclude that erosion has a negative effect on agricultural yields, expenditure, timing of operations, choice of crop, the position of the women with a general prospect of poverty and hunger.

# 5 Agronomic methods to control erosion

Agronomic methods include those erosion control measures that are related to arable farming. It is concerned with crop cultivation itself as well as tillage operations. Arable farming is an integral part of the natural surroundings. Woodland and grassland influence arable farming. Think of the cattle pastures where manure will again benefit the soil.

The felling of trees and the planting of trees also strongly influence the cropping system. All this is called a farming system. We will treat this in more detail in Chapter 6.

Agronomic measures play a key role in erosion control because in the first place they can be carried out relatively easily and cheaply. Moreover, often results are obtained quickly and if it is still found necessary to take technical measures, they contribute considerably to their success (see Chapter 7).

In this chapter we will give a survey of the most important agronomic measures. The principles of these measures are given in Chapter 3 and should be clear.

- Contour farming and strip cropping aim at preventing water to run off and at retaining the rain water.
- Minimum tillage, mulching and the use of a cover crops serve to protect the soil against the force of the rainfall, at the same time maintaining the soil fertility or increasing it.
- Manuring has the role of keeping the crop in good condition so that it can stand up to erosion better.
- Finally, mixed cropping aims at good crop growth with optimal use of available light, water and nutrients. This minimizes the chance of erosion.

Of each measure principles and execution are treated as well as drawbacks. Too detailed advice of course cannot be given for the execution; you will have to find out for yourself whether and how certain procedures can be carried out best in your local situation. Mixed cropping, for example will require a suitable combination of crops. Consultation with the local population and institutions is important here to benefit from the knowledge and experience of others. There will be a greater chance that the operations succeed too.

You can find more information about agronomic measures to control erosion and to improve infiltration of water and retention of water by the soil in two other publications in the Agrodok series: No. 2: *'Soil fertility management'*; and No 13: *'Water harvesting and soil moisture retention'*.

## 5.1 Contour farming

Contour farming is a collective name for contour ploughing and contour planting. This means that soil cultivation and planting are carried out along the contours.

**Purpose:**

- To prevent water from running off down-slope (see figure 13).
- To encourage infiltration of water into the soil.

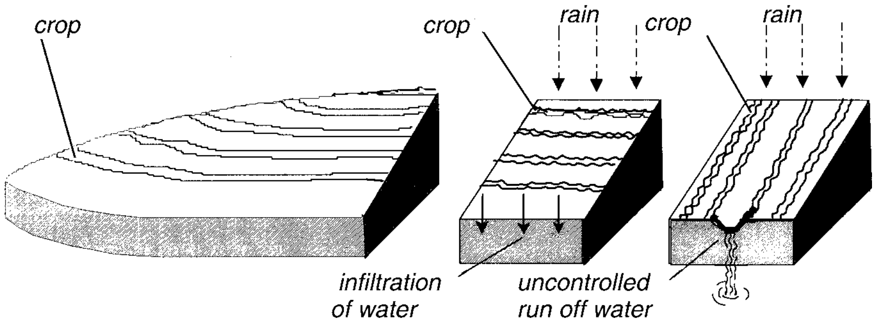


*Figure 13: Contour farming*

**Application:**
In general contour farming is practised if the slope is not steeper than about 10% but longer than 100m. On steeper slopes, combined methods are used. This is the easiest procedure (however remember the 10%). This method is sometimes combined with terracing and strip cropping which makes it more effective.

To show how the contours run, hedges can also be planted along the contours. If the farmer keeps ploughing parallel to the hedge, he will have the assurance that everything is following the contour line. This is difficult to see without a guideline. The hedge should not in any way be an obstacle; it is even possible to make good use of them as well (fodder crop, firewood, fruits, mulch) (see figure 14).

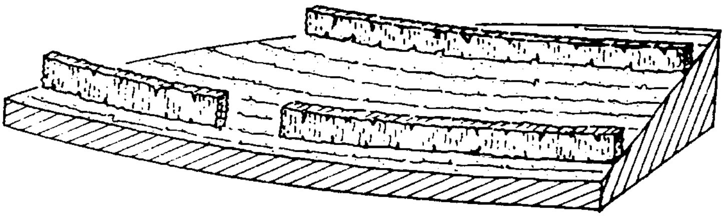

*Figure 14: Hedges along the contour*

For the purpose of erosion control only ridges and furrows should be as horizontal as possible. However, in practice this doesn't work out. There is a chance that the water collects at a somewhat lower point in a furrow behind a ridge and causes the ridge to break through, and with it the lower lying ridges; the results of all this being disastrous. So it is better to make a point of laying out ridges and furrows at a slight angle; about 1%, so that run-off water can be collected and safely removed via a discharge drain. The furrow should not be longer than 100m to avoid over flowing and also to reduce the stream velocity. Drainage channels can of course be used provided they are kept under plant cover.

Small dams (cross-ties) made of earth can be made at regular intervals in the furrows to check the water velocity; this is known as the 'tied ridging system' (see figure 15). If the rainfall is not so heavy it will be completely taken up in the soil. The method is effective in dry areas.

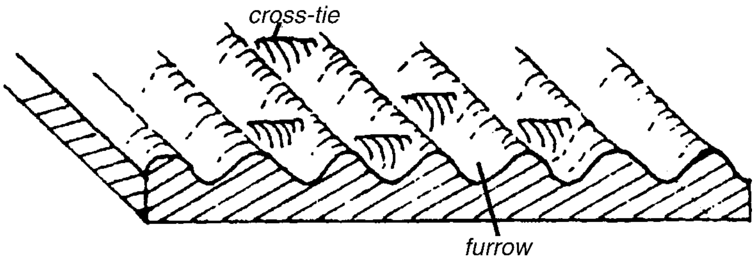


*Figure 15: Tied-ridging*

**Execution:**
First a number of contour lines have to be established for ploughing to be carried out. It is useful to set fixed orientation points for this so that the contours do not have to be set out again every year (see also appendix 1).

**Possible drawbacks:**

- If ridges and furrows are badly laid out, this may lead to more erosion. Water may collect at certain points and if the ridges break, there is a danger of gully erosion.
- Contour farming can also be risky if:
  1. The soil has a low infiltration velocity (see glossary). This is the case on very heavy soils or if there is a hard layer in the profile.
  2. The soil has a low infiltration capacity (Glossary). This is the case if the soil layer is shallow or has impermeable layers.
- Under these circumstances, a lot of water will collect, increasing the chance of breaking.
- On very irregular slopes it may be impractical to work along the contours. Strip cropping may be more effective here.
- Finally, for contour ploughing, a plough with a reversible blade is preferable.

## 5.2 Strip cropping and strip reclamation

Strip cropping is the cultivation of different types/sorts of crops planted in separate strips along the contour. Strips that do not stand up to erosion well are alternated with strips that can withstand erosion.

In strip reclamation the original vegetation is left to grow in places where there is a danger of erosion. Strips that are a poor protection against erosion are alternated with strips that are well protected by a crop (see figure 16).

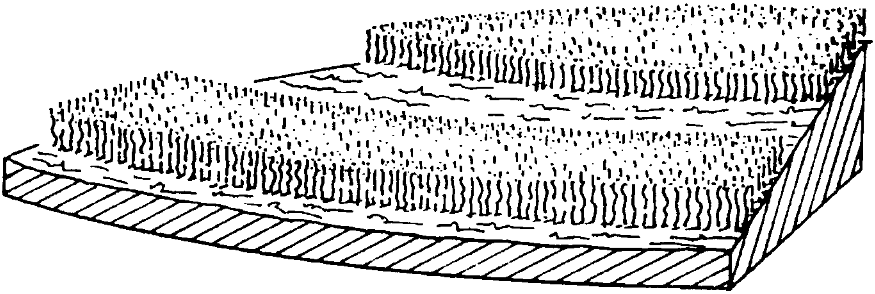

*Figure 16: Strip cropping*

**Purpose:**

- To hold back the run-off water with soil particles coming from the poorly protected strip, in the strip with the dense cover crop. Here water penetrates well and soil particles are held. In this way, the underlying strips are protected.
- In addition, the ‘soil protective’ strips can be used to provide cattle feed and/or mulch.

**Application:**

Strip planting is usually carried out on slopes that are not steep enough to warrant terracing, which are slopes of 15 to 20%. From a financial point of view and the technical know-how involved, strip planting is often preferred to terracing; the results of all this being disastrous.

So it is better to make a point of laying out ridges and furrows at a slight angle; about 1%, so that run-off water can be collected and safely removed via a lower lying ridges.

**Execution:**

- The strips with a poor cover crop are alternated with different strips that do protect the soil well.
- The best combination is to alternate strips of grass or grass mixtures with (about 25%) legumes. The strips are very suitable for providing fodder. Arable crops with a dense leaf cover can also be grown and permit very little erosion.
- In strip reclamation, only the 'cultivation strips' are reclaimed, and the natural vegetation strip holds back erosion.
- Tree crops, if pruned back to a hedge and which have an undercropping also provide a good buffer strip. The pruned material can be used as a mulch and sometimes as a cattle feed.

The width of the strip depends on the gradient of the slope and the infiltration capacity of the soil (Table 1). The principle is that the run-off water in the strips does not reach erosive velocity. The width of the grass/legume strips depends on the 'correction' that has to be made. The water in these strips has to be halted so that the underlying strips only have to cope with their 'own' water.

*Table 1: A guideline for the width of strips*

| Slope of | Width of |
|---|---|
| 0 - 2% | 40 - 50 m |
| 2 - 4% | 30 - 40 m |
| > 4% | 15 - 30 m |
| in very humid areas | 15 - 30 m |

This shows that the width of the strip also depends on the rainfall. It is useful for the farmers to decide together on the width or length of strips. When laying out strips, one tries to let the borders run along the contour line. Slopes are not always regular though, so a contour line may not be a suitable guideline for the strips to be laid out. The strips, in order to correct the slope, will not be the same width everywhere. This had disadvantages for arable farming in particular. Therefore arable farming strips are kept the same width and the irregularities in the slope are corrected in the buffer strips. This is less of a problem for non-mechanized cultivation unless contour farming is carried out on the arable strips. Strip cropping is most effective if combined with crop rotations. The value of rotations is discussed briefly in Chapter 6.

As an illustration, we will give an example of how strip cropping is carried out in Nigeria (Figure 17), with four crops each year.

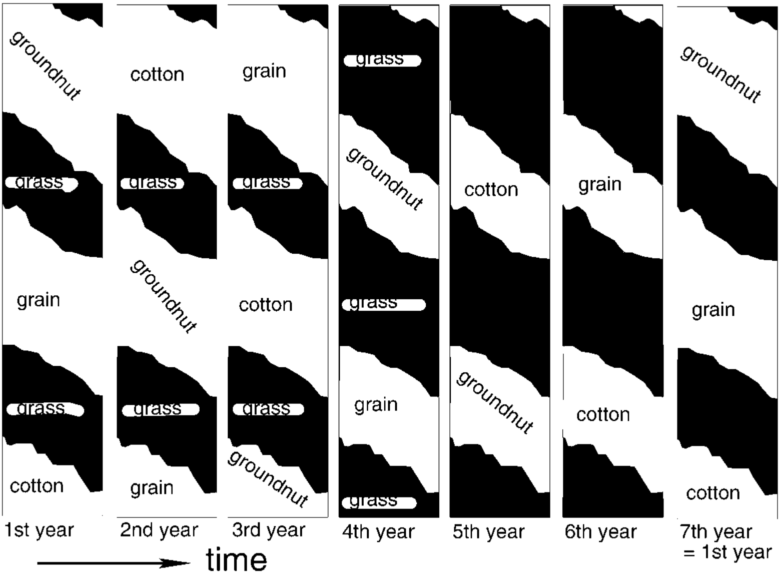


*Figure 17: Crop rotation in strip cropping*

The 'soil-protecting' ground-nut is followed by corn which can still benefit from the nitrogen fixed by the ground-nut. The poor soil-covering cotton follows the corn. Three years of cultivation are followed by three years fallow.

**Possible drawbacks:**

- An important disadvantage of strip cropping is that it takes up a considerable area of arable land, about one half. This is likely to be a problem if the farm area is small. However, this does not necessarily mean that yields will be halved. For instance, the strips could be used to produce mulch material, which will increase the yield in the crop strips. If the buffer strips are left fallow, this can be very beneficial too. The grass/legume strips can be put to good use if cattle are kept in the area, as extra feed in the dry season for example. If the strips are very narrow, then the fencing of the strips may be a problem. You might then consider harvesting the cattle feed yourself keeping the cattle in the stable.
- When weeding the buffer strips care should be taken that the grass if not trampled too much, otherwise these strips would have an adverse effect.

## 5.3 Limitation of tillage

Techniques known as reduced, minimum and zero tillage are considered here. In zero tillage, the land for crop cultivation is not ploughed at all, just holes for planting are made; in minimum and reduced tillage, only the places where the crop is going to be planted or sown are prepared, short before planting takes place. Existing vegetation and plant residues are largely spared.

**Purpose of limiting tillage:**

- To prevent loosening soil material that then might form a crust or be carried away by water.
- Left crop residues or vegetation prevent water from flowing easily over a smooth, erosion sensitive surface. On top of that organic matter is increased.
- There is a considerable saving of labour. Especially at high labour peaks, the time saved means an extension of the growing season. Planting can be done earlier though.

**Application:**

Reduced tillage is especially advisable on soils that easily form a crust on the newly worked soil. The soils should be well draining (i.e. not too clayey) have a crumbly consistency and a coarse surface.

Other soils may be difficult to work or there may be root systems difficult to break through. This technique is often combined with strip cropping and terracing.

**Execution:**

From the moment the soil is most sensitive to erosion (from tillage until a cover crop forms) it should be protected against splash erosion, by covering with plant residues. Only the vegetation around the plant hole is cleared (Figure 18).

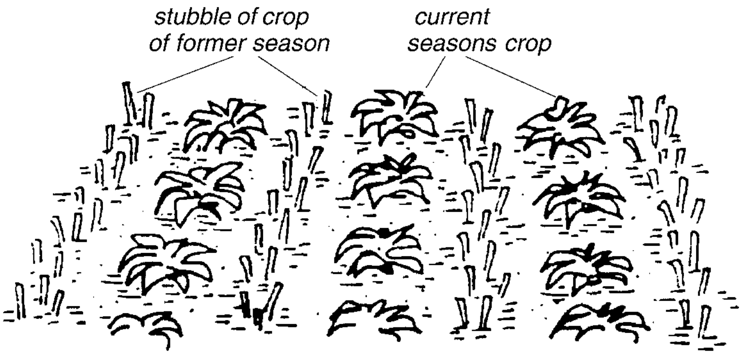


*Figure 18: Cropping between the stubble of the previous crop*

In 'strip tillage' only a narrow strip is worked for sowing the row crop. Useful soil covers are often used too. As long as they do not over grow the main crop, they are left to stand.

Minimum tillage is also often applied to relay cropping, whereby the new crop is already sown before the previous one is harvested. A good crop rotation can be applied in this way.

**Possible disadvantages:**

- The existing vegetation uses water which is then no longer available for the ‘useful’ crops. To prevent this, herbicides are sometimes used.

- Insects may thrive in the plant residues which sometimes necessitates the use of insecticides.

- Initially, an increased fertilizer application, particularly nitrogen, may be beneficial because the nitrogen from the decomposing organic material on the soil is not immediately available to the crop.

## 5.4 Mulching and stubble mulching

Mulching is the practice of spreading plant material or other organic material on the surface of the soil.

In stubble mulching the crop residues from the field itself are used and the root residues are left in the soil. In this case, tillage is restricted to loosening the top soil (not turned over) to facilitate infiltration.

**Purpose:**

- To protect the soil as long as there is no cover crop. Splash erosion and runoff are checked by the mulch layer because it prevents the soil from becoming washed away (Figure 7).
- To reduce evaporation by the mulch layer itself.
- To keep weed growth down.
- To improve the soil structure through an increase of the organic matter level after the mulch material has decomposed. This stimulates the soil fauna and allows for better penetration and storage of water (see figure 19).

**Application:**

Use mulch especially where good crop growth is important, such as in gardens or orchards. Since it is a costly item it is wise to use it for the most valuable crops.

A condition for mulching is that there is access to a plot of land that will provide the mulch material or that it can be obtained from elsewhere. Mulching is also carried out on steep slopes with erosion-prone soils, provided something can be done about the runoff so that everything is not washed away.

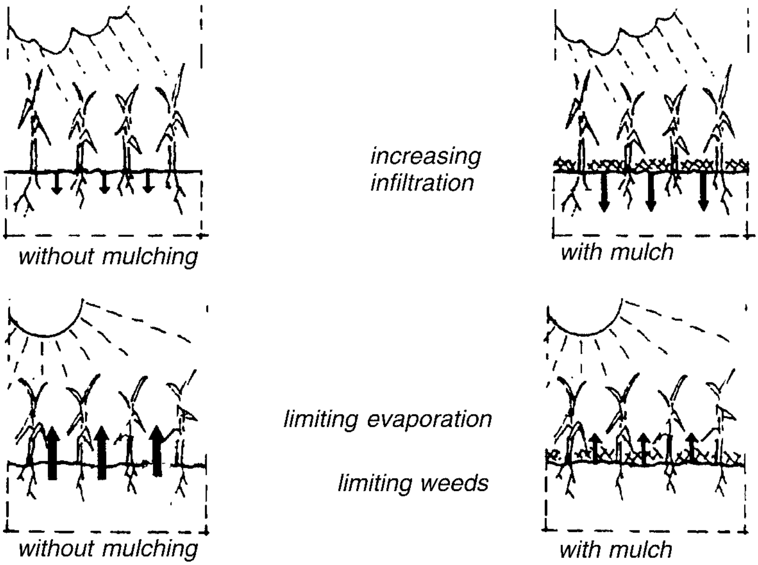


*Figure 19: Mulching*

**Execution:**

All available non-woody plant residues, such as grass, straw or refuse can be used as well as any material from natural or fallow vegetation.

Hedges are also included in the cultivation to provide mulch material. Branches cut to about 10 cm are brought on to the soil without working them under, to prevent runoff of water and soil. Runoff water from elsewhere should not be allowed to stream under the mulch layer, because this is only detected later. It may be necessary to hold down the mulch layer, from blowing away for instance, by covering it with a layer of soil.

During sowing or planting, the mulch is put to one side, but afterwards the planting hole is covered again.

**Possible drawbacks:**

- Sometimes the direct yields do not sufficiently compensate for the effort put in.
- Cutting, transporting and spreading the material is a lot of work whereas the high temperatures in the tropics often cause it to be broken down quickly. To ensure that the soil is protected for a longer time, it is advisable to use a mixture of quick and slow decomposing material as a mulch.
- In orchards the mulch should not rest against tree stems since it could be a carrier of disease.
- Sometimes, a mulch increases the fire danger of a field. It can then be lightly worked in. Fire pathways around the field are a solution too. Also, planting a closed hedge that remains permanently green and is barely inflammable reduces the fire hazard, too.
- Especially in well-populated areas it may be a disadvantage if large areas are needed to produce mulch. In this case marginal ground should be used as far as possible.
- The mulch layer should not be too thick because instead of cooling down it would then heat up, although this depends on the material used. Only 3 to 5 month old twigs of trees and shrubs should be used. Nitrogen fixing plants or cow dung could otherwise be used.
- Finally see that erosion does not occur in places from where the mulch has been removed.

To inspire the reader we will illustrate this practice of mulching by citing part of a letter from Brother Urbanus in North-East Brazil. He writes:

*"Our first step was to keep 'precious' moisture in the soil by covering it and protecting it from the scorching rays of the sun. But what could*

*be used to cover the soil? This was the problem. I was lucky: this month the council had started to tackle the problem of the water lilies which had over grown more than half of a large lake. Hundreds of lorry loads of water lilies were thrown away. I asked for a few lorry loads and got 121. This was a good start and we could get to work.*

*At the same time we got down to cleaning our pond where the water was too salty for irrigation purposes. This had never been done since the dam was laid out 22 years ago. In some places the layer of silt and mud was 1 to 1.5 m high. The salt concentration was found here, for every time the silt dried out it left a white sediment.*

*We also dug field drains on the contours of the land for the new and clean water later on. It will then penetrate via the drain into the ground (which is also still covered) and no evaporation of moisture can occur. The few rain showers that we had was a proof that the mulch layer of water lilies was excellent for holding water in the soil.*

*We intend to introduce water lilies into our pond because then it will be an extremely welcome supplier of organic material. The problem of someone else has proved to be a blessing for us.*

*Planting is continually going on because the soil is moist. A small hollow in the organic layer, - the soil turned over a little with a trowel - make a planting hole - beans sown and the hole filled up. That's all. Weeds don't grow because the more we leave the organic layer alone, the more the organic life will thrive. All that remains is sowing and harvesting. But the experiment is still in a very early stage."*

## 5.5 Cover crops

Cover crops are plants that are sown in order to protect the soil and/or increase the soil fertility. They are usually creeping legumes that cover the ground surface between a widely spaced perennial crop.

**Purpose:**

- To protect the soil against the force of the rainfall, and to retain the soil from being carried away by the rainwater.

- To protect the soil against too much heat from the sun and thus to prevent the humus to be broken down too quickly.
- To suppress weed growth.
- To increase organic matter in the soil and thus to improve the soil structure and soil fertility.

**Application:**
Cover crops are usually sown where crops themselves have a wide spacing and are poor ground covers (trees for instance).

Legumes used as a cover crop improve soil fertility even more because they can fix nitrogen from the air. Through decomposition of the plants this nitrogen becomes available for the main crop.

> **Green manuring**
> When the cover crop is worked into the soil in a green non-decomposed condition, this is known as green manuring. Green manuring increases organic matter in the soil and improves soil fertility, especially in the case of leguminous plants. In the Agrodok no 2: *'Soil fertility management'*, more information is given on this method to improve soil fertility.
> In the Philippines it appears that of all the practices, the use of cover crops is the most applied and successful. Particularly on poor soils the fertilizing effect of green manures with legumes is very important. Green manuring is often practised during the fallow period.

**Execution:**
Cover crops should be planted as soon as possible after tillage to be fully beneficial. This can be done at the same time as sowing the main crop, but also after harvesting it. In the last case the cover crops form a fallow vegetation which serve as green manuring for the new season.

In making a choice, the following points are important:
- If possible choose a useful crop such as groundnut, beans or a fodder crop.
- The crop should be a quick starter.
- It should really be a ground-covering crop that is low lying.

- It should compete with the main crop as little as possible. For deep rooting main crops, superficial rooting cover crops are used.
- The cover crop should not transmit disease to the main crop. The chance of this is very small if both crops belong to different families.

In appendix 3 a table is included giving the most common cover crops and their properties. In practice, it is good to mix different types.

**Possible drawbacks:**

- If the annual rainfall is low (less than 500 mm) the cover crop could take valuable water from the main crop whereby the costs will supersede the benefits derived. It would be cheaper then to let the weeds stand although they are sometimes inclined to over run the main crop and evaporate a lot of water. In cassava for example the weeds are left standing only after 4 - 6 months since before this time they are too competitive.
- Legumes often need to be fertilized with phosphorus.
- Legumes are rather sensitive to disease. Eelworms in particular are often a problem. The age-old practice of crop rotation is indispensable here.
- Sometimes it takes quite a long time, about a year, before sufficient nitrogen becomes available for the main crop.
- If legumes are being used for the first time at a field, the Rhizobium bacteria have to be brought into the field otherwise the fertilizer effect is not shown. It is often sufficient to bring soil from places where legumes are growing.

## 5.6 Fertilizing

Fertilizing is the application of organic or mineral fertilizers to the soil for the benefit of the plant.

**Purpose:**

- The improvement of the soil fertility to satisfy the nitrogen, phosphorus and calcium requirements of the plant. In this context, fertilizers have the same effect as mulching and green manuring.

**Improved fertility has the following effects:**

- Organic manure improves the structure of the soil (see Chapter 3).
- It accelerates and improves the crop coverage. The soil has better protection and again more organic material is formed.
- Yields are higher. This is very important in densely populated areas where the fallow periods are even shorter.

**Application:**

- Since tropical soils are generally deficient in nitrogen and phosphorus, manuring is usually beneficial. It provides an important complement to other practices by increasing or accelerating their effect. In other words, manuring alone hardly pays; it needs the support of other measures to be fully effective.

**Execution:**

- Where there is cattle, the manure should be returned to the soil where possible so that the nutrients, are not lost. In any case, you could try to herd the animals together in a corral at night.
- If available, artificial fertilizer can be used. General directions for fertilizer dosage cannot be given however. Each situation will be considered on its own merit as to which fertilizer is required and will pay. Artificial fertilizers do not improve the structure of the soil directly.

**Possible disadvantages:**

- In the past, net profits of artificial fertilizers have often been disappointing. Another drawback of its use is the dependence on outside help, bringing with it the uncertainty of supply.

## 5.7 Multiple cropping

Multiple cropping is the cultivation of different arable crops and/or other crops at the same time.

**Purpose:**

- Better protection of the soil by ensuring a more intensive and prolonged coverage. In this way the growing season is lengthened as it were and yields are higher. More organic material is formed which can benefit the soil structure.
- Reduce the risks by growing different crops taking into account the market as well as diseases and pests.
- Prevent nutrients being washed out by ensuring that the soil is covered as long as possible. In multiple cropping the various types will grow differently both under as well as above the ground. Water, nutrients and light are better utilized.
- The various types may even have a positive influence on each other.

**Application:**

- Multiple cropping is a traditional method of cultivation, which unfortunately has had to make way for monoculture. Especially in densely populated areas this cultivation method offers perspective by making a more intensive use of the land. The advantage of this method is of widespread importance, especially if cultivation is not yet mechanized.

**Execution:**

Well-known systems of multiple cropping are:

- **Mixed cropping**: The different crops are sown at random for the various bean varieties for example.
- **Inter cropping**: The different crops are grown in rows next to each other. Cassava is grown for instance between or under banana or coconut.

- **Relay cropping**: The second crop is already sown before the first is harvested. In India, sorghum and pigeon pea (Cajanus cajan) are often grown at the same time; after the sorghum is harvested the bean starts to branch and flower.

Maybe other examples can be given from your own surroundings. Field crops can be thus combined with spacious taller or shorter crops. In the first place the arable crop itself should be shade tolerant and it can be combined with tree crops for example. Tubers such as Colocasia and Xanthosoma, both with a low light requirement, are often grown under banana. In South or Mid America, coffee is often grown under Erythrina which is regularly pruned to provide cattle feed, firewood and nitrogen-rich mulch material. This is a form of agroforestry.

**Possible disadvantages:**

- If tillage is necessary for a second crop, this cannot be planted before the first crop has been harvested.
- The different crops may be strong competitors for light or moisture.
- Watch out for soil exhaustion, which could lead to soil degradation.

# 6 Using cropping systems to control erosion

## 6.1 Rotation and fallow

Many tropical farming systems have originated from shifting cultivation; a system of food production based on a rotation of cultivation followed by a long fallow period. The fallow period ensures a natural recovery of soil fertility. After a recovery period of 15 - 20 years the vegetation is again cut back and burned and the land can again be used for farming.

This farming system is still very common (it accounts for 8% of the world's food supply), but unfortunately a high population pressure in many places undermines the system. The land is then used too intensively and the fallow period is shortened. Too few nutrients are built up so that the soil fertility declines.

The reasons for this system being more susceptible to erosion are:

- In the cropping period and to a larger extent after a year, erosion is much greater than in the fallow period because the soil is less covered. The longer the cropping period the more the erosion.
- If the cropping period is longer, more crops are taken from the field and thus more nutrients are removed from the soil.
- This results in a decline in the organic material production, the structure of the soil deteriorates and with it the stability too.
- The condition of the crop and the cover crop also declines with an increasing chance of diseases and pests.
- In time erosion itself again results in lower yields.

This illustrates that a sufficiently long fallow period in the cropping system is very important for the soil. If the fallow period has to be shortened out of necessity, precautions should be taken in the cropping as well as in the fallow period, to minimize the risks.

The most important measure to keep the production up to level is to fertilize with organic manure or artificial fertilizers. Extra precautions will have to be taken to avoid the chance of diseases and pests.

The cropping techniques discussed in Chapter 5 are especially directed toward improving the soil stability, to limit water runoff and to conserve water.

In the fallow period improvements can be introduced by:

- taking care that the soil is covered again as soon as possible. The sowing of certain grass varieties will help here.
- taking care that the nutrients come into circulation again, and enrich the soil itself by using nitrogen fixing crops.

This is really a transitional stage between the fallow period and a rotation: variation in the times of different types of crop in the same field. It is good to alternate arable crops with turf forming crops (botanical caespitose) such as grass. It is therefore wise to include pasture in a rotation with arable cropping so that erosion is considerably reduced. In the crop rotation grass (preferably a grass-legume mixture 50/50) should be included every two years or more, depending on the local circumstances.

If the pasture is then converted to arable land, the arable crops benefit considerably from the improved structure and there is very little erosion. However in the second year after the transition, the 'after effect' has already considerably declined, so that the chance of erosion is greater again. Otherwise the 'after effect' seems to depend on the duration of the grass period. The area under grass is very slightly sensitive to erosion so that steep slopes for instance can better be permanently kept under grass (or woodland).

Other effects of the rotations are the limitation of pests and diseases and the check on weed growth. Rotation between different arable crops is important here too.

## 6.2 Grassland and fires

It is well known that gully erosion often originates at cattle tracks, especially around the water sources and villages. Cattle often have to walk kilometres every day to drinking places and in doing so they trample down the soil.

During rain showers water collects in the trampled tracks (the rain does not necessarily affect the structure; the hooves of the cattle have already done this) and slight gullies are formed from the rills. Through erosion the water will in the future stream off more quickly, the area dries out more and more, the water source gives less water or may even dry up completely. The cattle then have to go longer distances every day in search of water, costing them extra energy and a need for more food. Clearly this soon becomes a vicious circle.

Erosion increases through overgrazing, without an increase in cattle numbers. To prevent this, water should be available on the premises itself. For a farmer alone this is obviously not a working proposition. However, he may be able to prevent overgrazing. This can partially be realized by seeing that there are not more cattle than the pasture can support. This again is not without its problems because herdsmen are not always their own boss; the cattle may belong to someone from the town, the offspring having been promised to a family member etc.

Another way to reduce the pressure on pasture land is to improve it. For example, the food value of the pasture crop can be increased by sowing nitrogen-fixing crops (for instance clover) between the grasses. Fertilizers will of course improve the condition of the plants, too, though they are often more scarce than rainfall. There is an overall shortage of nitrogen and often phosphorus is in short supply too.

Overgrazed areas should be given the chance to recover by not using them for 3-10 years. Fencing will then be essential. For this, the so-called ‘living hedges’ can be used, that is of a type which should provide mulch, cattle feed or fuel. Then a grass rotation system could be applied.

Dried out pasture is often burned so that fresh new grass comes up again. Burning is an integral part of cattle farming in the tropics and improvements in the technique must be found. The timing and the method of burning seem to determine whether it is damaging or not. On erosion sensitive land it can best be done just before the rainy season, because the soil then lies bare for just a short while. The crop will come up again quickly in the rainy season.

A very important disadvantage of late burning is that the fire may get out of hand, because the vegetation is very dry. The strong fire causes a decline in soil fertility, organic matter is burnt and the nitrogen and sulphur released goes up with the smoke. Burning slightly at the beginning of the dry season has the advantage that there is less chance of spontaneous fires occurring later in the dry season when they are not so easy to control.

It may be better to strike a balance between early and late burning depending on the local circumstances. Regular and strong fires should certainly be avoided because as a result of the considerable drying out, hard layers form in the profile, the so-called hard pans which are clearly very damaging.

Unfortunately you are also dependant on what other farmers do and it would not be very effective to decide not to burn any more yourself. However if you do decide not to, it is sensible anyway to protect your land from the fires of others by laying out fire paths around your land. To give an example, a farm in Ghana was the only one in the wide surroundings not burnt by fire, thanks to a fire pathway. From this pathway, firewood, mulch material and cattle feed was collected so that there was no question of waste of land.

Finally it should be noted, that pastures are still communal ground in many areas and it is not customary to make seed, fertilizer or labour investment here.

## 6.3 Trees and woodland against erosion

Deforestation, often the result of increased population pressure or commercial woodcutting, is the cause of erosion in many areas. Deforestation exposes the deforested area as well as the low-lying parts of the flood area to erosion: large floods in Bangladesh in 1974 led to a great food disaster, the floods were partly the result of deforestation in India and Nepal. The drying out of water sources and the silting up of dams often go hand in hand with deforestation.

The effect of woodland on erosion is twofold:

- **Protection:**

In the first place woodland is protective against the force of rainfall. The leaf cover of the trees plays a much less important role here than the layer of fallen leaves from trees, shrubs and weeds. Large droplets can form on the leaves of trees which when falling from a height of 6 metres or more have more energy than the small drops which fall directly from the sky. However, a ground cover of litter or weeds intercepts this force. So this layer should not be removed to be used as fuel or as fertilizer. (This is more applicable to solitary trees).

- **Improved water conservation:**

The second important property of woodland is that it can quickly take up a lot of water. The woodland soil is compact with deep penetrating roots. This opens up numerous pores in the soil so that there is plenty of space for rainwater whereas there will be little run off water from the surface. The soil can be compared to a sponge: quickly a lot of water is absorbed and then slowly released. Low lying areas of a flood area can benefit from this action, less water flows through at the same time so that less soil will be eroded away there too. The water may be released so slowly that in the dry season the lower lying areas still benefit from it.

For these reasons reafforestation is often advised for an erosion control programme. The key question is then of course in how far this is feasible and justified. There is usually a good reason why woodlands have disappeared from certain areas.

- Is it because cattle have to graze there?
- Has the woodland been felled for fire wood?
- Does the land have to be used for arable farming?

When considering the reason for deforestation you can decide in how far reafforestation is the most acceptable form of erosion control. Poor soils and steep slopes should certainly be kept or brought under woodland since these soils are unsuitable for arable cultivation or cattle farming anyway. For reafforestation fast growing species that form a vigorous root system should be chosen. The so-called pioneer trees are suitable here, trees which naturally grow on poor land and which are adapted to the poor conditions. These are usually available locally so that simple material can be obtained. The species used should not be too susceptible to drought because the young seedlings may dry out on account of their undeveloped root system.

(See appendix 2 for a list of tree species that can be used for erosion control).

In most cases it is not possible to bring back an area completely under forest. The possibilities should be investigated for making as much use as possible of trees in the cropping system. In any case the species chosen should be adapted to the local needs.

- If cattle feed is required, the trees should be grown which provide appetizing material for the animals. In areas with a dry period, trees make an important contribution to survive this drought. Leguminous plants which form protein in their leaves, are often used as energy food for cattle. The local people can be asked what the preference of the animal is.

- To provide mulch material, hedges with some leguminous plants are grown around the field, following the contour. These hedges provide mulch material, firewood and food for cattle.

- As a fuel, almost any tree is suitable. Firewood is important because it prevents plant residues or dung being used as fuel, since they can be used on the field to keep soil fertility in equilibrium. Having firewood at hand saves the farmer a lot of time too (see Chapter 9).

- Finally, the fruits of some species provide a welcome addition to the daily menu and fruit trees are in popular demand by the farmers.

Nevertheless, trees are often considered a nuisance and planting often fails. There are a number of reasons for this:

In the first place trees may compete with arable crops: Trees take up nutrients and water from fields and pastures so depriving other plants. However, deep rooting species often have a pumping effect by drawing up leached and new minerals to the surface and via the fallen leaves put them back into the soil again for the benefit of the crop. Trees that fix nitrogen (such as Acacia and Prosopis) themselves have a fertilizing effect. Light intervention may be a problem too, however slight. On poor soils interception appears to be more favourable than detrimental.

However, it is better not to plant trees which bear leaves in arable fields in the growing season, but instead plant them along the boundaries, for example on the higher level of a field to collect the water run off from the slope.

Another reason is that young plants often dry out because planting was done too late in the season or the water supply was neglected. It is important to propagate the trees on the spot to establish the water supply and involve the local people in the nursery and its maintenance. It takes some time before there are results.

An agroforestry investigation in Kenya showed that trees were not planted because it was thought that they grew on their own accord without having to do anything about it. However, productive trees such as fruit (guava, citrus or mango) or timber trees (Eucalyptus or Pinus) are commonly planted and looked after. As well as making the importance of trees known, using fast growing species is a remedy to this problem.

In conclusion, we suggest: plant trees wherever possible (so called environmental farming) alongside rivers, roads, around houses and villages. This will often have to be done communally by the local people.

Also, planting should be carried out in places that are unsuitable for agricultural purposes to build up the topsoil and provide fuel or timber.

# 7 Measures to reduce runoff

Often technical measures against erosion are not very beneficial in themselves. They should go hand in hand with cultivation methods and good guidance. An important question is whether the farmer himself can pay for the operations and/or execute them.

The purpose of technical measures is to prevent water causing damage. This can be done by making better use of the available water for the crop (water conservation) and/or by controlling the runoff water. These subjects are covered in this chapter.

Another way is to develop a drainage system through which the runoff-water is collected and diverged before it reaches the agricultural land. Damage done by the uncontrolled runoff is then avoided. Drainage systems are explained in chapter 8.

## 7.1 Different levels of measures

The catchment area is the area from which the runoff contributes to the discharge at a certain point in a stream or river. The borders of this area are determined by the so-called watersheds, the tops of the surrouding hills. This means the farther downstream, the larger the catchment-area and the larger the flow in the stream. Further, the scale determines clearly the extend of the measures to be taken. This seems obvious, however, it determines a principle aspect of the problem. The number of people involved and therefore the level of cooperation.

The people in the flood-prone areas will have most problems, whilst the basic measures for prevention have to be taken mostly farther up in the hills. So, not only can we distinguish here between different methods, but it is also important to consider the level and the scale on which the measures are taken. This can be at:

- farm level,
- slope level or
- watershed level (see figure 20).

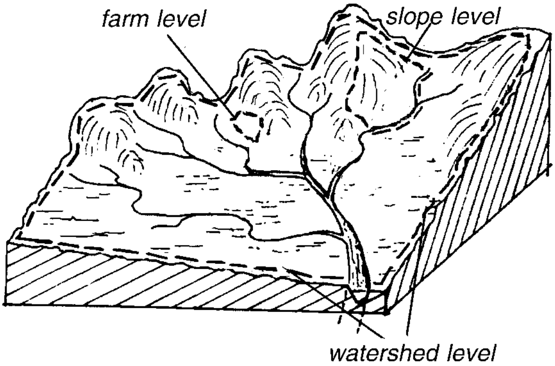


*Figure 20: Catchment areas*

All measures will need regular maintenance in order to be effective in the long run.

### Farm level

At farm level the starting point is that the land is used according to its potential. This is not always the case because of all sorts of other (socio-economic) factors (see Chapter 8). Technical measures at farm level can be carried out by the farmer himself, perhaps with some assistance from colleagues. Contour farming is simple but effective to apply (see Chapter 5).

To determine the contour lines, see appendix 1 in which some surveying techniques are briefly described. Further information can be found in Agrodok 6: *'Simple Construction Surveying, for Agricultural Practices'*.

### Slope level

At slope level as well as at farm level, work is carried out as far as possible from top to bottom (starting lower down involves the danger that operations carried out are destroyed by flood water and mud streams from higher up). The slopes should be well drained, for which diversion ditches are needed.

Gully formation will have to be kept in check too, if necessary (see also 7.5). Serious gullies and ravines are often found in areas with deep soil profiles and steep slopes. The type of precaution taken to check such gullies depends on their size, the extent of the drainage system and catchment area and the anticipated peak runoff (see glossary). Smaller gullies can usually be kept in check by the farmer himself.

At slope level, the size of the operations generally determines whether a farmer can take action single-handed or together with a few colleagues. However, depending on the nature and magnitude of erosion, a bigger organization will have to be brought in. Apart from the government this could be a cooperative, a communal or village society. A central government usually only becomes involved if greater interests are at stake, for example the silting up of a dam.

Apart from the organization of the recurrent maintenance work, another problem can be the costs and the labour involved. Not only those who benefit directly from the measures should be responsible.

**Watershed level**

A watershed level in principle includes both sides of the river and then erosion control is often part of a (civil engineering) development plan. Operations carried out at this level include reafforestation, improvement of rivers to prevent flooding in the lower reaches, and also terracing on a large scale (see 7.3). Such a development plan will usually cost a lot of time and money. Large-scale projects will then have to be carried out by the government. A well set up water conservation engineering plan for a larger area will make further small scale measures more effective.

However, depending on the point in the river from where one counts, a watershed area may be much smaller. So if the problems related to erosion (flooding, silting up of canals) occurs in a small tributary, the catchment area will be relatively small as well: perhaps as small as just the property of a single farmer. In this case the farmer will be able to, and has to, manage things by himself, for instance by terracing and lining of susceptible points in the embankment of the river.

## 7.2 Barriers to reduce the speed of running water

Contour farming has already been mentioned (in Chapter 5) as a measure against erosion. But if the land is very split-up and a continuous strip cannot be worked along the contour, then barriers can be laid out along the contour to reduce the speed of the run off. These barriers can be made of living vegetation or stones. Some farmers use plant residues such as maize stalks etc.

These barriers reduce the speed of the runoff and prevent the soil to be carried away by runoff-water. The soil carried along, piles up before the barrier (Figure 21). Gradually terraces are built up which keep erosion under control. As the slope decreases (division into terraces) the velocity of the running water is reduced and the chance of erosion is less. These measures are only suitable on gentle slopes.

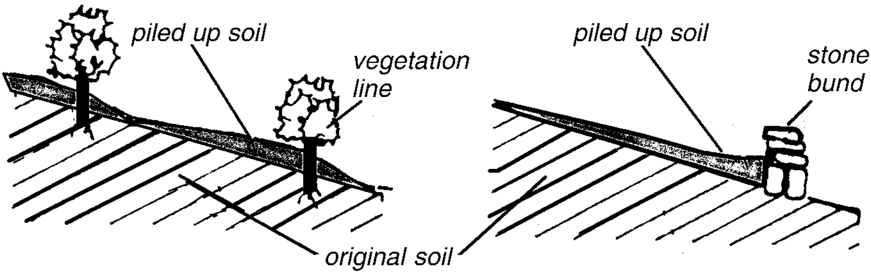


*Figure 21: Terrace formation by vegetation line or stone bund*

On the terraces the superficial runoff water is controlled and collected. The water can infiltrate into the soil (water conservation). See also Agrodok no 13: *Waterharvesting and soil moisture retention*.

Banks or walls can be strengthened by stakes, fastened together by liana or rope for example (Figure 22). Damage of the stakes by termites may be a problem here.

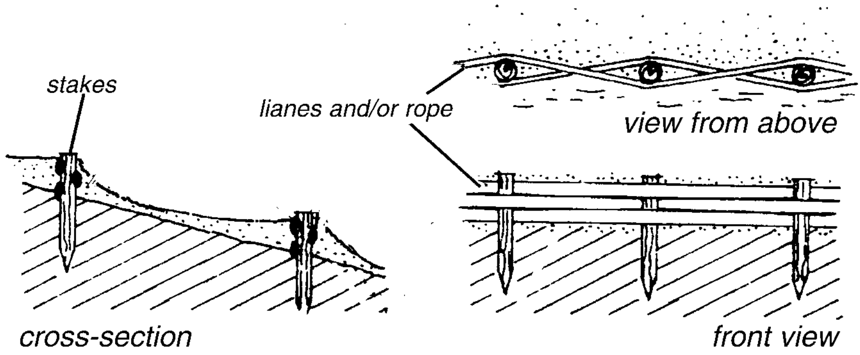


*Figure 22: Strengthening of a bank*

**Planning of the work**
Make sure that you choose the right measure to control erosion. Try on a smaller area before you apply the measure for a large area, or look for experiences of other people.

In order to make a good plan of operations it is important that good preparations have been made. Materials should be ready and enough labour available. Make sure you choose the right season.

## 7.3 Terraces

Terracing is a very effective measure against erosion. Terraces are more or less horizontal beds on the slope, laid out along the contour (Figure 23). The purpose of terracing is to prevent water flowing too quickly over a sloping field, and thus minimize the risk of erosion. This can be done by collecting the superficial runoff water on the slope and then let it infiltrate into the soil. Through terracing on steeper slopes the area for cultivation can be increased or improved.

There are a variety of terraces, depending on the way they are built or on their function. The different types will be explained. Earthen terraces are most frequently used. This type and other types of terraces are explained below.

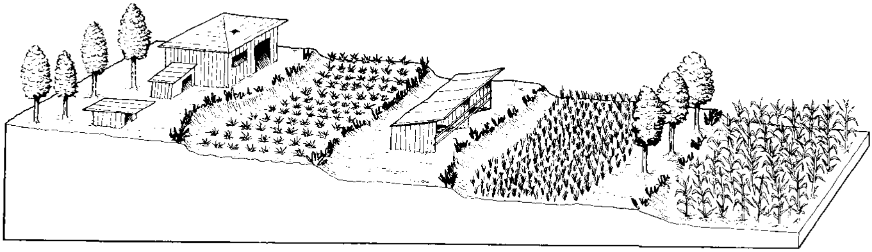

*Figure 23: Terraces (source: FAO)*

**Earthen terrace**

One possibility is an earthen terrace. The farmer can lay this out him or herself, perhaps with some help from neighbours, using a plough, hoe or spade. This is precision work however, which requires experience and knowledge. Earthen terraces are the simplest kind of terrace and are the most common in hilly regions.

Earthen terraces seem simple to make by oneself, but we advice to ask help from an expert because if terraces are not made properly, they might collapse in a hard rainstorm. The damage then will be worse than normal erosion and hardly to recover. A schematic diagram of such a terrace is figure 24.

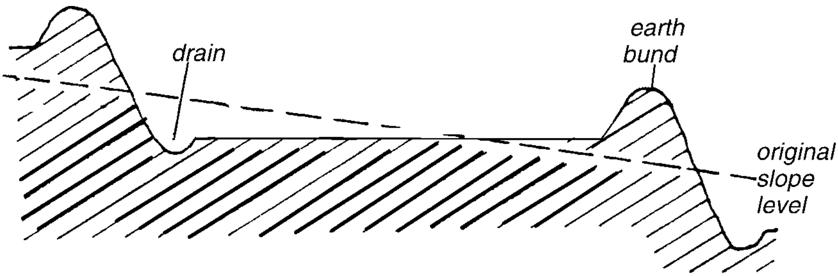


*Figure 24: Terrace with up-slope drain*

Along the terrace a channel for drainage is laid out, in order to discharge quickly of too much water in a heavy rainstorm. In dry areas the terrace drain is often laid out down-slope (as in figure 25) because there is not such a danger of silting up here as in wetter areas. In wetter areas the drainage channel is laid out up-slope, as in figure 24. This will reduce the risk of serious damage to the fields by a breakage in the earthen bund during a heavy run-off.

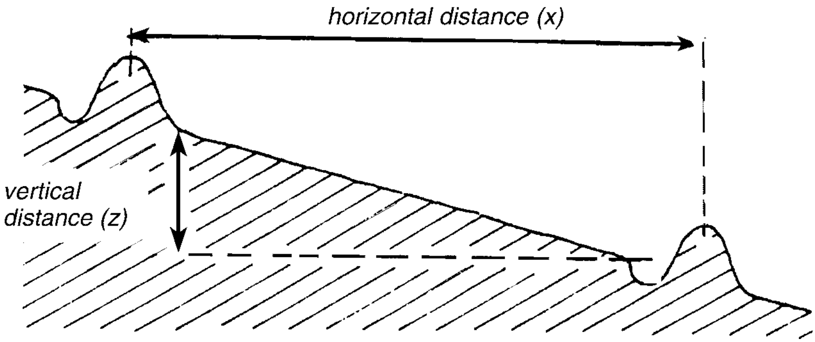


*Figure 25: Outline of an earthen terrace*

**Width of the terrace**

The width of the terrace depends on the steepness of the slope. Table 2 gives the measurements of the width of a terrace according to the slope percentage. Local conditions such as soil type and rain intensity, of course influence these measurements.

*Table 2: Width of a terrace according to the slope percentage*

| Slope (z/x * 100%) | Terrace distance (x) |
|---|---|
| 1% | 40 - 60 m |
| 2% | 20 - 40 m |
| 6% | 15 - 30 m |
| 10% | 10 - 20 m |
| 40% | 5 - 10 m |

If the slope percentage (see glossary) is 40% or more the terrace will be very small. Much labour is required for laying out, which is expensive. If such a slope does not have to be used for cultivation of crops, a permanent vegetation might be considered such as woodland, fruit trees, tuft-forming plants or suchlike (see Chapter 6).

### Length of the terrace

The length of the terrace (that is, parallel to the contour) will of course vary according to the local situation, obstacles, land ownership etc.

The terrace drain should not be too long because of the danger of scouring out. A solution to this is to incorporate cross ties in these drains at regular intervals. If runoff is not too much the velocity of the water is reduced and the water can infiltrate (Figure 26). You will of course have to calculate or experience whether the drain capacity is adequate to take all the water.

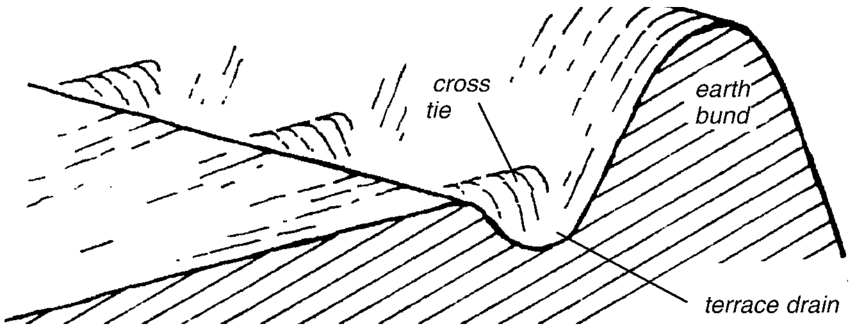


*Figure 26: Terrace drain with cross-ties*

### Absorption terraces

Apart from preventing erosion, absorption terraces have an extra important function: water conservation. These terraces collect runoff water after a rainstorm, store it up temporarily and then let it infiltrate into the soil.

This type of terrace is especially beneficial in fairly dry areas where there is often a water shortage. As much water as possible can then be collected in the sporadic and sometimes very heavy showers that do occur.

The soil surface should be fairly rough here so that the greatest possible infiltration surface is obtained (see figure 11). For less penetrable soils (such as heavy clay for example) and at very high peak runoff these terraces are less suitable.

In contrast to normal terraces, absorption terraces are horizontal or slope slightly backwards. Absorption terraces can best be laid out in one operation (see figure 27).

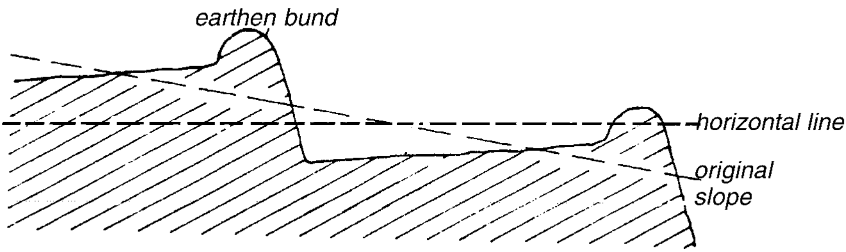


*Figure 27: Absorption terrace*

**Drainage terraces**
The purpose of a drainage terrace is to safely transport the runoff water from a field situated on a slope. Drainage terraces have a slight slope parallel to the contour line (see glossary: longitudinal slope). See figure 28.

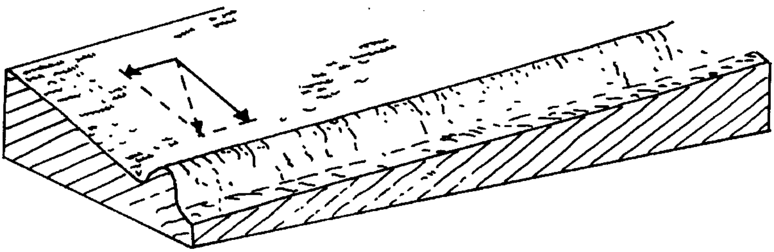

*Figure 28: Drainage terrace*

Depending on the expected peak runoff, type of soil and length of the terrace (catchment area) the slope perpendicular to the contour line is between 0.2% and 1%. The water will run down side ways. At regular distances drains carry away the runoff water preventing too much water concentrating in the terraces which could cause bursting or flooding. These secondary drainage canals diverge into a main drainage system or a gully. See the next paragraph about drainage systems.

## 7.4 Drainage

An essential preventive measure against erosion is the design, development and maintenance of a good drainage system for the catchment area. The excess water has to be spilled in a controlled way. As explained in section 7.1, drainage also has to be implemented at different levels, from catchment level to terrace level.

The principle of a good drainage system is that the large quantity of water suddenly released by a rainstorm, is discharged quickly and safely. This means that the ditches and overflows should have a capacity for heavy rainstorms, which do occur only once in about 20 years. A drainage system consists of several types of drains with different functions (See figure 29):

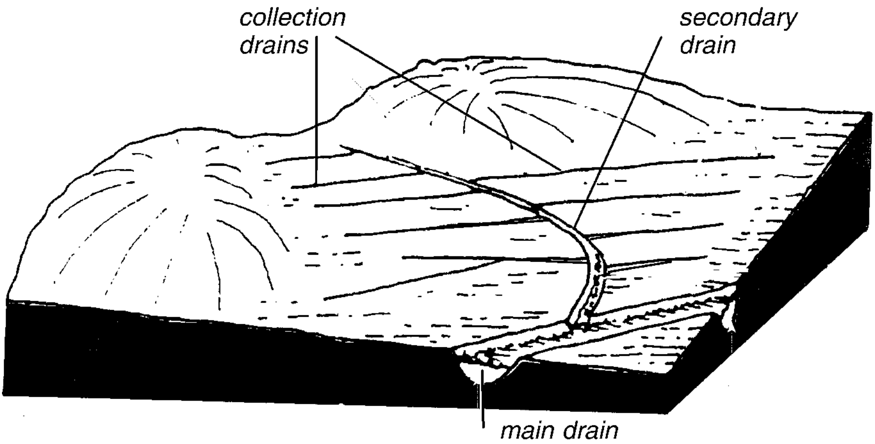


*Figure 29: Drainage system*

When designing and making a drainage system the rule is to work from bottom to top, that is: start with the main drain at the bottom so that the amount of water flowing into the drainage system at a given time can be led away in a controlled way. If you start at the top a gush of water may suddenly come down (in the up-stream area water flows away quickly) whereas the lower area of the drainage system is unable to cope with it. Because of the large quantity of water accumulating here, the catastrophe (gully formation, flooding) is soon complete.

### Main drain

The main drainage serves as the main channel where all the water is collected.

- One main drain at the bottom of the catchment area: all the collected water ends up in the main drain which then leads it to a river or so.
- Several secondary drains, which serve to collect the water from a larger area within the catchment area.
- Collecting drains, which can be drains from drainage terraces (see 7.3) or diversion ditches.

The size and shape of the main drain should be adequate to accommodate a large quantity of water flowing through in a short period of time. For main drainage, large natural drains, canals or stabilized gullies are used.

### Secondary drain

The secondary drainage consists of fairly wide discharge drains to carry away surface water to the main drainage. These drains are often artificially laid out and planted up with grass for example (they are referred to as grassed water ways). The grass protects them against damage from scouring water. These drains only carry water during peak runoff, otherwise they are usually dry.

### Collecting drain

The collecting drains of a terrace (especially the collecting drains) discharge their surplus water into the secondary waterways. Water from an established drainage system will flow in here too.

### Diversion ditch

A diversion ditch is a ditch on the upper side of good agricultural land that lies at the foot of steeper slopes. The runoff from up hill is collected in the ditch and regulated toward a gully. The soil excavated from the ditch forms a ridge down slope. Preferably this ridge is planted with grass or other vegetation to secure it (Figure 30).

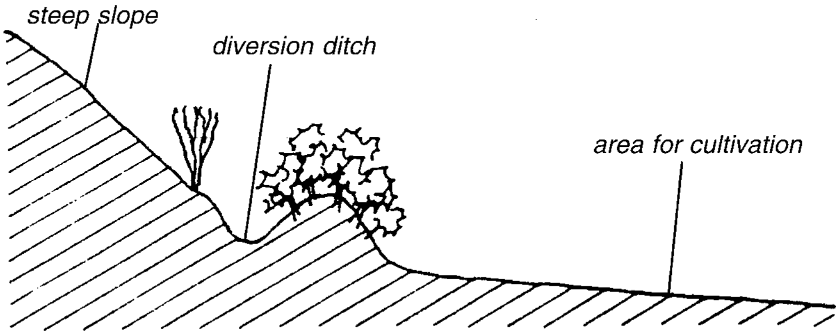


*Figure 30: Diversion ditch*

A diversion ditch is often a good starting point for controlling erosion.

The collecting drain should not slope too much lengthwise (to 1%) otherwise these drains are themselves damaged by the high flow velocity. Regular maintenance is also very important to prevent the drains from silting up. If a drain gets blocked you can imagine the problems that follow. These problems can best be prevented by ensuring that no soil material or dirt gets into the diversion ditch.

## 7.5 Gully control

Gully formation may be severe in areas with deep soils and steep slopes. On steep slopes the velocity of the water is very high and the scouring effect will be great. A deep soil profile with only little cohesion is susceptible to rapid and deep gully formation during heavy rainfall.

The purpose of gully control is not so much erosion control as an attempt to limit the effects of erosion that is taking place up-stream from the gully. Of course, existing gullies should be prevented from developing further. What measures are taken to prevent or control the process of gully formation depends on the size of the gully and the area to be drained (the amount of water to be diverged).

First of all we try to check the amount of water coming into the gully by protecting the soil upstream or even by diverging the water. The velocity of the water in the gully also has to be checked so that it doesn't scour out further.

The farmer himself can keep smaller gullies in check as follows: as far as possible the water is kept in the middle of the gully so that the walls cannot be undermined. In shallow gullies small dams with an overflow can be laid out with rubble, twigs, stones and wire bolsters. The water can then ooze through these fairly open constructions whereas any transported silt is held back upstream. In this way the longitudinal slope is reduced and with it the flow velocity too.

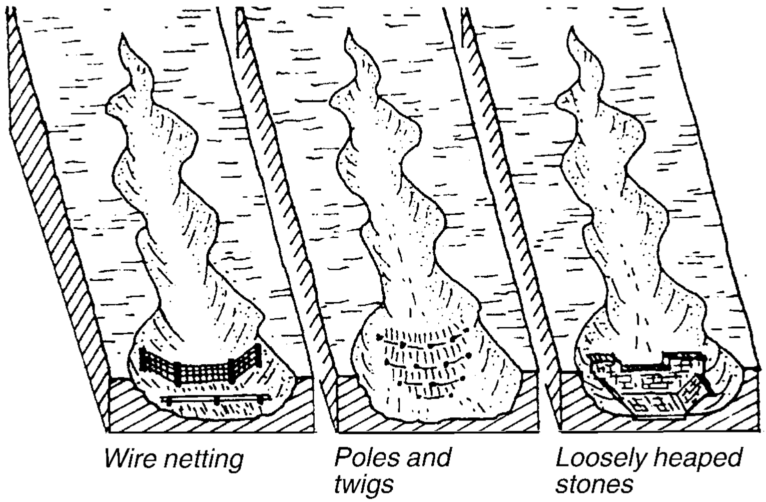


*Figure 31: Controlling smaller gullies: view from above*

If available, wire netting supported by wooden posts, can be used for smaller gullies (Figure 31). For larger gullies small stone dams can be used. (Figure 32).

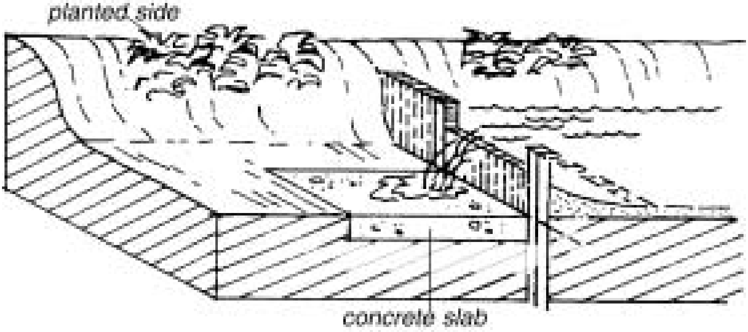


*Figure 32: Strengthening of a gully*

**Checkpoints for making dams**

When laying out these check dams, the following points should be taken into account:

- The principle is to shorten the length of the slope in the gully over which the water flows, so that the flow velocity (and with it the chance of further erosion) decreases.
- The gully walls at the position of the dam and also a part upstream are graded to a slope of 1:2 (going up 1 meter over a distance of 2 meters) or less, so that the chance of breaking is minimized.
- There should be good contact between the dam and the gully wall (well anchored); otherwise the temporary structure will wash away. Fencing poles are always driven deep into the soil so this applies to these structures too.
- The dam should be lowest in the middle where the flow has to concentrate at the overflow.
- The gully floor should be strengthened down stream against the scouring force of the water. This can be done by making a type of

mattress or cover which is well sealed. (For example broken stone, discarded car tires filled up, concrete rubble etc.). After overflowing, the water is very turbulent. Even though the stream is concentrated in the middle of the gully, the walls will have to be extra strengthened (Figure 32).

Obstacles within the gully that force the water to the sides have to be removed in order to prevent further scouring out of the sides of the gully.

In certain cases, the turbulence of the water causes undermining of the head of the gully. This means that the head (starting point) of the gully cuts in further backwards (up slope), see figure 33. Measures have to be taken to prevent this happening.

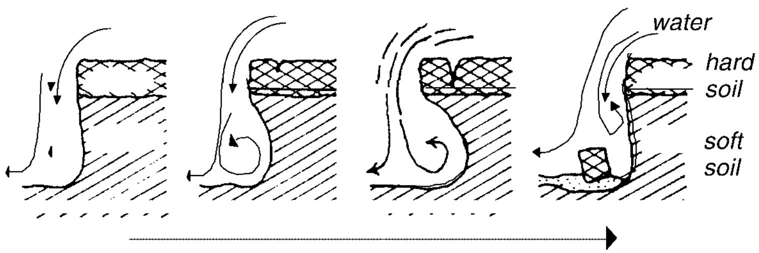


*Figure 33: An exemple of undercutting > process over a period of time*

Protection of the head of the gully can be done by protecting the soil with broken stone, rubble, twigs or similar material. It is also advisable to keep the area around the head of the gully planted up with trees or a tuft-forming crop, for example.

To prevent trampling by cattle (sometimes even the direct cause of gully formation) preventive measures should be taken by making a good fence (thorny hedge for example).

By leading the water along the lower parts of the land you must be sure that water actually comes into the gully.

## 7.6 General remarks for technical measures

In the design and execution of mechanical works, the following lay out directions could be useful:

- The main purpose is and remains to prevent erosion. Other motives (such as encouraging infiltration or making a reservoir) should not hinder this objective. This does not mean to say that the main purpose and other goals are contradictory, on the contrary.
- Land use measures are not always necessary. Often a simpler solution will suffice following the principle of shortening the slope length to limit the flow velocity. (Crop management techniques such as strip cropping or contour farming).
- The simpler methods are usually best because there is only a small chance of failure: Organization is less complicated; the work costs less; simple measures are often very effective. Adaptation can also be made after gaining some experience. Large-scale operations involve more risks because more water is involved.
- Mechanical measures (with machines) can only be applied to arable land, if required, because of the relatively high costs and the danger of erosion is greater here.
- A plan or measure should always be adapted to the method of execution: depending on the available manpower for hand labour or machines; size of operations should be in accordance with the available equipment (plough or bulldozer, for example).
- As far as possible the works to be carried out should fit into the future land development schemes. For example when laying out terraces, take into account the size so that still an easily manageable plot is left over for the farmer. Don't lay out terraces 30 m wide in a field 40 m wide, preferably choose 20 or 40 m. There is always some margin in the measurements of a terrace, make sure that the terrace is safe.
- Land use measures are potentially dangerous: That is to say without proper preparation or execution, the damage may only be worse. Expertise is a must here!

- Earthen structures, terraces, dams etc. require continuous and scrupulous maintenance (see Chapter 9). This essential maintenance can be made more attractive by growing fruit trees for example which will literally and figuratively bear fruit if nursed well.

- The design and layout, and the calculation of structures and drainage canals require knowledge and experience for which a hydrologist can be consulted.

# 8 Underlying causes of erosion

In the previous chapters we have seen how the chance of erosion can be lessened by taking certain precautions. However, circumstances are sometimes such that a farmer cannot adopt another method of production that would be less damaging. So we are confronted with the underlying cause of erosion. A simple comparison can be made here with a farm track (it is sometimes forgotten that roads and paths can be a serious erosion hazard). Naturally a road is seldom covered with a protective mulch layer; moreover roads are preferably laid out as straight as possible, if necessary straight through an erosion prone area, straight up a hill. This is for the simple reason that roads are laid out to transport people and products and not to control erosion.

Just as it is for the road in our example, so is it too in agriculture; agriculture is primarily for food production or as a money earner. The choices that are made in agriculture basically have an economic, social or agronomic background.

Thus it is very important to study these backgrounds carefully when asking yourself why erosion occurs in a certain area. Not only will the deeper causes of erosion be found in the socio-economic backgrounds, but the incentive will be found which motivates the farmer to alternative land use which would have less disastrous results for the soil.

### Crop choice

In Chapter 5, the importance of a good crop choice was pointed out. However, the choice of crop is not free. Under given circumstances some crops would dry out, others require tillage for which there are no machines. Some crops don't protect the soil well, such as maize or cassava but they are staple food. People are dependant on these crops for survival.

### Mulch

Farmers in certain areas used to use mulch before, but not any more. The reason for this is probably the increasing population pressure which brings with it an increasing need for fuel. The grasses that are there and the residues of harvested crops are used as cattle feed or fuel, so that there is no material for mulching. The cattle manure and the ash remains are put back.

Growing mulch material on marginal land that is not suitable for agriculture is a temporary solution, because the soil may deteriorate and in turn succumb to erosion. Yet the farmers will have to be offered an alternative. Maybe crops can be planted which can later be felled for firewood. If these crops are grown in strips they have a protective function too.

### Cost sharing

A farmer may be convinced of the necessity for taking precautions against erosion but if there is a question of share cropping, whereby the farmer is responsible for the cost of erosion control and the yields are shared with the land owner, of course he will not be inclined to take precautions, they are too expensive for him!

### Lack of security

Also, if the lease duration is shorter (one year for example), the tenant farmer is not very sure of a prolonged use of the same piece of land. Understandably the farmer will try to get the most out of his land in the shortest possible time without bothering too much about maintaining the soil quality.

### Being forced to farm steep slopes

In the Andes in South America as in other places, small farmers are driven from the highlands by large landowners wishing to start large scale farming there. There remains little choice for the small farmer than to move to the erosion prone steep slopes and try to go on farming there. The accepted farming methods are no longer suitable on the steep slopes and only cause erosion. With the decrease in yields the farmer slowly slides toward poverty.

Many other examples can be given but we hope that enough has been said to illustrate that the socio-economic relationship as a driving force behind land use, is often the deeper cause of erosion taking place.

# 9 Conditions for the success of operations

Erosion control will have the best chance of success if the underlying causes are removed. Unfortunately this is not always within reach of the farmer concerned or the well-intentioned development worker either. Sometimes the causes can only be tackled by political influence among the people themselves, a process in which you, as a development worker, can exert very little influence.

This does not mean that nothing can be done. It indicates the direction we should look when deciding on measures to be taken, not only considering the effects the plan will have on the soil, but just as much, if not more, the consequences for the people. However, often the lack of technical know-how and information is not the most important hurdle for controlling erosion. The fact that a certain requisite for the success of an operation is not satisfied is more important.

A few of these will be mentioned. Obviously you must decide for yourself the factors that should be taken into account in your area.

## 9.1 Trust

The first condition is that one is accepted by the inhabitants. A touching example of farmers accepting the advice for water conservation measures comes from a village San Lucas in Peru. A man on a donkey was allowed to travel through the area and talk to the people about water conservation. The man made himself known as San Lucas. For the people in the village this man was a living legend and they took his suggestions to heart. The advantage of this was that the effects of water conservation were soon noticed in the increased crop yields. The demonstration effect should not be underestimated.

## 9.2 Awareness

Only if people appreciate the usefulness of the operations to be carried out, will they be inclined to take them up themselves. They should be aware of exactly what is going on in their neighbourhood. Farmers are often well aware of the drawbacks of their methods but carry on in the same way because they don't know any alternative.

So you, becoming involved, can give timely advice so that money, time and effort and especially goodwill need not get lost. Together with the local people, other ways can be looked for to achieve the objectives in a manner which is better adapted to the soil. In this way the people will feel more responsible for the measures taken.

## 9.3 Correct choice of operations

When making a choice, take note of:

**The order of priority**

Erosion should be trickled at the source. A gully is the result of erosion during and after a heavy storm. The additional water upstream from the gully, which could not infiltrate into the soil flooded away and led to gully formation. If only the gully is kept under control then it will have just as much water and sediment to transport in the next heavy shower. As long as nothing is done upstream the mud and water flow will not change. Whereas gully control is not erosion control; erosion control is the way to control gullies. Preventing large amounts of water flowing into the gully is preferable to controlling the gully. Prevention is always better than cure and in this case cheaper too.

**The money at one's disposal**

Complicated operations are expensive and at first have very little result so the erosion authority is often considered to be an expensive luxury. However, if by taking measures to control erosion you also succeed in increasing yields (which is possible by water conservation for example) then there will certainly be a criteria in planning the priority of measures to be taken.

Associated with the costs is the risk for the farmer. The poorer soils are often owned by the less affluent farmers. They are in no position to take risks, so hardly invest in preventive measures whereas on these soils the measures are most needed. Yet there are simple measures especially concerned with crop management that almost any farmer could take without increasing the risks.

You could certainly point out erosion and its negative effects. But it is doubtful if this is enough to motivate the farmers. We don't want to advocate short term thinking but sometimes it might be more effective to motivate people through short term objectives.

### The time available

If the harvest fails there is little left for the farmer but to try to keep his head above water by working harder and longer. It should always be remembered that the farmers' family simply haven't the time to spend on erosion measures. The same applies to the problem of getting firewood. If trees are gradually disappearing in an area, then people will have to walk further and further to collect enough fuel. In Java this may take up to 4 hours a day in labour cost. In the Himalayas people sometimes have to work for 3 days to collect enough firewood for a week.

So the time factor has to be taken into account when planning operations, in the first place to plan them at a time that is less busy for the farmer. Secondly it must be taken into account that the soil may be unfit for cultivation or the farmer **may** be working for his neighbour or the landlord. The farmer will then be less inclined to put effort into something for which he or she will not directly benefit.

### Maintenance

Numerous examples can be given of projects which have failed simply because of bad management. Many operations are pointless if they are neglected. Since the inhabitants will have to carry on the works and maintain them, it is essential that they see their benefit and feel responsible for them too. The people should feel that the project belongs to them. For this reason too, the local population should be involved in the preparation and the execution of plans. After all, this is the land that is to provide their subsistence. They are more likely to keep a drain clean that they have dug themselves. Yet, we have also noticed that the live barriers have not always been planted or maintained, because in spite of the encouragement from the advisory service, the farmer was unable to do anything about it.

# 10 Conclusion

After reading this booklet you will probably be feeling confused by all the different ways to control erosion and what it entails. Perhaps you would have preferred some concrete advice; now you can't see the wood for the trees! Yet you will appreciate that we cannot give concrete advice to start you off because the situations vary too much in different regions. It is better if you can fill in the gaps yourself (with the help of this booklet), other literature, advice from different authorities and especially with help from the local population and a little common sense. However we can give you some assistance in making a choice. For this we have made up a sort of questionnaire making reference to the chapters in this booklet:

### 1 What are the signs of erosion in your area?

Make a tour, taking note in particular of the different erosion phenomena that occur (see Chapter 2).

### 2 How exactly does erosion arise and which processes play a role here.

Take a walk around a gully and try to explain how this originated (see Chapter 3).

### 3 How could all this happen and what is the deeper cause of it?

What crops are growing there? Why isn't the soil well protected? Are there social problems which determine the choice of crop and land use? (Fragmented land ownership for example). (See Chapter 8).

### 4 Can anything be done to change the underlying cause?

In the first instance the answer will readily be 'no' but sometimes certain development trends can be recognised which can be followed up or ignored (see Chapter 9).

### 5 What can be done about the phenomena?

A gully can be checked. Rill formation prevented by regulating runoff water (see Chapter 7).

### 6 What measures are considered in principle?

A gully controlled by broken stone and by grass growth. Laying out a drainage system, or terraces, making a mulch layer or all three together. (Chapters 5, 6 and 7).

### 7 What is needed to execute these operations?

Think of money, manpower, time, planting material, equipment organisation, knowledge and experience.

### 8 Can all this be obtained, and if so, is it readily at hand?

First make a plan so that you don't waste time on something unfeasible.

### 9 What results can be expected:

1 For the soil, that is to say, how does the method work exactly?
2 Agriculturally, what does the farmer have to do, when, and has he got the time then? Etc.
3 In the social sphere, commitments through loans the farmer makes in order to pay for the execution etc.

### 10 Is all this really attractive to the farmer?

You should continually ask yourself whether it cannot be simpler or cheaper and no doubt the farmer will have an opinion too.

Hopefully, following the train of thought of the questionnaire you will find out more or less what is possible in your situation. You may have to ask for help from authorities in your area, taking into account that they all have different interests at heart. (A soil protection service for example will be pleased to lay out beautiful terraces which will look good in the annual report. The government or banks are prepared to help farmers who grow export crops etc.)

Specialists can also give useful information but unfortunately they are only well up in their own subject. The list of references gives titles of further information, for example the design criteria applicable to a certain area. The procedures are often more extensively described than we have been able to do here. Ministries, universities and the soil conservation service in particular will be able to provide useful information, relevant to the local situation.

Finally we repeat a few remarks made earlier that are of vital importance.

Some procedures do more damage than good if not carried out properly!!

We welcome suggestions and experiences from practical situations, as well as any questions and criticisms.

# Appendix 1: Several techniques for levelling and measuring heights

To determine the contour of a slope and the course of a terrace, some simple surveying operations will have to be carried out. A levelling instrument is essential for these measurements.

For further information and different surveying methods and instruments, we refer to the Agrodok no 6: '*Simple Construction Surveying for Agricultural Practices'* by Agromisa. Along the lines of this booklet, the required basic information is given below.

**Levelling and making a simple levelling instrument.**
In the action of levelling you measure the height difference between two points. One pole is placed at the point you want to measure and by means of a levelling instrument the height can be read off.

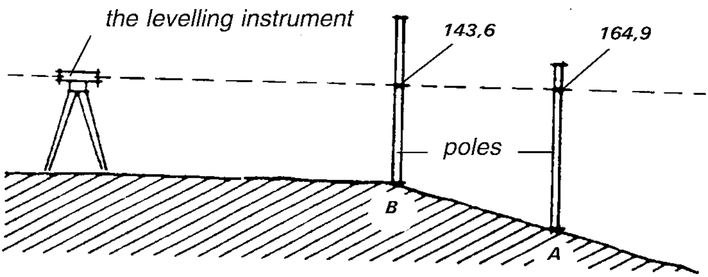


*Figure 34: Height measurements with levelling instrument*

For example: we have two points A and B and we wish to measure the height difference between the two, then the pole is first placed at point A (see figure 34). Using the levelling instrument we read the height, for example 164,9 cm (read along the line of collimation in the telescope). The pole is then placed at point B and we read, for example 143,6 cm. The height difference is then 164,9 – 143,6 = 21,3 cm.

Take note: The higher the reading, the lower the position of point A.

Well known levelling instruments are Wild, Zeiss, Kern, Sokkisha. Such instruments are fairly costly. Therefore it is attractive to make a simple levelling instrument yourself: a water-hose level. This is of course less accurate but also less costly.

**Water-hose level**

The water-hose level can be used for staking out contours and for measuring differences in elevation.

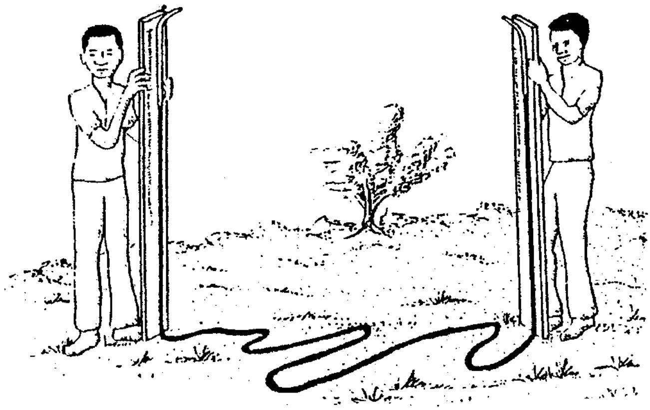

*Figure 35: Water-hose level*

Differences in height can be measured with the water-hose level. You put one staff in position A and the other staff at 10 m distance. The difference between the readings of the level in the water-hose on the two staffs is the difference in height (Figure 35).

*Construction:*

Material needed:

- transparent/clear (water) hose of 15 - 25 m length, diameter maximum 1 cm
- 2 laths, 200 x 10 x 2 cm with graduation marks
- pieces of inner tube (of a tire)
- U-shaped or L-shaped nails and a hammer
- rope, 10 m or more.

The ends of the hose are fixed firmly to the lath. This can be done using part of an inner tube that is then fixed with U-shaped or L-shaped nails. This makes it possible to move the hose up and down slightly when necessary during the work. The top ends of the hose should extend above the lath slightly (15 cm) to make filling easier (see figure 35).

Before filling the hose for the first time, rinse the hose with soapy water. This prevents the occurrence of air bubbles during use. Repeat this when necessary. A rope of 10 m or more is sometimes fixed to the laths to limit the distance between them. In this way the rope can help to prevent damage to the tube. The length of rope has to be shorter than the water-hose.

*Water-bottle level*

Another version can also be used: the water-bottle level (Figure 36). You need the same length of water-hose and two plastic bottles. These bottles are fixed (with tape, for example) to both ends of the water hose.

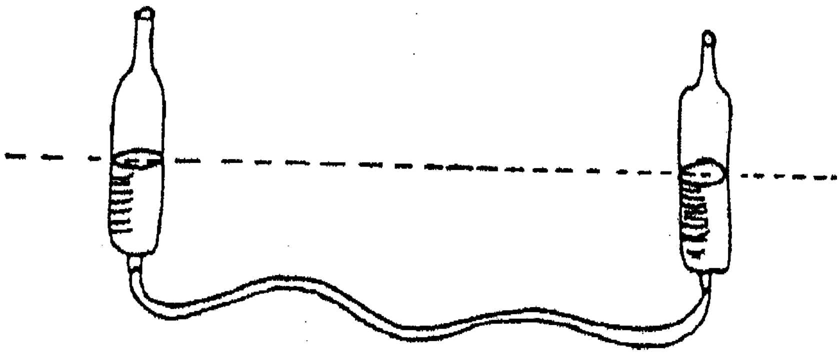

*Figure 36: Water-bottle level*

*Use of water hose and water bottle levels*

- Water:
  Always use clean water, otherwise the inside of the hose will become dirty, making reading impossible.

- Filling:
  Start sucking water from a tin or bucket through one end of the water-hose, and fill the rest of the hose by lowering this (suction) end below the surface in the tin or bucket. Stop filling when the water reaches the end of the marks on the laths.

- Transport:
  Close plastic hose ends with a cork or paper plug. Remove these before use!

- Air bubbles:
  Persistent air bubbles must be removed by refilling the hose or rinsing it with soapy water. Tiny air bubbles, covering less than half of the inside diameter of the hose, will not interfere with the measurement.

- Checking:
  1 Before use, always check whether the instrument works properly. Place the staffs side by side at the same level. The water level reading should be the same on both staffs.
  2 The sum of the readings on both staffs is called the **check value**. This value should not vary more than 0.5 cm between different readings. If the difference is larger, the reading is not acceptable. Do not use it and read again.

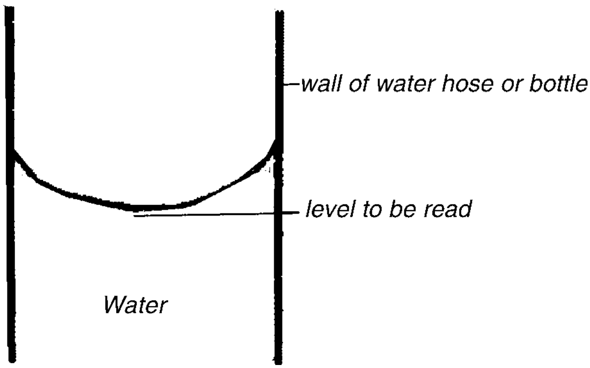


*Figure 37: The reading*

- Reading:
  The bottom of the water surface in the hose (called the meniscus), is taken as the level to be read (see figure 37).

- Costs:
  low (material is available locally)

- Accuracy:
  5 cm per 100 m (water-bottle level: 10 cm per 100 m)

- Source of errors:
  - air bubbles
  - loss of water during measuring
  - not alternating the position of the staffs (or water-bottles)

# Appendix 2: Tree species for erosion control in the tropics and sub-tropics

***Acacia sp.***

Many species suitable for (semi)-arid regions, often used under difficult growing conditions ('adverse sites'): A. aneura, A. catechu, A. cyanophylla, A. melanoxylon, A. nilotica. In sub-humid climates: A. auriculiformis.

***Ailanthus altissima.***

Mediterranean climate. Many seed and root suckers.

***Bambusa sp. and other bamboo sorts.***

In various climatic zones, in lowland and highlands, useful for stabilising steep slopes as well as river banks. Quick growing, spreading by rhizomes, closed root system, much litter, useful product.

***Casuarina equisetifolia***

(Sub)-humid regions, possibly semi-arid provided air humidity high.Much root-suckering.

***Cupressus sp.***

In mediterranean climate: C. arizonica, C. macrocarpa, and C. sempervirens var. horizontalis (see Bibliography). In tropical highland climate: C. lusitanica. Give much litter in close stand, but little undergrowth: Dalbergia sissoo. Monsoon climate: to protect river banks, gully stabilisation. Forms root suckers.

***Eucalyptus sp.***

In general not very suitable to control erosion: young plants, sensitive to root competition, require intensive weeding; closed cultivation permits very little undergrowth. Can be used on terraced slopes. Ficus sp. For stabilising gullies and river banks.

***Gliricidia septum***

For dry places in sub humid lowlands. N-fixer.

***Lantana camara***

Hedge with wide ecological application: In semi arid to humid regions, lowlands and low highland also on poor soils.

***Leucaena leucocephala***

Genetically very variable: Shrub or tree, suitable for ground stabilisation in semi-arid to humid areas. Easy to multiply by seed and cuttings, fast growing, strong root system, good cover crop, N-fixer, can be exploited as scrub. Many uses, such as firewood, fodder crop.

***Mimosa pigra***

Shrub with many long thorny branches that can form dense thicket. Used for stabilisation of riverbanks.

***Parkinsonia aculeata***

Shrub, can be used in very dry regions.

***Pinus sp.***

Favourable properties for erosion control: grown on dry, well drained, poor soils; can withstand competition by grasses; forms a good litter; in later stage undergrowth is often formed; thick bark gives tree resistance to bush fires. Wood very useful.

Tropical sorts are best for climates with conspicuous dry season but rainfall not below about 1200 mm/year: P. caribea in lowland (also in (sub)-humid regions); most species suitable for highlands. e.g. P. khasya, P. merkusii, P. insularis, P. oorcarpa, P. patula.

Mediterranean species: P. brutia, P. canariensis, P. halepensis, P. pinasta and P. radiada (see also Further Readings).

***Pithecolobium sp.***

Large trees with extensive and deep root system. Alongside river banks.

***Populus sp.***

Sub-tropics. Most species depend on good water supply often alluvial soils. P. suramericana, P. euphratica *may* be valuable in consolidation river banks. P. canescens is suitable in dry areas.

***Prosopis chilensis***

In semi arid climates: fast growing, also in difficult situations. Deep rooting. High regeneration potential: seed, root and stem suckers. Exploited as scrub.

***Psidium guava***

Small tree, edible fruit. In (sub-)humid tropics on various soils, also on dry eroded ground. Spreads spontaneously by seed.

***Salix sp.***

Sub tropics (S. babylonica and others), and tropical highlands (S. humboldtiana). Gully stabilisation and consolidating river banks, superficial rooting system, can withstand severe drought, easily multiplied by branch or root cuttings.

***Tamarix sp.***

Evergreen shrubs or small trees, for stabilisation of dried-out beds in arid regions (wadis).

# Appendix 3: Legumes; characteristics and utilization

| Species | Plant characteristics | Adaptation to the soil | Adaptation to the climate | Utilization |
|---|---|---|---|---|
| Arachishypogeae | 1, 4, 5 | 4, 5, 6 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Cajanuscajan | 3, 4, 9 | 4, 5, 7 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Calopogoniummucunoides | 3, 4, 5 | 4, 5 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Canavalis ensiformis | 1, 4, 6, 8, 9 | 4, 5, 6 | 1, 3, 4 | 1, 3, 4 |
| Cassia hirsula | 3, 4, 7 | 4, 5 | 4 | 4 |
| Centrosema pubescens | 3, 5, 6, 9 | 4, 5, 7 | 1, 2, 4, 5 | 1, 2, 4, 5 |
| Cicer arietinum | 1, 8, 9 | 2, 3, 4, 5, 6 | 1, 3, 4 | 1, 3, 4 |
| Crotalaria anagyroides | 3, 4, 9 | 4, 5 | 4 | 4 |
| Crotalaria juncea | 1, 4, 8, 9 | 4, 5, 6 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Crotalaria mucronata | 3, 4 | 4, 5 | 1, 2, 4 | 1, 2, 4 |
| Crotalaria spectabilis | 3, 4, 7, 9 | 4, 5 | 4 | 4 |
| Crotalaria usaromoensis | 3, 4 | 4, 5 | 4 | 4 |
| Desmodium adscendens | 3 | 4, 5 | 2, 4 | 2, 4 |
| Dolichos lablab | 3, 5, 6, 8 | 4, 5 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Glycine javanica | 3, 6 | 4, 5 | 1, 2, 4 | 1, 2, 4 |
| Lens esculenta | 1, 4 | 1, 2, 3, 4, 5, 6 | 3, 4 | 3, 4 |
| Leucaena glauca | 3, 4, 7 | 4, 5 | 1, 2, 3, 4, 5 | 1, 2, 3, 4, 5 |
| Medicago arabica | 1, 4, 5 | 2 | 2, 4 | 2, 4 |
| Medicago sativa | 3, 4, 9 | 1, 2, 3, 5, 6 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Mimosa invisa | 1, 2, 3, 4, 5, 6 | 4, 5 | 4 | 4 |
| Pueraria Phaseoloides | 3, 5, 6, 9 | 4, 5 | 1, 2, 4, 5 | 1, 2, 4, 5 |
| Sesbania aculaeta | 1, 4 | 4, 5 | 4 | 4 |
| Sesbania exaltata | 1, 4 | 2, 3, 4, 5, 6 | 4 | 4 |
| Sesbania macrocarpa | 1, 4, 9 | 2, 3, 4, 5, 6 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Stizobolium aterrimum | 1, 5, 9 | 4, 5 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Stizobolium deeringianum | 1, 2, 3, 5, 6, 9 | 1, 2, 4 | 1, 2, 3, 4 | 1, 2, 3, 4 |
| Stylosanthes gracilis | 3, 4, 5, 9 | 1, 2, 4 | 1, 2, 4 | 1, 2, 4 |
| Tephrosia candida | 3, 4, 7 | 1, 2, 4, 5, 6, 8 | 3, 4, 5 | 3, 4, 5 |
| Vigna oligosperm | 1, 2, 3, 5, 6, 9 | 6 | 1, 2, 3, 4 | 1, 2, 3, 4 |

### Explanation of the numbers in the table:

*Plant characteristics:*

1= annual

2= biennial

3= perennial
4= upright habbit
5= creeping
6= winding, climbing
7= poisonous
8= slightly poisonous
9= drought resistant

*Adaptation to the climate:*
1= temperate zones, excessive rainfall
2= temperate zones, only winter rains
3= temperate zones, only summer rains
4= tropical and subtropical regions, excessive rainfall
5= tropical and subtropical regions, moderate rainfall
6= tropical and subtropical regions, irrigation
7= tropical and subtropical regions, arid and semi-arid regions

*Adaptation to the soil:*
1= light soils
2= heavy soils
3= limey soils
4= shallow soils
5= well drained soils
6= wet soils
7= alkaline soils
8= acid soils

*Utilization:*
1= fodder crop
2= pasture crop
3= human food
4= green manuring, ground cover
5= soil conservation cover crop (erosion control)

# Further reading

Agpaga, A., and others, **Manual of Reforestation for the Philippines**. 1975, G.T.Z, Eschborn, West Germany. Practical handbook for reforestation and soil conservation techniques, also useful outside the Philippines.

ASPAC, **Soil Conservation Handbook**. 1977 ASPAC, Taipei, Taiwan.

Carruthers, I., Rodriguez, M., **Tools for Agriculture: a Guide to Appropriate Equipment for Smallholder Farmers**. 1992, 238 pp., Intermediate Technology Publications/GRET/CTA, London, United Kingdom. ISBN: 1-85339-100-X.

Chleq, J.L., Dupriez H., **Vanishing land and water: soil and water conservation in dry lands**. 1988, 128pp., Terres et Vie/CTA/Macmillan, London, United Kingdom. ISBN: 0-33344-59-7. Available from CTA, 20 credit points.

FAO. **Conservation in Arid and Semi-arid Zones.** 1976. FAO Conservation Guide no. 3, Rome.

FAO, **Soil conservation for developing countries**. FAO, Rome.

Greenland, D.J. and Lal, R. (ed). **Soil Conservation Management in the humid tropics**. 1977, G. Wiley and sons, Chichester, New York. Specialised handbook for Agricultural development workers who are concerned with erosion in the wet tropics.

Hudson, N., **Soil Conservation**. 1971, B.T. Batsford Ltd. Guildford, England. Much used book giving the principles of erosion and erosion control. Fairly technical.

Hudson et al., **Working with farmers for a better land husbandry.** 1993, 280 pp., IT Publications, London, United Kingdom. ISBN: 1-85339-122-0. Available from CTA, 20 credit points.

Reij, C., et al**. Sustaining the soil: Indigenous soil and water conservation in Africa.** 1996, 272pp., Earthscan. ISBN: 1-85383-37-2. Available from CTA, 40 credit points.

**Sistemas integrados de conservacion de suelos**. 1985, 11CA - Republica Dominicana. An interesting and practical book with good descriptions of various simple measures for the small farmer in humid and sub-humid regions.

**Soil and Water Conservation Handbook.** 1995, FFTC Book Series-11.

**Technical guide - Soil and water conservation for Northern States of Nigeria.** Agency for International Development and the USDA Soil Conservation Service Advisors, in cooperation with the State Ministries of Natural Resource. Handbook with detailed descriptions of control measures, many tables etc. Fairly technical.

Wenner, C.G. **Soil conservation in Kenya, especially in small-scale farming in high potential areas using labour intensive methods**. 1981, 230 pp., Ministry of Agriculture, Nairobi, Kenya. Describes labour intensive methods in small scale agriculture.

**Agrodok series:**
2. Soil fertility management, 1998, 80 pp.
8. The preparation and use of compost, 1999, 60 pp.
13. Water harvesting and soil moisture retention, 1997, 90 pp.
16. Agroforestry, 1999, 90 pp.
19. Propagating & planting trees, 1998, 80 pp.

*Available from Agromisa, Wageningen, The Netherlands*
*The address you find inside on the inside of the front cover.*

# Glossary

### Catchment area
A catchment area can be described as an area where all the water to be carried away leaves that area at one point. All this water comes together via the whole system of drains, field drains, canals and waterways until it finally flows into a river or the sea.

Two catchment areas are separated by a so-called water divide. This may be a ridge, mountain, impenetrable layer or a larger river or canal.

### Soil aggregates
Soil aggregates are naturally occurring clusters of non-organic and organic soil particles. The strength of the forces combining the particles within the soil aggregate are bigger than the forces of the surrounding environment, thus keeping the soil aggregate together.

Sand particles do not form aggregates, the soil has a grainy structure. Clay particles form aggregates and the soil has a coarse, compound structure. Organic matter plays an important role in the formation of aggregates. Soils that easily form aggregates are less sensitive to erosion.

### Manipulation test
The manipulation test is a simple method to get an idea of the texture of the soil. The test is based on the reaction of a small quantity of soil material (under certain moisture conditions) to remodelling. About 2 cm soil is moistened until it becomes pliable. From this moistened soil shapes are moulded as shown in the diagram below. With sand it is only possible to form a cone, whereas sand with some loam (silty loam) can be moulded into a slab.

If there is no problem with this, then a roll about 10 cm long is made by rolling the soil between the hands. If there are cracks, the texture will be like sandy loam; if there are no cracks then this is a so-called loam. If the roll can be formed into a horseshoe-shape in which there are cracks, then the soil is a clay loam; if there are no cracks then the texture is even finer (loamy clay). If it is possible to mould the horse-shoe still further into a ring without any cracking occurring, then we have a clay (see figure 38).

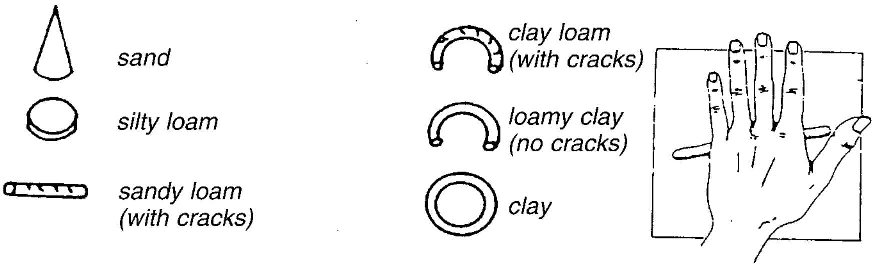


*Figure 38: Manipulation test*

**Infiltration capacity**

The ability of the soil to take up water and to retain it, comparable to a sponge. The water that infiltrates fills the pores, cracks, hollows or adheres to soil particles. The water taken up can gradually be given out again later by the soil to the plants (by capillary action), or it condenses on the soil surface or flows via the ground water (with excess supply) to deeper soil layers.

Maximum infiltration capacity is the greatest amount of water which a soil can hold. A shallow soil is easily penetrated, it doesn't hold much water and so the infiltration capacity is not great.

**Infiltration velocity**

Infiltration velocity is the rate at which a certain amount of water can be taken up in the soil.

**Peak runoff**

The runoff water occurring after a very heavy storm which happens occasionally (about once every five years), and has to be carried away in a short time. A drainage system is often gauged according to the expected peak runoff, which occurs every ten years for example. This is called the maximum probable runoff of an area. Rainfall data over a period of years is needed for this. This can be obtained from a nearby meteorological station, but make sure that the figures are accurate for your area. Otherwise, this could be disastrous.

### Permeability of the soil

The degree to which (and the speed with which) the water penetrating the soil flows down to the deeper soil layers and finally to the ground water. This depends on the soil structure, soil density, pore size etc. For example a heavy clay has poor permeability (because of its compact structure, small particles, very small pores) compared with sand for example (crumbly structure, larger particles, larger pores) which is normally very permeable.

### Slope percentage

Gives the percentage of how many metres the surface vertically rises or falls (A) if you cover a horizontally distance of 100 m (B).

$$\frac{\text{vertical distance (A)}}{\text{horizontal distance (B)}} \times 100\% = \text{slope percentage}$$

For a slope percentage of 10% for example you go up 10 m (A) over a distance of 100 m (B) (see figure 39).

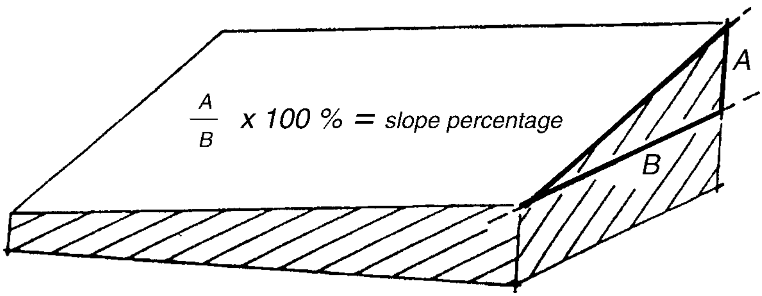


*Figure 39: Slope percentage*

### Longitudinal slope

A slope percentage of, for example, a terrace or drain in lengthwise direction. A longitudinal slope of a terrace (C) is therefore the slope measured along the length of the terrace. The length (B) is measured parallel to the terrace and the height (A) is measured perpendicular to it (Figure 40).

$$\frac{\text{height of the terrace (A)}}{\text{length of the terrace (B)}} \times 100\% = \text{longitudinal slope (C)}$$

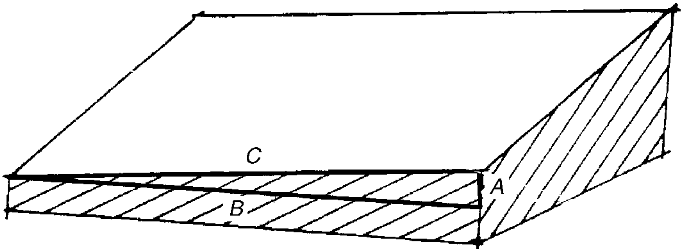


*Figure 40: Longitudinal slope*

**Contour**
An imaginary line joining all points of the same height on a land surface. For more information see appendix 1. For more detailed information see Agrodok 6, *Simple Construction Surveying, for Agricultural Practices.*

**Soil profile**
A term to describe the formation of a certain soil. In the profile of the soil (a section from top to bottom) various layers can often be distinguished relating to the soil compatibility, rooting, moisture level, colour, presence of organic material, state of decomposition, permeability etc.