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SOIL CONSERVATION PRACTICES

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SOIL CONSERVATION PRACTICES
(Lecture Notes)

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SOIL CONSERVATION PRACTICES

At present, millions of hectares of land are being affected by soil erosion. A recent estimate by FAO indicates that globally between 5 and 7 million hectares of land are lost for agricultural production as a result of erosion and related forms of land degradation.

Soil erosion results in the silting up of waterways and dams, reduces the life of hydro-electric and irrigation schemes and leads to an increase in the frequency and severity of flooding. All of these are serious, but the most important effect of soil erosion is that it leaves the land poorer and with a reduced capacity to produce our requirements of food, fibre and fuel.

Soil erosion is therefore undermining efforts to increase productivity and meet the increasing needs of a rapidly growing world population.

It is, therefore, fitting that soil conservation should be chosen as the final subject for discussion of the College of Soil Physics.

Causes of Land Degradation and Soil Erosion

Before discussing how soil erosion can be controlled, it is necessary that we first understand how and why erosion occurs and the basic principles which are followed in any technically sound soil conservation programme.

Land varies from place to place. The character of a unit of land is the result of a number of factors which include the geology, topography and soils, the hydrology and the microclimatic conditions it creates, and the plant and animal communities which it supports.

The particular combination of features at any place is the result of the interaction between them and the climatic conditions that have prevailed during the evolution of the landscape.

Under natural conditions, a balanced system normally develops under which the soil is covered by a mixture of different plants. Normally, this gives protection to the soil, little erosion takes place and the soil tends to gradually deepen over time. Occasionally, natural disasters, such as droughts and floods, occur and the soil may be temporarily left unprotected. But, these periods usually pass quickly and a balanced, soil protective system is soon re-established.

The main causes of land degradation and soil erosion stem from indiscriminate human interference in the natural ecological balance - from abuse and mismanagement of the soil and water resources - and from trying to farm the land beyond its capability.

When man tries to modify the land for his own use, he changes and upsets the natural balance. Most, or all, the natural vegetation is removed and perhaps replaced by a limited number of new plant species. The soil may be physically disturbed and left bare of protection for protracted periods. The hydrological characteristic of infiltration, moisture retention, run-off and seepage are altered.

Some units of land are very resilient and can absorb great changes in use without detrimental effects. Other land, however, is more fragile and less capable of absorbing change.

But, unless a system of land use is applied which is compatible with the characteristic of the land the soil will degrade.

The degradation of the soil may take different forms. These can vary from a massive physical loss of soil through erosion to the loss of soil nutrients or other problems such as salinization.

Whatever the form the degradation takes, the end result is a lowering of the productive potential of the soil.

In view of this, the first and most important principle in controlling soil erosion, and any other form of land degradation, is the necessity (if change is necessary) to replace the natural system with a new system which is compatible with the land and which is ecologically stable. This implies selecting a form of land use compatible with the soils, topography and climate.

Correct Land Use

As a first step in controlling erosion, it is common to classify the land according to capacity or suitability.

Work in this field was pioneered by the United States Soil Conservation Service and has now been adopted, with variations, for a number of different countries and regions with such different climatic conditions that there is little doubt that it can be applied anywhere there is a soil erosion problem.

There is not sufficient time to go into the details of this system here, but the essential features are that various facts about a piece of land are gathered in a survey. These include items like soil depth, drainage characteristics and slope which can be quickly measured or assessed in the field. On the basis of these facts, the land is allocated into one of eight classes. These classes reflect the risk of erosion and indicate the main type of land use, e.g. forestry, arable, to which the land can be safely put.

Appropriate forms of land use are then selected and applied. Where necessary, some mechanical erosion control works are also introduced to ensure that the different units of land remain stable. But, basically, the control of erosion depends upon the correct form of land use being applied and supported by sound conservation land use practices.

Again, without going into details, correct land use implies, for instance, that:

- annual cropping should only be carried out on the deeper, more fertile soils and on flat or gently sloping land;
- land with intermediate slopes and soils of medium depth should be used for pasture or tree crops;
- land with steep slopes and shallow soils should be used for forestry, or limited grazing or for wildlife reserves, etc.

The Process of Erosion

Soil erosion takes place when particles of soil are detached and then transported to a different place. The agents for this detachment and transportation are either wind or water. The study of soil erosion and its control is, therefore, normally divided into water erosion and wind erosion and dealt with as separate subjects.

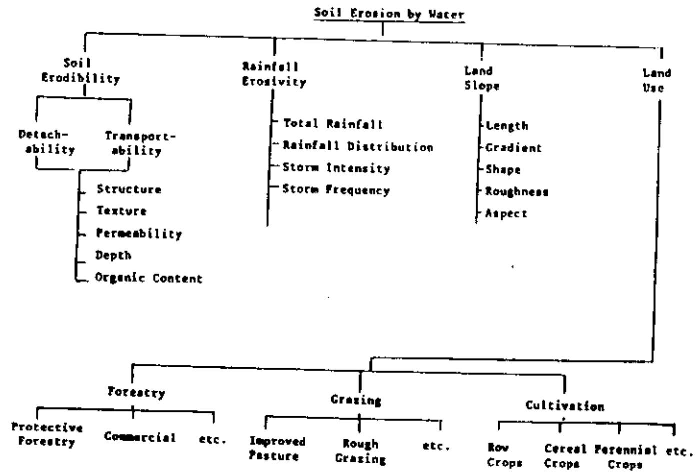
While this division may be convenient, it must be remembered that whether the erosion is by wind or water, the causes are frequently the same, or similar, as are most principles of control.

Water Erosion

Raindrops falling on bare soil break down the structure of the surface soil and detach particles. If the land is sloping and the water cannot be absorbed by the soil, or detained by the micro-topography, the water moves off down the slope in the form of run-off, carrying dislodged particles with it.

The basic factors affecting water erosion are the erodibility of the soil, the erosivity of the rainfall, the slope of the land and the type of land use.

Diagramatically, this can be illustrated in a simplified form as follows:



The Prevention and Control of Water Erosion

A great variety of soil conservation practices and techniques have been developed for preventing and controlling water erosion. These range from simple practices, such as contour cultivation, which can be laid out and managed with little training, to complicated, sophisticated soil management and engineering works which require specialized skills for their design, implementation and maintenance.

Fundamentally, however, what soil conservationists try to do is to introduce and promote stable systems of land use and management which control and prevent erosion in three different but related ways:

(i) by protecting the surface of the soil, as far as possible, from the effects of raindrops directly striking a bare soil surface;

(ii) by ensuring that the maximum amount of water reaching the soil surface is absorbed by the soil;

(iii) by attempting to make any water, which cannot be absorbed, drain off at velocities which are low enough to be non-erosive.

On flat, or gently sloping land, soil conservationists have at their disposal a large array of techniques to accomplish these three aims and the techniques can be used in various combinations to allow for the requiremnts of different land uses. Thus, if it is necessary to leave the land exposed to the direct action of raindrops for a period (so that an annual crop can be grown), compensating techniques can be used which will help infiltration and slow down the speed of run-off.

Soil Conservation for Control of Water Erosion

Soil conservation measures are normally described under the two convenient headings of biological measures and physical or mechanical measures.

In practice, there is an overlap between the two, and soil conservation plans for any area normally consist of a combination of both types of measures.

The underlying principle of biological measures is that vegetation is used, either living or dead, in sufficient quantities to shield the soil surface from the direct impact of raindrops and to create a rough surface which will physically impede run-off and slow it down to non-erosive velocities.

Mechanical conservation works on the other hand do little, if anything, to prevent the effect of raindrop impact, but are designed to slow down, partially or entirely, the movement of run-off water so that the infiltration rate is increased and the velocity of run-off is reduced.

Physical conservation works are normally designed to achieve this in one of two ways: either by reducing the length, or changing the degree, of slope. For example, countour banks or bunds are used to reduce the length of slope. A well-designed system of contour banks will be spaced close enough together to intercept run-off before the flows become too large or before the flows start to concentrate in channels and to form rills.

On the other hand, bench terraces are constructed to actually change the slope. While the overall slope remains the same, sections of flat, or nearly flat land, are created which allow forms of land use which cannot be practised on steep slopes without causing erosion.

These, then, are the basic principles which guide soil conservationists when they attempt to plan and implement soil conservation measures to control water erosion. Although a wide variety of practices and techniques are now known and are available for use, they all have their limitations and these limitations increase with the slope.

Examples of Soil Conservation Practices to Control Water Erosion

A great variety of different biological and physical conservation practices have been developed over the years and space does not permit for more than a brief mention to be made of some of the more widely used of these practices:

(a) **Biological Measures**

(i) For arable land:

- The use of crop rotations which will provide a protective cover at the time of the year when the heaviest storms are expected.

- Relay planting, a technique whereby a second crop is planted between the rows of a growing crop. Thus, by the time the first crop is harvested, the second crop is growing and providing protection to the soil.

- Mulch tillage, a system under which crops such as wheat or maize are harvested but the crop residues are left on the surface, or partly worked into the soil, to provide protection.

- Minimum and no tillage systems, as the names imply, little or no tillage is done prior to planting of crops. The soil is not inverted, weed growth is controlled by chemical sprays and a protective cover of vegetation is always maintained on the surface.

(ii) For grazing land:

- Rotational grazing, a system whereby the grazing land is divided into units and the animals are systematically moved from one unit to another. In this way each unit is given a chance to recover after being grazed and sufficient ground cover is maintained to prevent, or at least control, erosion.

- Avoiding concentration of livestock; water erosion frequently starts on grazing land where small patches of particularly vulnerable land have been left bare of vegetation by the trafficking of animals. This can be avoided by the careful alignment of fences, roads and careful selection of watering points.

(iii) For forestry land:

- Maintenance of ground cover. Trees by themselves will not prevent erosion. Raindrops falling from a high canopy onto a bare soil can do as much damage as if the trees had not been present. It is necessary to ensure that there is a ground cover under trees, either living undergrowth or dead leaves and twigs.

- Controlled logging. Poor logging operations can lead to severe erosion before a new cover is established. Logging should be planned to do the minimum of soil damage and practices, such as dragging logs out along waterways, should be avoided.

(b) Mechanical Measures

Mechanical water erosion control measures should only be looked upon as supplementary to correct land use and good management. Unfortunately, because they are often spectacular, such measures are often considered the only way of controlling water erosion. Because of this, these measures are often incorrectly applied and, without good land use and management, prove ineffective. In fact, badly designed or constructed mechanical works can result in erosion increasing rather than decreasing. Because the process of water erosion is not well understood, mechanical works are often used to treat the symptoms of erosion rather than the causes. Nevertheless, mechanical erosion control works, if well designed, well constructed and used in the right way, can be very effective in helping to control or prevent water erosion.

The concept of mechanical erosion control is not new and large areas of the earth's surface have been treated at different periods. Examples of this can be seen in the Middle East and Asia where large areas have been bench terraced. Some of this terracing is very old - indeed we know that some of it dates back at least 2000 years - and it has proved very effective where it has been well maintained.

Most mechanical water erosion control measures are based on what has been referred to as the "contour principle". Generally, they consist of various types of earth or stone works built on, or close to, the contour. Usually, they aim to either reduce the length of a slope or the angle of the slope itself. In either case, the result is to increase the infiltration of water into the soil, to reduce run-off in both quantity and velocity and to trap soil which may have been detached higher up the slope.

Some of the most commonly used mechanized erosion control works are as follows:

Contour cultivation

This is the simplest form of mechanical control. As the name implies, it consists of cultivating the land on, or close to, the contour. Each furrow acts as a small dam, slowing down the movement of water over the soil, increasing infiltration and trapping moving soil.

Contour cultivation, by itself, is a cheap but effective way of controlling water erosion. An advantage of contour cultivation is that it is immediately effective when the land is newly cultivated - the time when the land is usually at its barest and most prone to water erosion. A disadvantage is that the furrows often break down quickly and sometimes are not effective for a very long period.

Contour banks

Contour banks, or bunds, as they are sometimes called, are small banks usually 20 to 50 cm high and built along the contour. These banks are built with the idea of catching and retaining all run-off water and allowing it to infiltrate slowly into the soil. Banks of this type can only be used effectively where the infiltration rate of the soil is high and the rainfall intensities are relatively low, because if one bank overtops and breaks, the whole system can fail.

With contour banks, cultivation is also carried out on the contour. This, in turn, helps to reduce run-off and erosion.

Graded banks with waterways

This is a very common system used over large areas of cereal growing land in different parts of the world. With this system, waterways are constructed either along natural depressions or along some other suitable selected lines. The waterway is graded to a more or less regular shape and then planted to grasses or trees.

Once vegetation is established, the waterway is not cultivated again, but is left as a permanent, safe disposal area for excess water. Banks are then constructed across the fields with a very slight grade or fall towards the waterways. Cultivation is then carried out on the contour between the banks. The principle of the system is that the contour cultivation and banks will allow maximum absorption of water, but when heavy or high intensity rains fall and the soil cannot absorb all the water, the excess water will run slowly along the banks at a velocity which will not cause erosion. When the water reaches the end of the banks, it can then run slowly down the waterways and be safely disposed of.

Bench terracing

This is probably the oldest and best known mechanical type of erosion control. Bench terracing is usually undertaken on slopes of between 12 and 35 percent, but sometimes on steeper slopes. It is usually applied to land which otherwise would be too steep to permit cultivation. With bench terracing, the land is levelled in a series of steps or benches. The principle of the system is that while the overall slope of a hillside remains the same, the sections to be cultivated (the benches) have been changed to level or near level areas.

This is a very effective way of controlling water erosion and a way of changing steep land into a form whereby it can be cropped. Unfortunately, it is normally expensive because of the large volume of soil which has to be moved and they require careful maintenance is subsequently required.

There are several different types of bench terraces varying in design from flat terraces to inward sloping or outward sloping terraces. Different designs are used according to the slope, soil, soil depth and proposed land use.

Wind Erosion

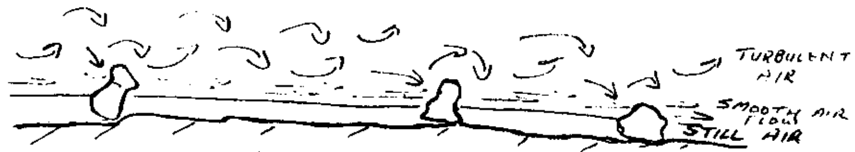
As with water erosion, a wide range of practices have been developed to control wind erosion.

Again, these can be conveniently divided between biological measures and mechanical or physical measures. In practice, there is an overlap between the two and soil conservation systems, to control wind erosion, frequently combine both biological and mechanical measures.

However, in the case of wind erosion, biological measures are the more important as the possibilities for mechanical erosion control are more limited than in the case of water erosion.

Without going into the details of the mechanics of wind erosion, the movement of soil particles is caused by wind forces exerted against the surface of the ground. As wind moves over the surface, it results in a gradient in velocity; the velocity being lowest near the ground and increases with height above the surface.

At some point, near the surface of the ground, usually in the range of 0.03 to 2.5 millimetres, for a bare, relatively smooth surface, the wind velocity is zero. For a very short distance above this level, the flow of air is smooth or laminar, and above this is turbulent air flow.



SMOOTH SURFACE

THIN LAYER OF STILL AIR

It is this turbulent air which produces the forces which cause soil movement. Soil particles, or other projections on the surface protruding into this layer of turbulent air, absorb most of the force exerted on the surface.

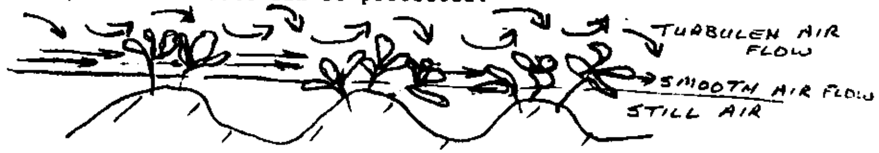
ROUGH SURFACE

ONLY TOP OF CLODS EXPOSED TO TURBULENT AIR

If these projections are sufficiently large, or firmly attached to other particles, they may resist the force of the wind. If, however, they are not attached, or light, the wind may lift them from the surface and initiate soil movement.

The factors determining soil movement by wind are therefore the size and density of detachable soil particles and the turbulent force acting on them. With a given surface configuration or roughness, the height of zero velocity is constant for all turbulent winds. However, the height of zero velocity is greatly influenced by the roughness of the surface.

It, therefore, follows that if we are able to increase the roughness of the surface, and if the protruding material is either too heavy, or too firmly attached to be removed by the wind, then the soil can be protected.



RIDGED SURFACE WITH VEGETATION

SOIL SURFACE COMPLETELY PROTECTED FROM TURBULENT AIR

In view of this, the four basic methods of wind erosion control are to:

(i) produce, or bring to the surface, aggregates or clods which are large enough to resist the wind force;

(ii) roughen the land surface to reduce wind velocity and trap any moving soil;

(iii) establish barriers, at intervals, to reduce surface wind velocities; and

(iv) establish and maintain vegetation, or vegetative residues, to protect the soil.

These principles apply everywhere but where they can be used, and in what combination, vary with local climate, soil and land use circumstances.

Examples of Soil Conservation Practices to Control Wind Erosion

As with water erosion, there are a great variety of different soil conservation practices and techniques used to control or prevent wind erosion. Some of the more common of these are as follows:

1. Cultivation to produce a rough surface - Tined implements are used in cultivation to bring surface clods to the surface. Seed beds are not worked to a fine tilth, while the use of implements like disc cultivators, which tend to pulverize the soil, are avoided.

2. Surface ridging - Where the soil is too dry or too sandy to form clods, the surface can be ridged in lines across the direction of the prevailing wind. This has much the same effect as producing a cloddy surface and the ridges tend to trap any moving soil.

3. The use of vegetative strips - Strips of vegetation may be planted at intervals across the direction of the prevailing wind to reduce the length of exposed bare surface areas.

4. Stubble mulch systems - These are cultivation systems designed to leave crop residues on the surface, or partly incorporated into the surface soil, to provide a protective cover at all times. Special equipment has been developed, such as deep furrow seed drills and weeders which allow cultivation and seeding through crop residue.

5. Wind breaks - Probably the best known method of controlling wind erosion is the use of trees and shrubs, grown in belts across the direction of prevailing winds. Care has to be taken in selecting the type of vegetation which will give the desired effect. A badly designed wind break can increase erosion.

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