Soil Tillage in the Tropics and Subtropics

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Arable crops can be successfully and permanently grown on these soils only when the pH value and the organic matter content can be increased and kept at acceptable levels. Many of the fields have to be drained. The latosols - typical soils in these regions - are difficult to cultivate. Since they tend to dry out considerably after being tilled, they are susceptible to erosion and have limited nutrient absorption capacity. So they should be kept under cover as long as possible. Tillage should be reduced to a minimum; "no-tillage" systems may perhaps be intermittently employed. When sufficient organic matter is available - as is often the case in these regions - the stability of the yields can be improved by an appropriate crop rotation combined with a gradual incorporation of adequatly pulverized organic material.
The climate usually allows crops to be grown throughout the year. This often means that harvesting and tillage operations for the next crop have to be carried out under adverse conditions. The soil will often be too wet; harvesting operations may compact or destroy the soil structure (puddling, creation of ruts).
It is essential to limit the number of operations. In addition to preventing erosion, weed control must be a primary objective of the tillage operations. Minimum-tillage methods which use plant residue as a protective mulch are beneficial as regards the soil structure and erosion control but usually fail because of (perennial) weed infestation.

3.4 Literature

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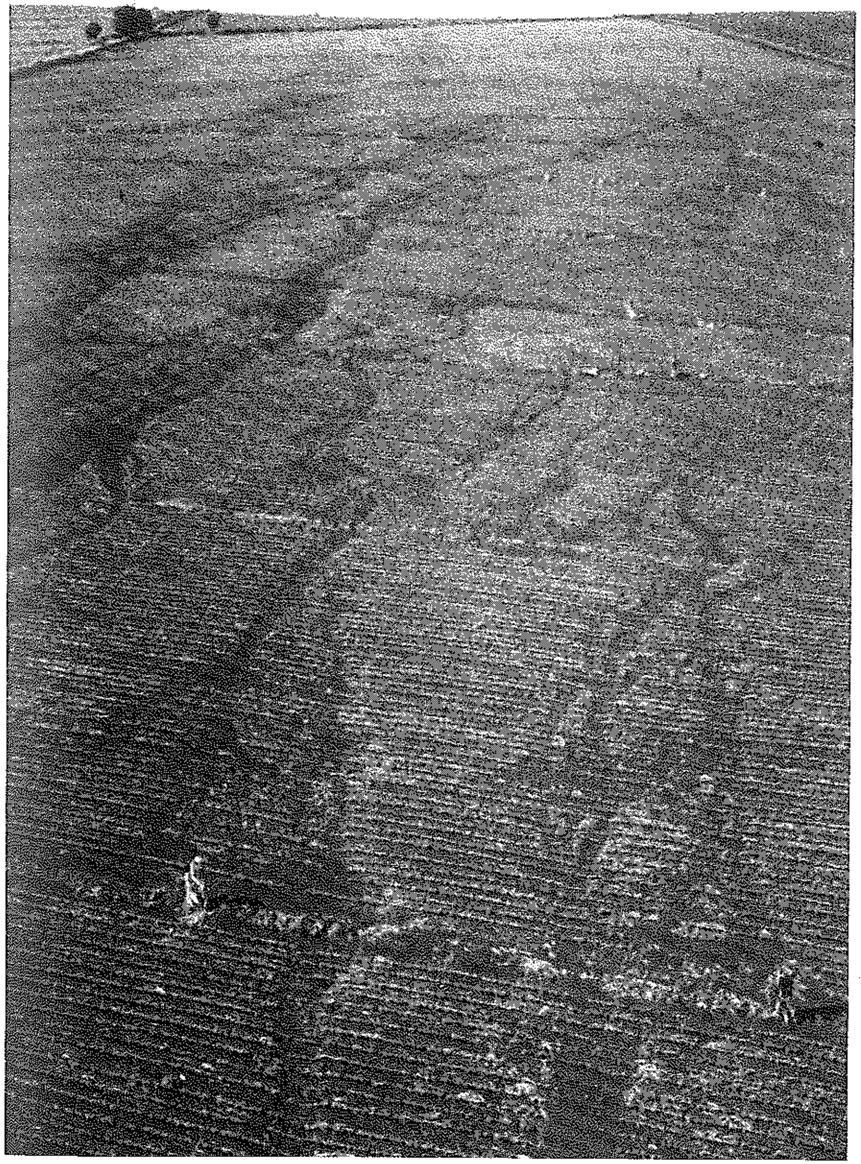
4.0 SOIL EROSION



Soil erosion can be defined as detachment and removal of soil particles by wind and water, especially the fine particles. The significance of soil erosion throughout the world should not be under-estimated: at least 15% of the world's total area of agricultural soils is (severely) damaged by erosion. Apart from a very small proportion of the damage which is caused by "natural" geophysical erosion processes, soil erosion is now the result of human influence. After the natural plant cover has been cleared, soil erosion can be induced by leaving the soil uncovered, by working the soil or by pulverizing the surface aggregates, to name only some of the causes. Even when improvement measures are applied, such as fertilization, irrigation or plant protection, negative results are produced if soil is lost by erosion.

There is no need to cite examples of the spectacular and disastrous effects erosion has caused, especially in tropical regions.

The damage resulting from erosion is serious from the agricultural point of view: losses of soil from fields with a shallow layer of fertile or cultivable soil may complete destroy the production potential. In Parana, Brazil, annual losses of up to 700 tonnes per ha have been reported. The damage is not confined to the loss of soil but includes losses of seeds and fertilizers and consequential losses, such as extra expense on resowing, more difficult farming operations, etc. In addition to the losses at the farm level, serious environmental problems arise, particularly pollution of rivers, harbours and reservoirs.

The two principal agents of soil erosion are wind and water; both will be briefly examined in this chapter before we formulate some general principles. Reference should be made to a recent FAO publication by Unger (1984) for a comprehensive examination of soil tillage systems from the point of view of erosion control.

4.1 Erosion By Wind

Wind erosion can be expected under the following conditions:
- a fine, loose and dry topsoil;
- a flat smooth surface with little or no vegetation or plant residue;
- a high windspeed (in case of fine sand, a minimum of 15 km/h at 30 cm above the surface).

The windspeed is virtually zero along the surface but increases logarithmically with height. At low speeds the wind flow is laminar but as speeds increase it becomes turbulent. Severe erosion can be expected when turbulence occurs because soil particles can then be carried up to higher wind layers. Three types of soil movement by wind can be distinguished:

a. SALTATION - This is a jumping motion which, in the case of certain light sandy soils, accounts for 50 - 70% of the soil transported by wind erosion. Saltation occurs mainly with particles having diameters of between 0.05 and 0.5 mm. The particles are lifted almost vertically, start to spin and are carried by the wind over a distance of approximately 10 - 15 times the height of the "jump". When they return to the surface, the impact can cause loosening and erosion of other particles. 90% of these particles do not "jump" higher than 30 cm and very few reach 1 m.

b. SUSPENSION - This occurs when, after being lifted by the saltation process, soil particles are raised by the wind-stream, possibly to heights of 2 - 3 km! This may cause a duststorm when large amounts of material are transported. Soil can be carried over long distances (loess deposits). It is estimated that of all the small particles (< 0.05 mm) transported 40% are moved by suspension.

c. CREEP - With this process particles (mainly 0.5 - 1 mm) are displaced by a rolling and sliding motion ("surface creep"). Extreme winds may take up particles larger than 1 mm but particles of more than 5 mm are rarely moved by wind.

There are two ways of preventing wind erosion:
- by increasing the resistance of particles to erosive forces,
- by reducing the wind-speed.

A vegetation cover is the most effective means but is difficult to establish in arid regions. Between the harvesting of annual crops and the emergence of the next crop a period will occur during which the soil surface is bare. A very young crop is also extremely sensitive to the impact of blowing sand particles (sand blasting). A layer of mulch provides some protection (stubble or plant residue worked into the surface). Tillage should aim at producing a coarse surface with large stable aggregates. The soil should be left uncovered for as short a time as possible. Tillage operations in moist (wet) conditions may form clods which are more resistant to wind erosion. Essentially, the line of direction of all the tilling, planting and sowing operations should transverse the prevailing wind direction. This alone may reduce the soil losses to as little as one-thirth of those which can be expected when the operations are carried out along the wind direction.

Soil losses or damage can also be prevented by "strip cropping". With this system alternate strips of erosion-resistant and erosion-susceptible crops are formed, again transversing the prevailing wind direction. The widths of these strips depend upon the soil type and range from 6 - 8 m on (loamy sand), 30 - 70 m on (sandy) loam to 130 m on silty loam. For practical reasons strips of less than 15 m should not be used for mechanized farming.

The implements suitable for tilling soils susceptible to wind erosion are the sweep (Chapter II.7.2), possibly fitted with a rod weeder, and the chisel plough (Chapter II.2.3). Ridges transversing the wind direction are also an effective means of controlling erosion; ridges 10 - 15 cm high are best (see Chapters II.4.7 and II.5.2).

Mechanical weed-control operations generally leave a fine surface; when use of herbicides can eliminate this operation, this is an effective erosion control measure.

4.2 Erosion By Water

Erosion by water occurs on sloping land with very intensive rainfall when it has no protection against the weather.
Two processes of water erosion can be distinguished:

a. The destruction or disintegration of larger soil aggregates to form smaller particles, often accompanied by separation of the particles into their size categories;

b. The detachment and removal of small particles by water falling on or flowing over the surface.

The soil particles are detached from the soil surface by the impact of the raindrops or by water flowing over the surface (when the speed of flow exceeds a specific minimum). The size and impact of the large raindrops are very important factors in this process of destruction and detachment (splash). The kinetic energy of the falling raindrops is generally employed as a parameter for determining the erosivity of the rainfall. This kinetic energy may be very high in the humid and semi-arid regions; in Africa, for example, it is at least twice and may even be six times as high as in the temperate zones. The very fine soil particles detached from the surface by the impact of heavy raindrops may obstruct the pores in the surface layer and considerably reduce the infiltration rate. This increases surface run-off and the risk of erosion. Silty soils are particularly susceptible to this process.

Even slight gradients (1 - 2%) or depressions are capablé of producing surface run-off with high flow velocities and thus cause damage by erosion. Generally speaking, three types of erosion by water can be distinguished:

a. SHEET erosion. Soil is removed uniformly from the entire surface. This type of erosion is not obvious to the eye but may nontheless cause considerable damage.
b. RILL erosion. Water run-off very soon starts to concentrate in small depressions (wheeltracks!) and removes the soil in the bottom of rills, sometimes right down to the bottom of the tilled layer. The rills can generally be restored by tillage (levelling) but the damage is considerable. If rill erosion occurs repeatedly, the topsoil of a field may be removed in a few years or seasons.
c. GULLY erosion. This is a more extreme form of rill erosion. Large concentrations of water running over a slope cut channels which are impassable to agricultural machinery and cannot be restored by tillage. In their extreme form, gullies may be several tens of metres deep, making the land almost unusable.

The damage caused by erosion:

- Loss of soil fertility owing to the removal of topsoil which contains nutrients, organic matter, soil organisms, etc.;
- Removal of seeds, seedlings or young plants, causing bare patches and usually reduced yields;
- Young plants are covered with eroded soil material, which also causes bare patches;
- Increased production costs when resowing is necessary (as is often the case in regions with a high risk of erosion). The extra costs are required for tillage, fertilizers, pre-emergence chemicals, seeds, and the actual resowing operation;
- Increasing wear and tear of the machine when rills and gullies have to be crossed;
- Deposits of eroded soil material in valleys;
- Streams are polluted and reservoirs become filled with soil.

The basic measures required for reducing or preventing water erosion are:

- Reducing the impact of the raindrops on the soil surface;
- Preventing the separation and destruction of soil aggregates;
- Increasing the infiltration rate of water into the soil;
- Reducting the flow velocity of the water running off over the surface.

The aim of every farming and crop production operation connected with water erosion should be to produce a dense plant cover and maintain that cover for as long as possible. A plant canopy can virtually eliminate the kinetic energy of raindrops. The degree of protection provided varies from crop to crop: for example, cotton is not very effective while cereals and soybeans give a good cover. A suitable type of crop rotation, mixed cropping systems or a system with intermediate cover crops can be very effective. The most suitable system does, however, depend upon many factors and must be tested on the site. Plant residue should not be buried but worked into the surface as mulch. Burning is very damaging from the point of view of protection against erosion and should be carried out only when essential for phytosanitary reasons.
Strip cropping has proved to be an effective way of preventing water erosion. Different crops are grown in alternate strips which follow the contour lines. The choice of crops ensures that some part of the field has plant cover at all times. When one strip is susceptible to erosion (especially around sowing time), the adjoining strip with its vegetation cover acts as a buffer and blocks surface flow.

The construction of contour dams or terraces is an engineering rather than an agricultural operation for controlling erosion. Dams can be built along the contour lines either by ploughing or by employing earth-moving equipment. The distance between the dams or the width of the strips depends upon the gradient, soil type and climate. Strips are not usually parallel and this arouses practical difficulties when they are cultivated. Special effort is required to work the entire surface area of long narrow fields. It is impossible to work crosswise when performing succesive tillage operations. On slight gradients the strips may deviate a little from the contour in order to form parallel borders.

One system which can be incorporated in normal farming operations is the "tied ridging" system whereby furrows between ridges which do not run along the contour line are blocked by cross-dams at regular intervals (depending upon the size of the ridge, the gradient, rainfall and soil type). This is a very effective system for preventing run-off and erosion but requires special equipment for constructing the cross-dams (Chapter II.4.7). The "ties" also impede other farming operations (they are usually knocked down and rebuilt in each operation).
Broad-based dams can be constructed on slopes with gradients of up to 6%. These dams form part of the field, are also used to grow crops and can be crossed and worked by machinery.

The actual distance between contour dams depends upon many factors: soil type, climate (rainfall intensity), gradient, etc. The recommended intervals may range from more than 100 m on soils with good drainage and a gradient of only 1% right down to 10 or 12 m on unstable soils on 15% gradients. Arable cropping should not be carried out on slopes with gradients of more than 15%.

Tillage implements which cause pronounced crumbling or pulverization of the soil should not be used. All operations should be carried out across the slope, following the contour lines. Conventional tillage operations for annual crops may particularly increase the risk of erosion. The usual sequence - ploughing and disc harrowing for seedbed preparation - buries plant residue and leaves a bare fine-grained topsoil. The structural stability of the aggregates may also be reduced, causing drying-out in the top layer and crust formation. The infiltration capacity of the soil is reduced and run-off begins more quickly. The infiltration capacity may also be reduced by the formation of less permeable layers in the profile by traffic or some tillage operations. A thin ploughsole may be formed by the smearing effect of blunt or incorrectly adjusted ploughshares and the weight of tractorwheels in the bottom or of heavy disc implements may produce a thicker compacted zone. In such cases the layer above that zone will soon become satured under heavy rainfall and this "mud" layer can easily be eroded.

There are a number of ways in which suitable tillage operations can help to control erosion:

- An adapted tillage system where as much crop residue as possible is kept near or on the soil surface as a mulch. This can be achieved by using implements such as chisel ploughs, sweeps, etc. The factors favouring this system are the large proportion of crop residue left on the surface and the ability of the implements to break up hard impermeable layers (pans), thus improving the infiltration capacity.
  The practical difficulties of this system are the amounts of plant material (which block the implements) and the sowing of the next crop (suitably adapted sowing equipment is necessary). Sufficient amounts of crop residue must also be available: at least 3 to 4 ton of material per ha to ensure reasonable protection.
- Very careful consideration must be given to the use of subsoilers for erosion control. They can be employed to break up compact impermeable layers but require considerably more power when working at depths of over 20 - 25 cm. A single subsoiling operation sufficient to destroy existing (natural) layers may be economical but repeated use as a primiry tillage operation is questionable not only because of the high energy consumption but also in view of the possibility of recompaction. A subsoiling operation is not effective when the subsoil is moist.
- Suitably adapted tillage systems may also be useful for cutting the time required for the operations. The period during which the soil is exposed to the weather can be shortened if the number of passes with tillage equipment is reduced. For example, the time during which the soil remains bare is shortened by combining primary and secondary tillage into one pass (or possibly even combining with sowing: see Chapter II.8) although the tillage intensity is maintained.
- The extreme form of adapted "tillage" is the no-tillage or direct drilling system whereby the surface is opened only for the purpose of placing the seed. This system is highly effective for controlling erosion and has received a great deal of attention throughout the world. It will be discussed in chapter II.10.

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