Soil Tillage in the Tropics and Subtropics

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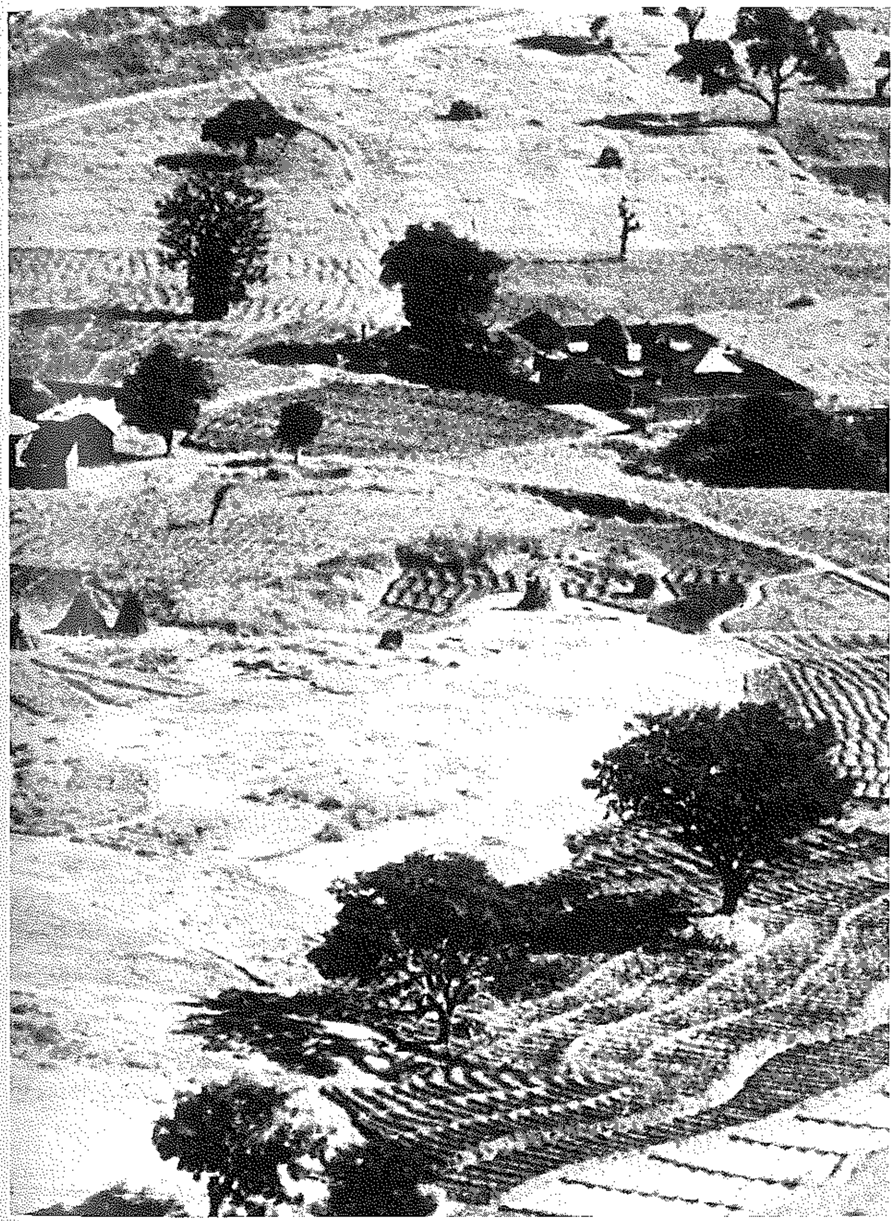
5.0 FARMING SYSTEMS AND SOIL TILLAGE



5.1 Dry (Rainfed) Farming

Rainfed farming is a crop production system employed in both temperate and tropical regions whereby the water required for the growth of the plants is supplied only by natural precipitation. Dryland farming is a special form of rainfed farming under arid conditions.

All the cultivation operations should be aimed at making optimum use of the (sometimes sparse) precipitation. As regards soil tillage this means that only those operations should be carried out which ensure that:

- as much precipitation as possible is absorbed by the soil. This also prevents or reduces surface run-off which causes erosion and water loss;
- the water holding capacity of the soil is increased (in particular in summer-rainfall areas);
- the organic matter content of the soil is preserved and, possibly, increased;
- unproductive evaporation is reduced;
- intensive weed control is achieved (since they are serious competitors for water).

The maximum amount of rainwater can be absorbed only if the soil surface is neither crusted nor compacted. This means that an erosion-resistant coarse cloddy surface covered with plant residue must be created - preferably before the rainy season begins. When a surface crust has been formed by intensive rainfall, it must be broken up by means of a superficial loosening operation; only methods which leave trash on the surface should be employed and not soil-inverting operations.

These operations can also reduce the water-loss caused by evaporation. The sweep, cultivator and crust-breaking rollers are suitable implements. These operations are also usually effective in controlling weeds. The tillage operations may be carried out in fixed patterns or rows, thus forming contour ridges to prevent erosion.

The water holding capacity of the soil can be improved only by increasing the soil pore volume. Losses caused by deep drainage through cracks in heavy soils should, however, be prevented. A deep (non-inverting) loosening operation may be considered but this also facilitates aeration and thus evaporation and accelerated decomposition of organic matter. A compromise must be found allowing for the fact that the possibilities of increasing the pore volume by tillage are limited and the water intake is a much more important factor.

The preservation and augmentation of the soil's organic matter causes problems in semi-arid regions because the decomposition rate is rapid under the high temperatures, particularly when moisture is available. This objective can be achieved by:

- Keeping the plant residue in the soil when possible (there may be a risk of pests, etc.) , instead of burning it, as is often the case with crops such as cotton, sugarcane and wheat;
- Leaving the plant residue on the surface during the dry season and mulching it only at the start of the next rainy season. In this way the trash acts as a protective cover against soil erosion and dries out, thus retarding decomposition. When it is worked in immediately after the harvest, a small amount of moisture is sufficient to initiate decomposition. This method also provides better erosion control. Weeds and pests have to be controlled by chemicals.

- Introduction of a suitably adapted crop rotation. Basically, two types of dryland farming may be distinguished:

a. Rotation between natural pastures, to collect water and improve fertility, and cultivation of plants with low water demands and correspondingly low yields. This system of shifting cultivation has a long cycle (in the order of 10 or more years, depending on climate) with low capital input and low production costs.

b. Production of crops in a system demanding higher input without fallow, or with one or more fallow years to collect water and/or store surface water in small ponds to be used for supplemental irrigation. The soil under fallow may be kept bare by repeated tillage; the resulting "dust mulch" is very susceptible to erosion. Growth of water-use efficient (cover) crops can combine a high production of root mass (organic matter) with surface protection. This latter system is used with success in Australia; in between cropping periods (cereals), there is a period with "grazed fallow". Sheep are allowed to graze on the fields which are sown with subterranean clover and other water-use efficient legumes or grasses. Main benefits involved in this "ley farming" system are accumulation of organic matter and nutrients and a better structure, rather than an improved water supply.

5.2 Irrigated Farming

In areas where water is the restrictive growth factor during (part of) the growing period, it should be possible to supply water at the correct time and in sufficient amounts by means of a properly-designed irrigation system.

Crop production conditions can be completely changed by irrigation (different types of crops, a more closely integrated rotation, higher yields, stronger weed growth and a need for additional operations).

Three types of irrigation can be distinguished, depending upon the method by which water is conveyed and supplied to the plant:

- SURFACE irrigation. Water is transported by (open) canals from the source to the fields (either entirely by gravity or with the help of water-lifting units). The water is applied to the field by an open furrow system of flooding.
- SPRINKLER irrigation. Water is pumped from the source to the field in a pressurized (closed) system. Water is applied to the field by aerial spraying through sprinklers.
- TRICKLE irrigation. Here again, water is transported to the field in a pressurized system but is fed very slowly to the soil adjoining the plant through (rubber) tubes or hoses.

All these irrigation systems have a considerable influence upon the soil tillage system, an influence which is most pronounced in the case of surface irrigation in which the soil becomes a component of the irrigation system. Special tillage operations may be needed to:

- level the fields to ensure uniform water distribution;
- construct dams, furrows or rills to convey water;
- supply and distribute water on the field and remove excess water.

There are, however, a three other essential processes of irrigated farming which require special soil manipulation operations:

1. Irrigation water usually contains salts in solution which remain in the soil after the water has evaporated (very quickly in arid regions). These

salts accumulate in the soil, crystallize on the surface or reach the groundwater.

2. The repeated wetting and drying cycles (which often increase the soil moisture content to levels above field capacity) may cause considerable swelling and shrinkage of the soil.
3. The application of water may cause slaking (erosion, crust formation) and consolidation (compaction) of the soil.

So soil tillage should produce soil with a high infiltration capacity, good internal drainage and good capacities for removing surplus water. These objectives can be achieved by creating large stable soil aggregates and a continuous macropore system and by preventing or destroying dense layers.

When layering is caused by the combined effect of tillage and irrigation (e.g. puddling), the top layer can again be made homogeneous again by inverting ploughing operations. In hot climates the tillage - and especially deep tillage - should be carried out shortly before the growing period. The aeration of the soil resulting from the tillage causes pronounced mineralization and nitrification of the organic matter; in particular, nitrogen may be leached away. More attention should be given to spreading the fertilizer applications over the entire season in order to reduce leaching losses. One main advantage of irrigation is that it makes it possible to supply water to the soil irrespective of the weather; the soil consistency, which depends upon the moisture content, can be altered to create optimum conditions for soil tillage (energy and time saving, better results from the tillage operations). On the other hand, the timing of the irrigation should take account of the fact that soil is impassable and/or unworkable for some time after a water input, not only in the pre- sowing period but also during the growing period (maintenance tillage).

Although, as regards soil tillage, sprinkler and trickle irrigation cause less problems than surface irrigation, some important aspects should be considered. For example:
- the layout of the water distribution system is usually permanently fixed in the field. The locations of the water outlets restrict the choice of different patterns of plant rows, beds, etc. On sloping fields in particular, this restricts the flexibility of the tillage system;
- the freedom of manoeuvre on the field may be restricted when tubes or pipes are laid down.
- a trickle irrigation system cannot be used for pre-tillage conditioning of the soil.

The installation of irrigation systems involves a high capital investment which can be amortized only by higher yields. Measures for increasing production should include in particular properly-adapted tillage methods.

5.3 Cultivation And Harvest Practices

A large number of crops, such as potatoes, groundnuts, maize, sunflowers, sugarbeet, cotton and many types of vegetables, are grown on beds or ridges. The ridges (and furrows) are usually formed immediately before sowing or planting but can also be constructed after the previous crop has been harvested. Small ridges may even be created during the growing period, e.g. as part of the weeding operation.

The tillage operation employed to construct the ridges may be carried out for various reasons:
- water and temperature control in the soil;
- furrow irrigation;
- erosion control;
- to improve the efficiency of the harvesting methods.

With furrow irrigation the plants stand on the top or shoulder of the ridges and the furrows are used for supplying water to the crop. The aim of the tillage should be to wet the ridges uniformly over their entire length (slight but constant gradient). The machinery used has to fulfil different functions depending upon the conditions of the field and soil; sometimes a low infiltration rate in a clean furrow is better (long gentle slopes) while completely opposite requirements may obtain in other cases (short steeper slopes). On very permeable soils the bottoms of the furrows may even have to be compacted to prevent too much water infiltration at the beginning of the furrow near the water inlet.

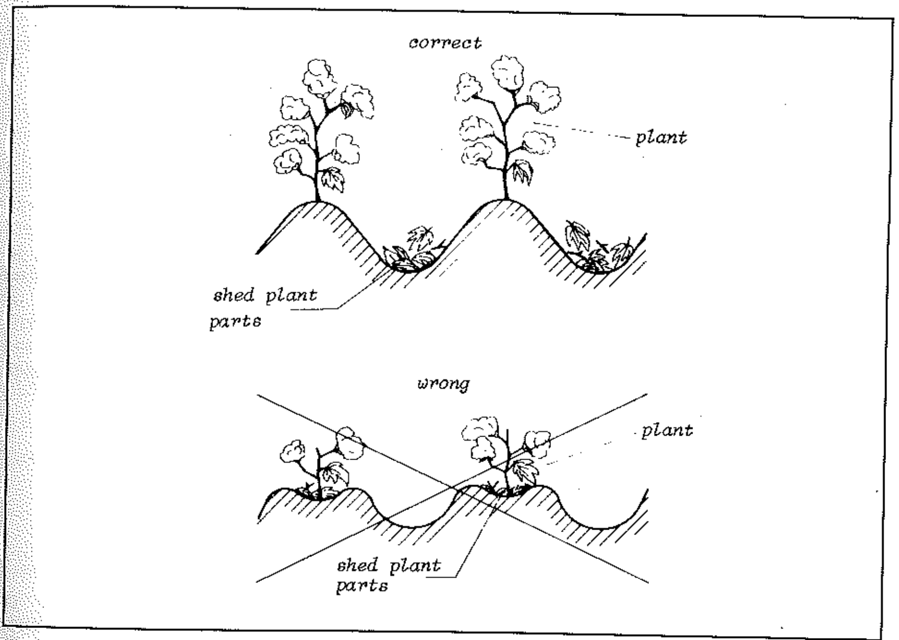


Fig. 16. Ridge shapes for cotton; Dead leaves should drop in the furrow (top fig.) and not on the top of the ridge (bottom fig.).

Erosion can be reduced and gully formation prevented by measures which decelerate the flow in the furrows or by growing crops in ridges which follow the contours. The latter method may be particularly effective in summer-rainfall regions but the ridges must be large enough not to collapse. If they do, the damage caused by "crossflow" can be very serious. All the rainwater should infiltrate in the furrows and so the soil should be kept loose in case the infiltration capacity is too low.

When rainfall distribution and intensity are such that the risk of crossflow is too great, the furrows may be formed with a slight gradient (about 0.5%) so that surface drainage can be controlled.

Some harvesting methods require that the crops are grown in ridges (e.g. minimum movement of the soil when digging potatoes or groundnuts). When cotton-picking machines are used the crop is best grown on ridges. The ridges should have the shape shown in Fig. 16 with the plants sited on the crest. In this way all the leaves shed before the harvest are deposited at the bottom of the furrow and cannot be caught up by the picking machine and foul the cotton. Cotton is also grown in beds with the same widths as the picking machine (this is approx. 2 m for dual-row machines).

For various reasons mechanized harvesting often cuts sugarcane directly below the surface of the soil. This is facilitated if the cane is grown on (small) ridges.

Maize is often sown in the furrows while the ridges are used to bury the residue of the previous crop. Ridges can also be split open after the harvest to cover the residue lying in the former furrows and to form new furrows under the previous ridges. This system makes it possible to prepare a new surface configuration and seedbed in one pass while permitting thorough movement of the soil (loosening).

Under some climatic conditions slow warming and/or drying of the soils (especially heavy soils) in spring can cause problems. The preparation of the seedbed may be delayed because the soil is unsuitable for traffic while sowing should be as early as possible. These conditions obtain, for example, in the northern part of the US Corn Belt (wet and cold in spring) and in Israel's Mediterranean climate (wet or moist conditions in spring). In the Corn Belt, advantage should be taken of the short hot summer while in Israel optimum use should be made of the rainwater stored in the soil during the winter. Consequently, ridges and beds can be prepared in the autumn so that sowing can take place as early as possible in the spring without the need for further preparation. This method can save at least one and possibly two weeks. The speed at which the soil is warmed is also increased by aligning the ridges along an east-west axis.

5.4 Literature

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PART II

Tillage Equipment and Operations