Chapter 3

Tillage systems

DEFINITIONS

The term "tillage" is a generic term and is used broadly. Tillage embraces all operations of seedbed preparation that optimize soil and environmental conditions for seed germination, seedling establishment and crop growth. It includes: mechanical methods based on conventional techniques of ploughing and harrowing; weed control using chemical herbicides and growth regulators; and fallowing with an aggressive cover crop that can be easily controlled for direct seeding through its residue mulch. There is a wide range of tillage systems used in the tropics, the chief of which are described below.

Traditional tillage

Farmers in the tropics employ several traditional methods of seedbed preparation. Traditionally, weeds and bush regrowth are slashed manually and left on the soil as mulch or are burnt *in situ*. The land is then hand-hoed, often superficially. Farmers also make mounds or ridges, often with manually-operated hoes or with equipment drawn by draught animals. Mounds, ridges and other forms of raised beds are widely used throughout the tropics. On poorly-drained soils in southeastern Nigeria, large mounds are constructed. These are often 3-4 m in circumference, and about 1 m high. Various crops are grown on top of the mounds, and rice is sown between them. Raised beds are specifically constructed to grow vegetable crops in swamps in eastern Cameroon. A slightly modified version of the mound system is used in Zaire. In the "Mofuku" system, crop residue and weeds are buried in the mound. The residue is later burnt. A similar system using ridges and burning residue is used in Ethiopia.

Traditionally, farmers mulch the mounds with crop and weed residues. The practice of mixed cropping provides a continuous ground cover that protects the soil against erosion and improves soil temperature and moisture regimes. The technique of building mounds is also useful in concentrating nutrient-rich surface soil. With the native method of cultivation, mounding is clearly beneficial, especially when mixed cropping is practised with little or no fertilizer input. This practice is only slightly superior to a mulched flat seedbed on which inorganic fertilizers are applied. On some shallow soils, crops are sown in depressions rather than on mounds. The depressions help conserve water and minimize risks of drought.

Plough-till

This system is based on mechanical soil manipulation of an entire field, and involves mouldboard ploughing followed by one or two harrowings. Plough-till embraces primary cultivation based on ploughing or soil inversion, secondary

cultivation using discs, and tertiary working by cultivators and harrows. These tools are often drawn by animals or by tractors and other mechanically-powered devices.

The mechanical soil disturbance involved increases the risk of erosion. Ploughing removes the vegetation cover and exposes the soil to rainfall, wind, and overland flow. The technique gives a weed-free seedbed, incorporates fertilizer and improves soil conditions.

The effects of tillage methods on soil properties and on the erosion risk are hard to generalize. The effects vary depending on basic soil properties. For example, where the soil has favourable structure with a high proportion of water-stable aggregates, and is permeable, mechanical soil disturbance is likely to increase the risks of soil erosion. On the other hand, where the soil has a smooth crusted surface and compacted subsoil horizons, massive non-porous unstable structure, carefully-judged, timely mechanical tillage is likely to decrease the risks of soil erosion, at least temporarily.

Conservation tillage (CT)

The term *conservation tillage* has been used for varied tillage practices under a range of conditions (Mannering and Fenster, 1983). The vague use of the term for differing situations has created confusion and misunderstanding. The term encompasses a broad spectrum of practices ranging from no-till to intensive tillage, depending on soil conditions.

Conservation tillage has been defined as "any tillage sequence that reduces the loss of soil or water relative to plough-till"; often it is a form of non-inversion tillage that retains a protective layer of mulch. The key techniques used for soil and water conservation are (1) residue mulches and (2) an increase in surface roughness. Increases in surface roughness can be achieved by chisel ploughing, strip tillage, ridge-furrow systems, or tillage methods that cause soil inversion. If done at the right soil moisture content and with the right equipment, inversion tillage can produce an almost ideal rough seedbed. Adequate supplies of mulching materials are not always available. In such situations, conservation tillage techniques may include contour ridges, tied ridges, camber bed system, and broadbed and furrow systems. In the light of the above, a broad definition of conservation tillage, such as that of Wittmus *et al*. (1973), seems appropriate: "conservation tillage includes tillage systems that create as good an environment as possible for the growing crop and that optimize the conservation of soil and water resources, consistent with sound economic practices."

Some commonly used practices used under the generic term of CT are described below:

No-till: When a crop is planted directly into a seedbed that has not been tilled since the previous seedbed it is called a *no-till* or *no-tillage system*. The maximum amount of crop residue is retained on the surface, and weeds are controlled by chemicals, by residue mulch, by using an aggressive cover crop, or by a combination of these methods. If a soil is disturbed at harvesting, as in the case of root crops, some workers argue the system is no longer a no-till system. According to the definition given here, however, soil disturbance at harvest is allowed in a no-till system.

Minimum-till: The term *minimum-till* has caused the greatest confusion because the minimum cultivation required to grow a crop successfully varies from zero to a complete range of primary and secondary tillage operations

depending on soil properties and crops. It is commonly defined as "the minimum soil manipulation necessary for crop production or meeting tillage requirements under the existing soil and climatic conditions". It often means any system that has few tillage requirements. It may also mean tillage of only part of the land e.g. strip tillage or zonal tillage. Minimum-till may also refer to a "stale-bed" system in which the soil is ploughed at the end of the previous crop cycle. The crop is then seeded with a minimum of seedbed preparation performed at the onset of the next rains. This is commonly recommended for soils in the semi-arid tropics in west Africa (Charreau and Nicou, 1971).

Mulch tillage: A tillage system that ensures a maximum retention of crop residue on the soil surface is called *mulch tillage* or *stubble mulch farming*. The soil is prepared in such a way that plant residues or other mulching materials are specifically left on or near the surface. Mulch tillage is a broad term. It includes practices such as no-till, disk plant systems, chisel plant systems, and strip tillage systems. When a grain crop is seeded through the mulch of a chemically killed cover crop, it is called *sod seeding*. If the crop cover is untreated or only temporarily suppressed, the system is called *live mulch.*

When a cover crop, usually a legume, is specifically grown within the cropping cycle to produce mulch material, the system is called *planted fallow.* Another variant of planted fallowing, practised in North America, is referred to as *summer fallow* or *ecofallow.* The latter is a system of fallowing in which weed growth is restricted by shallow cultivation or by using herbicides to conserve soil moisture. Crops are grown every other year or once in 3 years. This type of "cropless" fallow is mostly used in arid climates to conserve soil moisture.

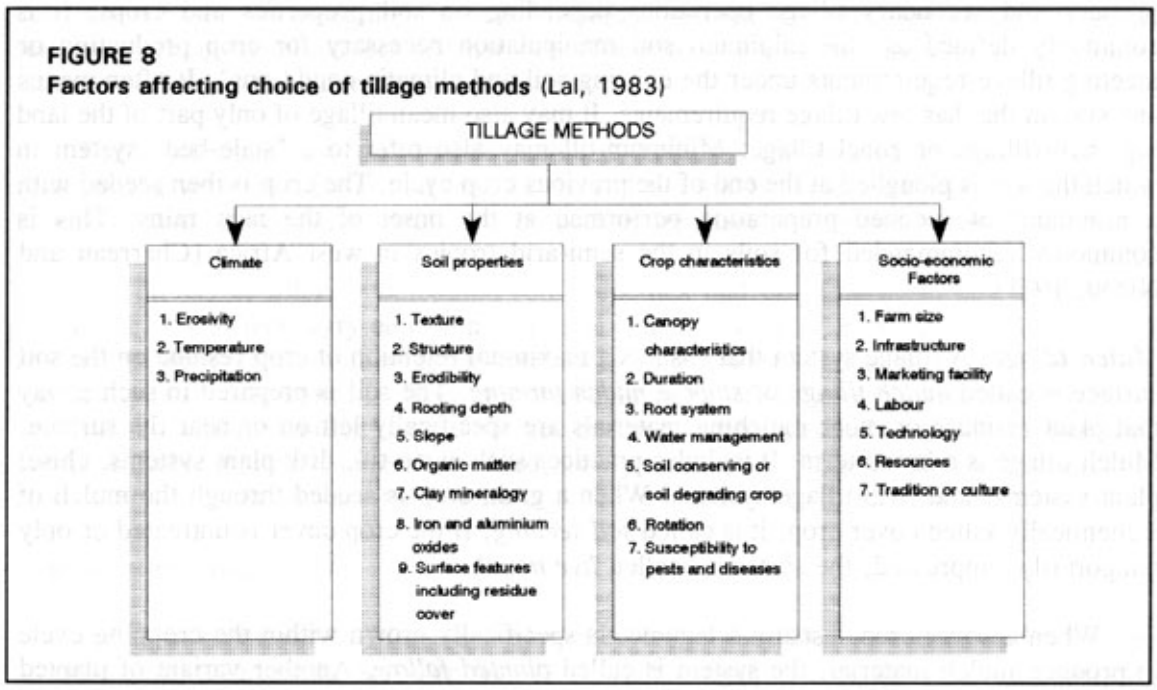
Mulch tillage is also practised within agroforestry systems. A common practice is alley cropping, where annual food crops are grown between widely spaced hedges of perennial shrubs. The hedges are planted on the contour and are regularly pruned to provide mulch.

Ridge tillage: The practice of planting or seeding crops on ridges is widespread in both temperate and tropical climates. The crop row may be planted on the ridgetop, along both ridge sides, or in the furrow. Ridge tillage facilitates mixed cropping systems in which more than one crop can be grown simultaneously in the same plot of land, a common practice throughout the tropics and subtropics (Bradfield, 1970). The ridges may be made every season. Alternatively, in a semi-permanent ridge-furrow system, necessary repairs are done at the onset of a new cropping cycle. The ridges may be on the contour with graded furrows draining into a grassed waterway, or the ridges may have short cross-ties to create a series of basins to store water. The latter system with cross-ties is called the *tied-ridge system.*

QUALIFYING CRITERIA FOR CONSERVATION TILLAGE

The criteria to be met for a method of seedbed preparation to be considered as conservation tillage include:

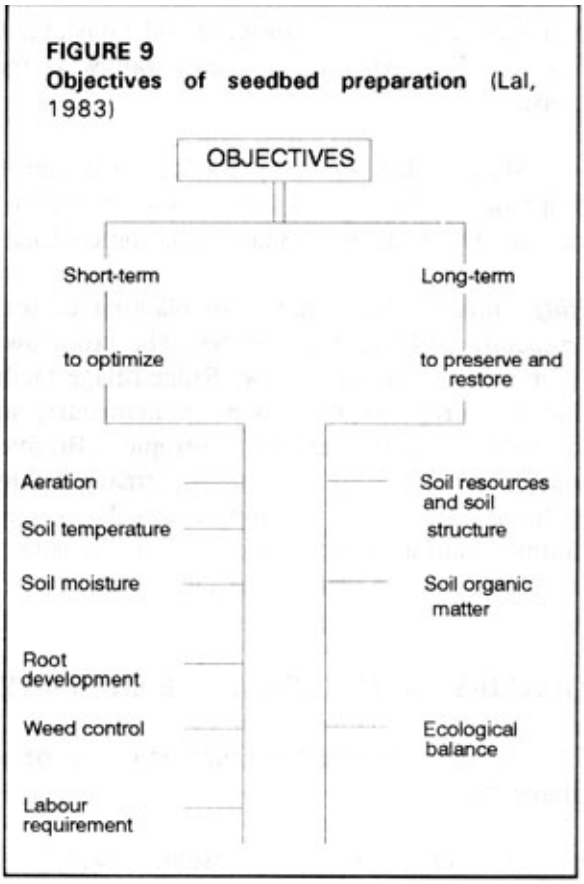
- the presence of a crop residue mulch;
- effective conservation of soil and water;
- maintenance or improvement of soil structure and organic matter content;



- maintenance of a high and economic level of productivity;
- minimum need for chemical amendments and pesticides;
- preservation of ecological stability;
- minimum pollution of natural waters and environments.

These criteria can be satisfied by various cultural practices, including:

- adopting non-inversion or no-till systems;
- using crop rotations based on cover crops, buffer strips, and/or agro-forestry;
- improving infiltration capacity of soil by crop rotation with deep-rooted perennials;
- increasing surface detention capacity of the soil through using rough and cloddy seed-beds and ridge-furrow systems;
- enhancing the biological activity of the soil fauna;
- reducing cropping intensity to conserve soil and water resources and improve soil fertility.



FACTORS AFFECTING THE CHOICE OF TILLAGE SYSTEM

The choice of an appropriate tillage system depends on factors listed in Figure 8.

In the short-term, choice of tillage method also depends on the objectives of seedbed preparation. For the immediate crop these are to optimize soil and environmental conditions for seed germination, seedling establishment and crop growth (Figure 9). In the long-term, however, methods of seedbed preparation should aim to maintain or improve soil organic matter content and soil structure, and enhance pore stability and continuity. The methods adopted should meet both short- and long-term requirements.

TILLAGE METHODS AND SOCIO-ECONOMIC FACTORS

These include farm size, land tenure system, credit availability, source of power, educational status of the family, family structure, and the role of the sexes.

Farm Size: Most farms in the tropics are less than 5 hectares and it is difficult for them to adopt improved tillage tools and herbicides. In some countries, as much as 80% of the population depends on agriculture. It is desirable that other kinds of jobs are developed so that pressure is taken off the farms and farm size can be increased to allow farmers to adopt modern tools and improved technology.

Land Tenure Systems: Community ownership and transient rights to use land do not encourage investment to improve farm conditions. Where the land is owned by the village chief, the right to cultivate it can be withdrawn at will.

Credit Availability: Credit on fair terms is rarely available for resource-poor farmers to adopt improved technology.

Power Sources: It is estimated that as much as 80% of the arable land in sub-Saharan Africa is cultivated manually. Draught animals are rarely used, especially in the tsetse fly-infested areas of the humid forest regions. Large farms cannot be worked effectively by hoe and machete.

Education: Most farmers are illiterate, and often unaware of improved systems of soil and crop management and their availability. This is not to say that uneducated farmers cannot comprehend the usefulness of science-based technology.

Family Structure: Most farm families are large. Although the causes and effects are difficult to separate, the availability of cheap labour may hinder the adoption of labour-saving technology.

Role of Women: In sub-Saharan Africa, food crop farming is predominantly done by women. Credit is not usually available for women farmers. The design of tools and planning of tillage systems should take their role into account.