Chapter 7

The challenge of tillage development in African agriculture

Tillage has been an important aspect of technological development in the evolution of agriculture, in particular in food production. The objectives of tilling the soil include seedbed preparation, water and soil conservation and weed control. Tillage has various physical, chemical and biological effects on the soil both beneficial and degrading, depending on the appropriateness or otherwise of the methods used. The physical effects such as aggregate-stability, infiltration rate, soil and water conservation, in particular, have direct influence on soil productivity and sustainability.

Tillage technology began with the use of stick or metal jab for seeding and with gradual agricultural development the technology passed through a phase of ploughing - animal-drawn ploughs, subsequently followed by tractor-drawn implements and recently with more powerful machinery. At the centre of all this development, is the availability and employment of energy sources. In developed countries and in some developing countries today, fossil fuel is the main energy source, whilst in most developing tropical countries human labour is still predominant. However, animal draught power has been the tradition in many developing countries, particularly in the semi-arid tropics. A major constraint on the use of animals is and has been the availability of adequate fodder.

Recently, many developing countries have introduced tractors and various implements in attempts to increase food production. The general lesson learnt in most such countries is that often the machinery chosen has not been matched to the various agro-ecological zones and soil types. Furthermore technicians engaged in the tillage operations have not been properly trained. This has resulted in widespread soil degradation and loss in soil productivity.

Today there are major problems facing the modernization of African agriculture. Food production must necessarily keep pace with population growth. Many countries will soon have limited new land for agricultural development leaving no alternative other than intensifying yield per unit area. Soil management and conservation must play a major role in increasing crop yields and soil productivity on a sustainable basis.

Tillage and residue management which have direct influence on soil and water conservation are two important components of soil management in Africa, especially in the semi-arid tropics. This agro-ecological zone has a great potential for increased agricultural roductivity but at the same time poses a major challenge due to the various soil and climatic constraints, and the ease with which serious soil degradation occurs if farm operations are not carefully managed.

Tillage aspects of soil management, in particular, research, development and technology transfer to users to increase agricultural production in Africa are discussed and highlighted in this paper.

TILLAGE EFFECTS ON SOIL AND CROP PRODUCTION

One of the basic and important components of agricultural production technology is soil tillage. Various forms of tillage are practised throughout the world, ranging from the use of simple stick or jab to the sophisticated para-plough. The practices developed, with whatever equipment used, can be broadly classified into no tillage, minimum tillage, conservation tillage and conventional tillage. Energy plays a key role in the various tillage systems.

An important question underlying all these practices is: why till? Much has been written on this topic and it can be summarized as follows:

- seedbed preparation
- soil and water conservation
- erosion prevention
- loosening compacted soil
- weed control

The best management practices usually entail the least amount of tillage necessary to grow the desired crop. This not only involves a substantial saving in energy costs, but also ensures that a resource base, namely the soil, is maintained to produce on a sustainable basis.

Tillage Effect on Soil Properties

Tillage affects soil physical, chemical and biological properties. Research results have been widely reported on the effects of tillage on soil aggregation, temperature, water infiltration and retention as the main physical parameters affected. The magnitude of the changes depends on soil types as well as soil composition. Changes in chemical properties are dependent mainly on the organic matter content of the soils. Tillage affects aeration and thus the rate of organic matter decomposition. Biological activities in the soil are vital to soil productivity through the activities of earthworms, termites and the many other living creatures in the soil. These influence water infiltration rates by their burrowing in the soil and their mucilage promotes soil aggregation.

Tillage effects on soils are closely related to the management of crop residues in and on the surface of the soil. Unger *et al.* (1991) point out that the two practices with major impact on soil conservation are crop residue management and tillage. The traditional ploughing-in of crop residues is now giving way to surface soil residue management, which is more related to soil and water conservation, particularly in the semi-arid tropics.

Tillage Effect on Crop Yield

A large volume of experimental data has been published on tillage effects on crop yields under various climates, agro-ecological conditions, soils, crops and residue management systems. Under some of these conditions, the tillage effect is either closely linked to soil aggregation, hence water infiltration rate and water storage capacity, or indirectly related to soil and water conservation. Moisture conservation is particularly important in semi-arid conditions.

Soil types and their various reactions to tillage are of paramount importance in determining the superiority of one practice over the other. Socio-economic considerations, however, should always be taken into account in decision making for the adoption of one practice over another. Difficulties have arisen in the past because limited information was given on soil types when comparing one tillage treatment with another. There must be some caution with technology transfer from one agro-ecological zone or one soil type to the other.

There has also been some confusion with the treatment regarded as no-tillage. Whereas in some cases, surface soil was mulched, or herbicides used to kill weeds *in situ*, there have been many instances in which residues were removed. In such cases comparison becomes not only difficult but conclusions are drawn which may not apply to similar agro-ecological conditions and soils.

Tillage effects may differ from one agro-ecological zone to the other. In semi-arid regions moisture conservation is one of the key factors to consider. Nicou and Chopart (1979) show the importance of tillage and residue management on soil profile water content. The soil was mechanically tilled to a depth of 20-30 cm (Table 14).

TABLE 14
Effect of tillage system on profile water content to a depth of 1 m at 2 weeks after planting (Nicou and Chopart 1979)

Tillage system	Profile water content (mm)
No till, residues burnt	49.4
Ploughing, residues incorporated	95.8
Ploughing, residues incorporated followed by addition of external mulch	103.7

Results reported by several workers show the importance of tillage effects on soil moisture (Lal 1977; Klute 1982; Norwood *et al*. 1990).

The effect of tillage systems on crop yield is not uniform with all crop species, in the same manner as various soils may react differently to the same tillage practice. Results presented by Nicou and Charreau (1985) (Table 15) show the effect of tillage on yields of various crops in the West African semi-arid tropics. Cotton showed the smallest yield increase with tillage within the range of crops tested.

Tillage effects in semi-arid zones are closely linked to moisture conservation and hence the management of crop residues. Unger *et al*. (1991), Larson 1979, Brown *et al*. 1989, Thomas *et al*. 1990 and other researchers emphasize the link between crop residue management and tillage and recognize them as the two practices with major impact on soil conservation in the semi-arid zones.

TABLE 15

Effect of tillage on crop yields in the West African semi-arid tropics (Nicou and Charreau 1985)

Crop	Number of annual results	Yield (kg ha^{-1})		Yield increase (%)
		control	with tillage	
Millet	38	1558	1894	22
Sorghum	86	1691	2118	25
Maize	31	1893	2791	50
Rice	20	1164	2367	103
Cotton	28	1322	1550	17
Groundnut	46	1259	1556	24

TABLE 16

Effect of cropping sequence and residue management on cowpea reproductive physiology and grain yield in the Sudan Savannah of Burkina Faso (IITA/SAFGRAD 1985)

Preceding crop	Residue management system[1]	Date of flowering[2]	Date of maturity[2]	Yield (kg ha^{-1})
Maize	Residues removed	48.7	71.2	436
Crotalaria	Residues retained	46.6	69.2	918
Maize	Residues retained	45.7	68.5	921
	LSD (0.05)	1.6	1.0	175

[1] No tillage in all treatments
[2] Number of days after planting

TABLE 17

Effect of different tillage treatments on sorghum grain yield, runoff and soil loss, Luvisol (ICRISAT Centre 1983-1987) (ICRISAT 1988)

Treatment	Sorghum grain yield[1]	Runoff[2] (mm)	Soil loss[2] (t ha^{-1})
10 cm deep traditional ploughing	2.52	128	1.66
15 cm non inverted primary tillage	2.83	102	1.62
15 cm deep mouldboard ploughing	2.76	106	1.70
25 cm deep mouldboard ploughing	3.22	85	1.41
s.e.	+0.07	+4.9	+0.279

[1] Average values of four years (1983, 1984, 1986 and 1987)
[2] Average values of 1986 and 1987

Residue retention in a cropping system in Burkina Faso significantly increased the yield of cowpeas as shown in Table 16.

Adequate quantities of residues retained increase porosity, water infiltration and water storage. Other effects of different tillage practices on sorghum yield are presented in Table 17.

On the Luvisol in this experiment, deep ploughing increased grain sorghum yield over other treatments. Many results reported in literature show crop yields under conventional tillage as superior to those under conservation tillage. There are, however, also many other results which show the reverse. In both cases the economics of the tillage input are not considered, namely energy and labour costs as well as capital investment in equipment. With tillage effect on soils, both short and long term effects must be considered in working out the economics of a system.

It is evident from the extensive published data on tillage that the effect on crop yield and soil differs with soil conditions. Generalization and technology transfer should be treated therefore with more caution than hitherto. The choice of tillage methods depends on several factors but soil properties play an important role in determining intensity, frequency and type of tillage required. Many developing countries therefore will benefit, making full use of their soil data in acquiring tillage technology packages developed elsewhere. In addition to the soil factors, climatic factors such as soil temperature regimes, rainfall characteristics and length of growing season should be taken into account (Lal 1985). The relationship between tillage and climate underscores the importance of soil and crop specificity in determining the exact nature of tillage operations.

Under semi-arid conditions in India (Rao *et al*. 1986) conventional tillage is superior to no tillage, reduced tillage or mulching with a number of crops - sun hemp (*Crotalaria juncea*), barley (*Hordeum vulgare*), mustard (*Brassica juncea*) and chickpea (*Cicer arietinum*) grown in the dry season. In West African semi-arid regions, Nicou (1977) and Charreau (1972; 1977) obtained data which showed soil inversion and deep ploughing superior to no tillage in increasing plant-available water and crop yields. similar data showing greater responses to tillage than no tillage or greatly reduced tillage were reported by Karaca *et al*. (1988), Prihar and Jalota (1988), and Willcocks (1988) on a variety of soils. Several workers in the United States and elsewhere have found conservation tillage superior and a more cost effective farming practice than conventional tillage (Underwood *et al*. 1984; Frengley 1983, Stonehouse 1991) on some soils and under certain climatic conditions. Although conservation tillage is being widely adopted, for example, in the United States, generalization should be avoided. There is strong evidence that soils prone to surface crusting and sealing would benefit from conventional tillage once every 2 or 3 years.

APPROACH TO TILLAGE DEVELOPMENT IN AFRICA

Tillage research in developed countries has progressed alongside equipment development. In Africa, the limited range of tillage research and the neglect of small scale tool development has had an adverse effect on food production, since the bulk of the food is produced by small scale farmers. The situation is complicated by complex factors such as increased population and food demand, exodus of youth from rural areas and the ageing farming population. It is increasingly difficult for these farmers to cope with the drudgery of work using small unimproved tools. There is urgent need therefore to establish more centres to develop and improve tillage equipment and train technicians and farmers in their efficient use. Such centres may initially be located in the savannah and semi-arid areas where the use of draught animals is traditional. Crop rotations and cropping systems will have to be improved to provide fodder for animals so that crop residues are released for soil management purposes.

Considerable work on tillage has been carried out during the past two decades in Africa, considering the limited number of research institutions. However, more intensive work is required on the different soil types, climatic conditions and cropping systems. The use of crop residue for soil management purposes must be given serious consideration. But this can by achieved only if alternative fodder and fuel sources can be developed for draught animals as well as for the provision of domestic energy supply. The development of appropriate cropping systems and inclusion of legumes in the rotation offers promising options.

Greater emphasis needs to be given to the use of soil and climatic data in developing tillage experiments. Tillage effects on different soil types need to be assessed to provide reliable guidelines to the type of conservation tillage system applicable to the various soils. Furthermore, these guidelines should be such that farmers can easily use them.

One of the important approaches to the development and transfer of appropriate tillage technology in Africa is the improvement of information dissemination systems among tillage research workers. This will not only ensure effective use of the limited human and financial resources, but also avoid unnecessary repetition of research work carried out under similar ecological and climatic conditions elsewhere. countries may consider cooperation and linkages of research programmes through networking systems. Such arrangements can only have their desired impact when individual countries devote adequate resources and time to the development of cooperative programmes.

CONCLUSION

Tillage work carried out in Africa has been mainly in the semi-arid and sub-humid agro-ecological zones. Relatively little data is available for the humid tropics.

The semi-arid zone has the highest prospects for rapid tillage technological package development, firstly, because of the availability of animal draught power, secondly, because of the crops and cropping systems used and, thirdly, because of the urgent need for the development of soil and water conservation and management practices to increase crop production.

The need for more efficient use of soil-, climatic-, and cropping system-data in developing tillage systems in the region cannot be over emphasised. Identification and classification of the soil types are necessary pre-requisites. Research methodologies should be standardized and information dissemination should be an essential component of any common tillage network programme to be developed in Africa.

Lack of institutions in Africa for the development and improvement of tools suitable for small farmers is a serious drawback to increasing production on the predominantly small farms. In aiming for sustainable productivity it is imperative that planning should take into consideration the conservation of the resources base, in particular any proposed soil, and tillage practices should be tested prior to their adoption on a wider scale.