5.5

Erosion and Mechanization

R. FAUCK

The spread of mechanization of agriculture in humid tropical Africa has been characterized by a rapid increase in soil erosion. This fact has brought many to recommend, if not the rejection of mechanization, great prudence in its systematic utilization. A careful appraisal leads to the conclusion that mechanization should be examined critically in relation to existing conditions, particularly the various types of soils where it is to be applied.

5.5.1. THE MODALITIES OF EMPLOYING MECHANIZATION

All large mechanized cultivation projects in forest regions start by clearing the trees, mostly using powerful machines, followed by systematic removal of roots and stumps. The entire operation involves felling, uprooting, root-cuttage and soil inversion before planting the crop. Planting presupposes a certain amount of tillage. Tillage operations are done with three objectives. The first is the preparation of the soils by ploughing, inversion and pulverization in order to create a seedbed. This means creating an environment where the seeds find suitable conditions to germinate. The second objective is to improve the infiltration of rain. The last involves the post-planting operations such as interculture.

All these operations have different influences on soil erosion, but it is difficult to separate the individual effects since they all interact. When other factors remain constant, erosion is a function of soil depth, water content and time of rainfall in relation to tillage operations. In addition, the results vary between sandy types (12 per cent of clay in Casamance) and those of high clay content (65 per cent clay in the valley of Niari in the Congo). It is difficult to separate the variables and to define, among the mechanization methods, those factors which increase erosion. It is the complexity of these factors which has resulted in controversy over mechanization.

5.5.2. THE PRINCIPAL RESULTS

Some researchers have measured directly the influence of mechanization on the amount of soil loss and runoff. There are other experiments which deal with the evolution of the physicochemical characteristics of mechanically cultivated soils (Cointepas, 1958; Cunningham, 1963; Dumas, 1965; Pereira *et al.*, 1967; Goujon *et al.*, 1968; Seguy, 1969; Fauck *et al.*, 1969; Charreau and Seguy, 1969; Le Buanec, 1971; Roose, 1973a; Lal, 1974).

Most data come from experiments conducted in Senegal (Sefa, Bambey), in the Ivory Coast (Adiopodoume, Bouake), in Upper Volta (Saria), in Benin (Cotonou) and in Nigeria. The following conclusions can be drawn.

Clearing disturbs soil the most, resulting in an heterogeneous A horizon, bringing gravel to the surface, causing rapid changes in the chemical and physical characteristics, notably a decrease in organic matter and nitrogen contents and structural stability, and a spectacular increase in soil loss and runoff. But it is difficult to attribute the soil erosion to mechanization, since forest removal and other operations also disturb the ecological equilibrium. Nevertheless, excessive tillage and the heterogeneity resulting from uprooting are certainly responsible for a decrease in the physical stability of the surface horizons and an increase in the susceptibility of the soil to erosion. In this connection, it is advisable to attempt to improve the soil structure destroyed by clearing and uprooting by growing leguminous or other cover crops before adopting arable cultivation.

The conventional method of seedbed preparation consists of ploughing, pulverizing, rolling, harrowing, spreading of fertilizers and sowing. The effects of these operations should be carefully analysed, because the results obtained are sometimes contradictory. The different results can be explained not only by the diversity of the techniques employed, but also by the influence of the soil type and the variability of the clay and silt content in the upper horizons. For instance, fairly sandy soils, such as those in Senegal, are exposed to high evapotranspiration rates at the end of the rainy season. This results in crust formation. It is necessary to break this crust before the rainy season in order to prepare a seedbed (Charreau and Nicou, 1971). The desirable aggregate size for most seedbeds is 3 to 12 mm (FAO, 1974), and it is therefore necessary to pulverize aggregates formed from crusted soils. However, susceptibility to erosion is correlated with the fineness of the seedbed, so that a compromose must be achieved between the necessity to break the crust and the need for protection against erosion. Charreau and Nicou (1971) believe that it is climatic aggressivity more than soil erodibility that is responsible for erosion and soil degradation. But it seems that overintensive pulverization by tillage is also a cause of the increase in susceptibility to erosion, regardless of the climatic conditions. Lal (1974) reported that it is the detachability of fine particles by splash because of the predominance of coarse sands in many tropical soils that results in erosion. In the view of the author of this chapter, it is the excessive crumbling of the soil at the beginning of the cultural cycle, when the soil is bare, that is the principal cause of erosion resulting from mechanization. In traditional agriculture, where the erosion is not serious, the soil is tilled only when the seeds are placed into the soil. Perhaps it is desirable, at least theoretically, to consider a fine preparation of the soil only along the seed row.

With soils of higher clay content, the results are not so pronounced. Soils with more than 20 per cent clay usually show relatively slight erosion. Charreau and Nicou (1971) consider that clay soils maintain their structure, while sandy soils tend to compact. That is why sandy soils have to be ploughed to improve root development and establishment and minimize the adverse effects of erosion. Consequently, soils of different texture should be considered separately when comparing the diverse advantages and disadvantages of methods of soil preparation.

Erosion is also affected by the soil moisture content at the time of tillage. More data relating to these effects are needed in tropical humid Africa, and this is especially true as regards the consequences of ploughing.

Furrowing and ridging have been practised by many researchers. Under proper conditions, contour ridges offer a mechanical drag for runoff, and when combined with tie-ridging, effectively increase the time for rainwater to infiltrate. However, many observations indicate that in addition to rapid drying, degradation of the upper part of the ridge occurs under the effect of splash, resulting in separation of sand and clay particles and deposition of sand. After some years, the upper horizon is significantly modified by erosion of the surface layer. This process results in a progressive destruction of the ridges due to structural degradation and, in spite of the reduced runoff, the consequences of its use on the structural stability of the soil should be carefully considered. Once more, it is in the sandy and sandy-loam soils that structural degradation is more pronounced.

Whatever the techniques used, mechanization, with or without local modification of the micro-relief, results in a drastic change in the aggregate size distribution. While it may be better to decrease aggregate size to facilitate germination and seedling establishment, one must avoid overpulverization to keep soil erosion under control. The choice of techniques to be adopted, therefore, depends on the soil texture and the moisture content at the time of tillage. But there is another important factor: the depth of tillage. In several experiments, tillage to constant depth has resulted in the formation of a plough-pan, especially in the '*sols ferrallitiques*', where the clay content increases progressively from the A to B horizon. Under some conditions this plough-pan can increase erosion and compaction, resulting in temporary waterlogging and poor soil aeration.

All these disadvantages can be eliminated or minimized by altering the plough depth every year, by avoiding overpulverization of soil, by limiting the tillage to the planting row, and by performing tillage operations only under optimum soil moisture conditions. But these are theoretical conclusions, because in practice it is always difficult to choose the date of ploughing as a function of soil–water content. However, choice of plough-depth in terms of the stage of the cultural succession is usually possible.

Secondary tillage involves inter-row cultivation during the crop growth. These tillage operations are designed to break the upper crust, eliminate weeds and increase soil permeability. Such inter-row cultivation must be done on the contour, to avoid concentrated runoff which can result in serious soil erosion.

A last group of tillage operations concerns post-cultural or post-harvest techniques. Some of these practices such as mulching are very efficient in preventing soil loss. Practices such as ploughing at the end of the cycle, as Charreau has shown, have the advantage of improving infiltration at the start of the rains, when the erosive storms fall on bare but not crusted soil. Post-harvest or early tillage may also help in saving time during the periods of peak labour demand at planting. In regions of short rainy periods, timely planting facilitated by post-harvest tillage can result in significant yield increases, because this technique enables rapid crop establishment and vigorous growth. Some biological techniques are efficient in erosion control (Chapter 4.1). It is desirable to develop mechanized techniques which aid favourable biological processes, such as those which accelerate the establishment of a vegetal cover. That is why it seems necessary to recommend more than one method, such as mulching, strip-cropping and ploughing at the end of the cycle, along with balanced fertilizer use.

5.5.3. CONCLUSIONS

- In certain conditions, intensive mechanization of tropical agriculture presents a real danger of accelerated soil erosion.

(i) Mechanical clearing of the soils modifies the micro-climate and decrease resistance to erosion. Adverse effects can be minimized by appropriate methods of root ploughing and by creation of a homogeneous cultural profile, by the use of leguminous cover crops after forest removal.

(ii) Soil preparation techniques must be chosen taking into consideration soil texture, and when ploughing is adopted, the effects if it is done at the beginning or end of the rainy season. One should avoid overpulverization of soil and change the depth of ploughing every season. Investigations of the effects of soil moisture at the time of ploughing on structural stability need to be carried out on soils of different textures.

(iii) Whenever feasible, ground cover should be maintained by practices such as mulching. New research is also necessary to define the consequences of diverse tillage techniques on the structural stability of the soil, on the modification of the porosity of soil aggregates (quantitative and qualitative), and on the development of a cultivated horizon of favourable tilth, merging with the adjacent lower horizon.

(iv) Mechanization presupposes the use of other anti-erosive techniques of contours and terraces, strip-cropping, mulching, and restriction of tillage to the seeding row.

REFERENCES

Bertrand, R, 1967, Etude de l'érosion hydrique et de la conservation des eaux et du sol en pays Baoulé, *Colloque sur la Fertilité des Sols Tropicaux, Tananarive*, 19-25/11/67, No. 106, pp. 1281–1295.

Charreau, C, 1969, Influences des techniques culturales sur le développement du ruissellement et de l'érosion en Casamance, *Agron. Trop.*, **24**, 836–42.

Charreau, C., and R. Nicou, 1971, L'amélioration du profil cultural dans les sols sableux et sablo-argileux de la zone tropicale sèche Ouest-africaine et ses incidences agronomiques, *Agron. Trop.*, **26**, 903–78.

Charreau, C., and L. Seguy, 1969, Mésure de l'érosion et du ruissellement à Séfa en 1968, *Agron. Trop.*, **24**, 1055–1097.

Cointepas, J. P., 1958, Bilan des études chimiques et pédologiques entreprises à la Station expérimentale de Séfa, ORSTOM, Dakar.

Cunningham, R. K., 1963, The effect of clearing a tropical forest soil, *J. Soil Sci.*, **14**, 334–335.

Datiri, B. T., 1974, Soil and water conservation practices particularly in areas of shifting cultivation, *F.A.O. Soils Bulletin*, No. 24, 237–241.

Dumas, J., 1965, Relation entre l'érodibilité des sols et leurs caractéristiques analytiques, Cah. ORSTOM, sér. Pédol., **III**, No. 4, 307–333.

FAO, 1974, Soils Bulletin No. 23, *Management Properties of Ferralsols.*

Fauck, R., C. Moureaux and C. Thomann, 1969, Bilans de l'évolution des sols de Séfa (Casamance, Sénégal) après quinze années de culture continue, *Agron. Trop.*, **24**, 263–301.

Goujon *et al.*, 1968, Conservation des sols en Afrique et à Madagascar. III. Influence des rotations et des pratiques culturales sur le ruissellement et les pertes en terres à Madagascar, *Bois-Forêts Trop.*, **120**, 3–14.

Henin, S., R. Gras and G. Monnier, 1969, *Le Profil Cultural*, 2nd edn, Masson.

Lal, R., 1974, Soil erosion and shifting cultivation, *FAO Soils Bulletin*, No. 24, 48–71.

Le Buanec, B., 1971, Dix ans de culture motorisée sur un bassin versant du centre Côte d'Ivoire—Bilan général, Multigr. IRAT/CI, Bouaké.

Pereira, H. C., P. Hosegood and M. Dagg, 1967, Effects of tied ridges terraces and grass leys on a lateritic soil in Kenya, *Exp. Agric.*, **3**, 89–98.

Roose, E., 1973, Dix sept années de mesures expérimentales de l'érosion et du ruissellement sur un sol ferrallitique sableux de Basse Côte d'Ivoire, Contribution à l'étude de l'érosion hydrique en milieu intertropical, Thèse, Faculté des Sciences de l'Université d'Abidjan.

Russell, E. W., 1971, Soil structure: its maintenance and improvement, *J. Soil Sci.*, **22**, 137–151.

Seguy, L., 1969, Mésure de l'érosion et du ruissellement à Séfa en 1968, *Agron. Trop.*, **24**, 1055–1097.

See also:

Charreau, C. and R. Fauck, 1970, Agricultural development of soils of the Sefa region, *Agron. Trop.*, **25**, 151–191.

Christoi, R., 1966, Erosion measurements in Upper Volta, *Oléagineux*, **21**, 531–534.

IFAC, 1955, Sloping terraces for interception and removal of water, *Fruits*, No. 7.