Conservation Tillage – Gateway to Food Security and Sustainable Rural Development

Impact of Conservation Tillage on Soil Quality

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Background

The main functions of soil tillage and the reasons why farmers invest labour and time in this operation are:

- To produce optimal conditions for seed germination and emergence
- To increase water infiltration and aeration
- To eliminate the competition with weeds
- To bury or incorporate organic material, crop residues and/or manure

- *Short and Long Term Effects of Soil Tillage*

The short term effect of tillage, especially of ploughing, is remarkable. Yield increases of 20 – 50% were reported for such crops as millet sorghum or maize in West Africa (PIERI, 1989). This can be attributed mainly to the deeper loosening of the soil (15-20 cm instead of 5-10 cm by hand hoeing), which allows for increased water storage and exploitation of a greater soil volume by the plant roots. However, with time undesirable long-term effects are observed like the formation of hoe or plough pans and the compaction of the subsoil. The exhaustion of soil organic matter (SOM) leads to a deterioration of the soil structure, the crusting and sealing of the soil surface, a reduced water infiltration and storage on the one side and on the other side an increased water run-off and soil erosion. The results are declining yields and more pronounced impact of droughts.

- *Management of Soil Organic Matter*

Soil organic matter (SOM) constitutes a key element of tropical soils, especially of light, sandy soils with low content of swelling and shrinking clay minerals. The management of SOM is therefore the core of sustainable soil management. It is difficult to keep a sufficient high level of SOM under tropical conditions. SOM decomposes more rapidly in the tropics if compared to sub-tropical and moderate climates because of the higher temperatures. Soil inversion and thereby an increased soil aeration accelerates this process. In order to manage these soils in a sustainable way, tillage operations have to be reduced or even better stopped completely and SOM has to be restored.

The Main Function of soil organic matter (SOM)

- Improvement of soil structure
- Increased water storage capacity
- Slow release of plant nutrients

Changing from Conventional to Conservation Tillage

Before starting with conservation tillage CT, soils have to be corrected. This means that the major constraining factors caused by conventional tillage have to be adjusted.

- Breaking of soil compaction layers - especially plough layers or hoe pans, by:
  - Mechanical measures
    - subsoiling by use of tractors or draught animals
  - Biological measures
    - fallows with plants forming tap roots which can penetrate and break the hardpan (e.g. pigeon pea, oil reddish)
- Adjustment of pH - application of lime, farm yard manure

7 weeks after planting Mucuna roots already penetrate the hard pan, caused by frequent ploughing and hoeing. (Photo: W.Mariki)

Breaking of hardpans and liming creates a more favourable environment of crop development.

- Increased water infiltration and aeration
- Deeper rooting of plants
  - This helps to avoid or at least to reduce drought stress
  - Plant roots can exploit a greater volume of soil and so they can access (leached) nutrients in deeper soil layers

The correct application of CT practices, including crop rotations and planting of deep rooting green manures/cover crops, prevents the formation of new hardpans. Subsoiling is a costly repair work and should be considered as initial investment, only.

With subsoiling maize withstands even prolonged periods of drought and yields a crop while it fails completely on compacted soils (Photo: W.Mariki)

Major Effects of Conservation Tillage on Soil Characteristics

Proper application of CT practices provokes a number of effects, which helps to overcome soil degradation and to slowly improve the soil quality. The better the groundcover and the lesser soils are disturbed the more pronounced these effects are:

- Reduced soil erosion by wind and water
- Reduced water run-off = loss of water
- Increased water infiltration and storage
- Reduced evaporation
- Prevention of overheating of the soil surface affecting seed germination
- Build up of SOM
- Improved aggregate stability and soil structure, but increased bulk density
- Deepening of rooting horizon through earthworms and roots of deep rooting green manure plants
- More abundant soil life - earth worms and arthropods loosen the top soil, incorporate surface organic matter, stabilise the soil surface with stable soil organic excretions (e.g. earth worm casts)

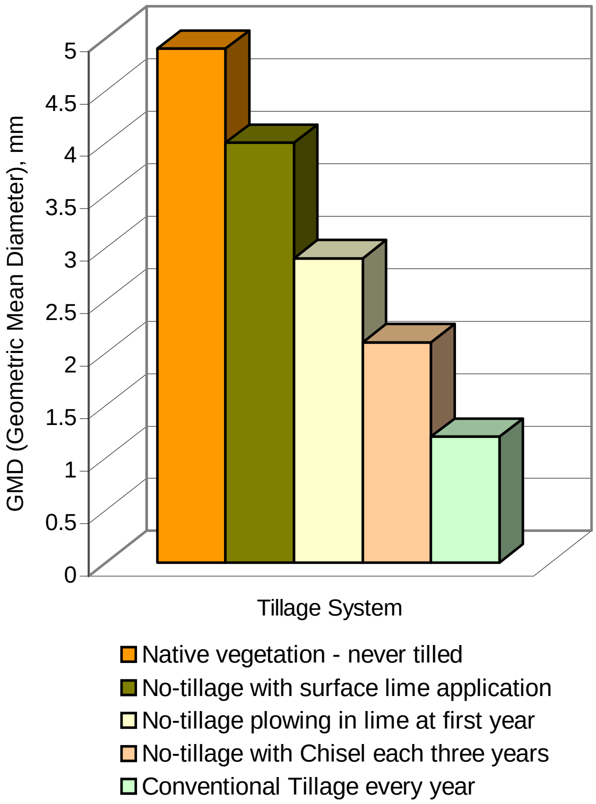
Periodic ploughing disturbs this improvement of soils and leads back to square one (the need for periodic ploughing is in the mind of many people but is not necessary when fields are managed appropriately, with the exception of very light sandy soils.*)*

The improvement of the soil structure builds up slowly and depends highly on soil type and climate, as well as on the production methods. Light sandy soils, which are prevalent in the semi arid tropics of West and Southern Africa tend to compaction and might need renewed subsoiling after a couple of years (Berry, 2000). In fully mechanised production systems trafficking fields lead to soil compaction, especially when soils are moist. The same is valid for cattle grazing when soils are still moist.

- *Bulk density versus soil structure*

Soils become denser when not ploughed and the bulk density increases. This is often misinterpreted as a negative impact. However, the bulk density needs to be seen in relation to the soil structure. Soil structure improves under CT, especially under no-tillage. Stable aggregates are formed, which do not break down easily under the impact of rains. Thus crust formation, surface run-off and soil erosion are reduced. More deep reaching macropores are formed, which assures water infiltration and aeration. Water does no longer stagnate on the soil surface and farmers are allowed to enter their fields earlier after a rain, even with a tractor (= prolonged period of workability).

Water aggregation stability under different soil management in an Oxisol



Source: DA ROS, 1997

- *Soil moisture*

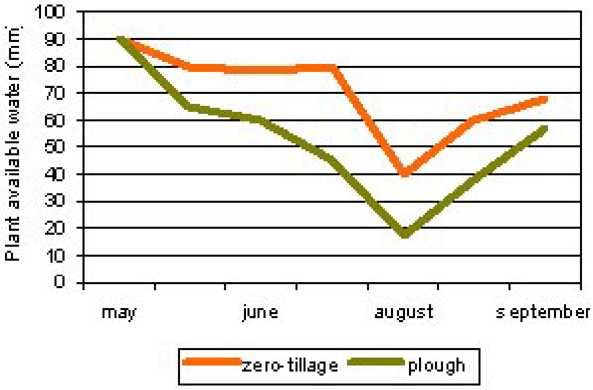
The soil surface of ploughed fields tends to crusting and sealing under the impact of intense tropical rains. This often happens already after one downpour. The reduction of water infiltration through sealed and crusted surfaces may be enormous. Losses of precious rain water in the order of 50 to 90% (of the volume of rain showers) are not uncommon and influence the water balance. Drought in many cases is therefore not the result of too little rain but of too much run-off.

Physical structures like contour lines can stop the run-off water, but the objective should be to maximise the infiltration and to prevent water from starting to flow. Only excess water during heavy rain storms should run-off. A good ground cover slows down the speed of the flowing water and together with a higher soil aggregate stability soil erosion is prevented. In the ideal case, the excess water that leaves a field is clean. No precious soil (especially fine clay and organic particles) and plant nutrients are lost. This effect can be demonstrated in an impressive way with rainfall simulators on larger plots or with small devices and a watering can.

The status of soil moisture is the result of water infiltration and losses due to evaporation at the soil surface and transpiration by plants (= water balance). A good groundcover or mulch reduces the losses of moisture by evaporation. Soils do not dry out so quickly.

In semi-arid regions, where mulch material is rare, minimum tillage techniques like ripping of planting rows, or digging of planting station (planting basins, *Zaï*) facilitate water infiltration and prevent water run-off.

Plant available water under zero tillage and under plough



PHILIPS at al., 1984 cited from STEINER, 1998

- ***Soil life***

The soil must be understood as a living organism. Only a living soil, with abundant soil life, can fulfil its main functions. Tillage operations disturb the soil life. Soil organisms are suddenly exposed to the sun, heat, and drought. The number of soil biota decreases rapidly and builds up only slowly during the growing season. Under No-tillage and to a lesser extent under minimum-tillage soil life is not disturbed. The soil cover helps to create a more stable environment and the organic matter serves as "fodder" for the soil biota. Application of herbicides might affect soil life negatively. But as data from ecotoxological analyses and observations in Paraguay suggest, the broadly used *glyphosates* and their metabolites do have no negative effects. The diversity and frequency of soil life of treated fields resemble that of undisturbed soils under forest. Soil biota improve the soil structure. The microfauna and flora improves the soil structure by forming stable soil aggregates, while the macrofauna forms macropores which are important for water infiltration and aeration. Organic matter, plant residues or mulch, is incorporated into the soil and decomposed. Lime applied at the soil surface is translocated into deeper soil layers.

Soil fauna and CO^2-Production under Conventional Tillage (CT), Cultivator(C) and Zero Tillage (ZT)

Parameter	CT	C	ZT
Earthworms/m², November 1979	5,8	7,5	13,0
Earthworms/m², November 1981	3,2	5,2	27,6
Arthropoda/300 cm³			
Soya beans/wheat	7,0	-	33,0
Soya/cover crop	23,0	-	192,0
CO^2-production (cm³) $100g^{-1}h^{-1}$	4,4	8,9	10,7

Source: DERPSCH ET AL. 1986

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