UNDERSTANDING THE PROCESS OF SOIL EROSION AND WATER INFILTRATION

by Rolf Derpsch

INTRODUCTION
Soil erosion is caused by non infiltrated water that runs of a field. It is astonishing that often the process of soil erosion and water infiltration into the soil is not well understood by farmers, but also by extension workers and scientists as well. Pictures showing the raindrop impact on a bare soil surface and information explaining the mechanisms of water infiltration into the soil goes back to the 1940s. Despite scientific and empirical evidence explaining these processes, many people still think that the soil has to be loosened by tillage to increase water infiltration and reduce runoff.

Soil erosion by water and runoff is often accepted as an unavoidable phenomenon associated with agriculture on sloping land. But soil loss by erosion or runoff is not an unavoidable process. According to Lal (1982), occurrence of erosion damage on cultivated land is merely a symptom of land misuse for that ecological environment. In other words inappropriate farming practices have been used. It is not nature (slope and rainfall intensity), but rather irrational farming methods used by man, which are responsible for erosion and its negative consequences. The farmer can, through the utilization of site specific and adapted farming systems and management practices, effectively control erosion, reduce runoff and increase water infiltration on his land. Runoff water is lost to crops, while infiltrated water can be effectively used by plants, which is very important in dryer climates.
Conventional farming practices utilized in many parts of the world have had negative consequences in terms of soil and water preservation as well as on the conservation of the environment as a whole. This is due to improper soil use, monoculture and the use of tillage tools that leave the soil bare and pulverize it excessively, leaving it in such a condition that it can be carried away by heavy rains. The utilization of inadequate technologies that are not adapted to site specific conditions (slope, rainfall intensities) results in runoff, soil erosion and degradation. Thus, the consequence of traditional cultivation methods is the gradual loss of soil and fertility until the land becomes unproductive.
Failure of landowners and agricultural managers to comprehend the significance of erosion, as well as intensive weathering under hot, humid conditions, has brought about the widespread distribution of poor, badly eroded, infertile soils all over the tropics and subtropics (Ochse, et al., 1961). But the same process has also happened in more temperate climates (e.g. United States, Russia, etc.). Eroded, unproductive and abandoned land as well as advanced signs of desertification are silent testimonies of this phenomenon all over the world.
Besides making agricultural soil unproductive, erosion of agricultural land and runoff results in the deposition of soil particles in unwanted areas (sedimentation of roads, creeks, rivers, lakes, dams, etc.) with all its negative consequences for traffic, the generation of electric power, the delivery of drinking water, leisure areas, etc., resulting in important expenditures for the government as well as for society as a whole.
Furthermore, the importance of erosion control is not restricted to the maintenance of the productive potential and fertility of soils for future generations; it is also an effective means to ensure employment in rural areas and reduce rural exodus. Efficient erosion control is therefore very advantageous from the ecologic and social perspectives, besides being highly significant from an economic point of view.
THE EROSION PROCESS

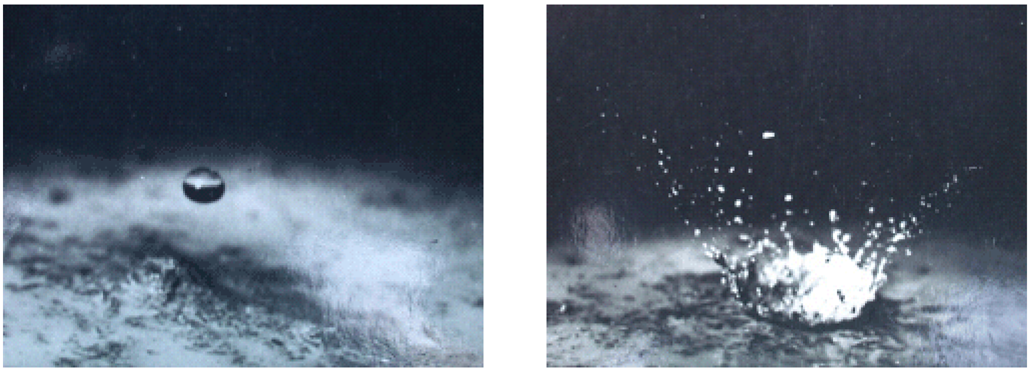

Figure 1: The impact of raindrops on a bare soil surface. When it rains, drops up to 6 mm (0.24 inch) in diameter bombard the soil surface at impact velocities of up to 32 km per hour (20 mph). This force throws soil particles and water in all directions on a distance of up to 1 m (3.3 feet). (Pictures made by USDA in the 1940s).

Runoff and erosion start with raindrop impact on bare soil surface. Soil splash seen on fence posts, or on walls in a field or plot of bare soil, is evidence of the force of large raindrops striking bare soil (Harrold, 1972). Meyer and Mannering (1967) reported that in one year, raindrops deliver to an acre of land an impact energy equivalent to 20 tons of TNT (50 t/ha dinamite). The impact of falling raindrops disaggregates the soil into very fine particles, which clog soil pores and create a surface seal that impedes rapid water infiltration (Figure 2).

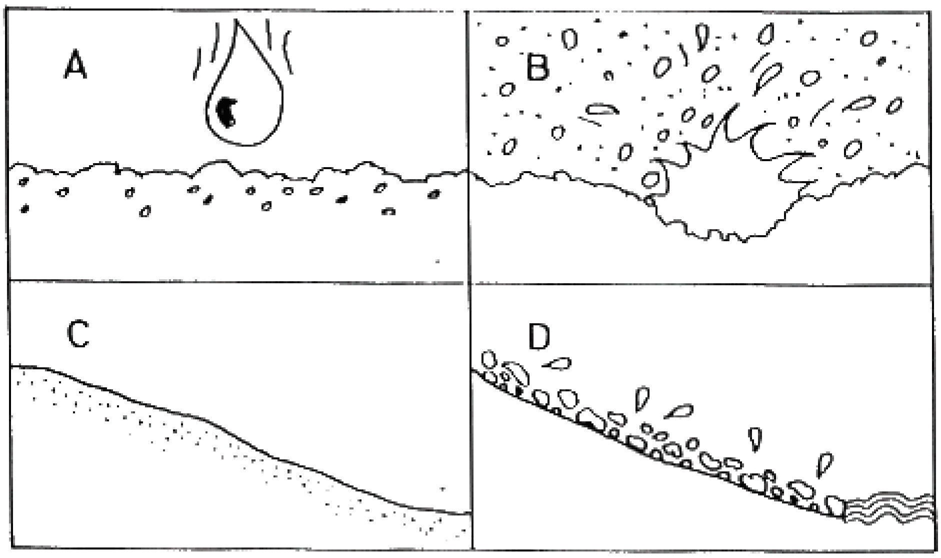

Figure 2

Phases of the erosion process:
The impact of rain drops on the bare soil surface (A), causes the detachment of small soil particles (B), that clogg the pores and form a surface sealing (C). The water that runs off carries soil particles, which are deposited down slope when the runoff velocity is reduced (D).

(Derpsch, et al., 1991)

Due to surface sealing, only a small portion of rainwater can infiltrate into the soil; most of it runs off over the soil surface, therefore is lost to plants and causes erosion damage when flowing down the slopes. On the other hand, when the soil is covered with plants or plant residues, the plant biomass absorbs the energy of falling raindrops and rainwater flows gently to the soil surface where it infiltrates into soil that is porous and undisturbed. In this way soil cover impedes the clogging of soil pores (Figures 2, 3, 4 and 5).

The drying of surface sealing, results in soil crusting, which may hinder or impede the germination and emergence of crop seeds. Soil crusting only develops under a condition of bare soil. Soils highly suceptible to crusting do not present this problem once no-tillage and permanent cover systems are used.

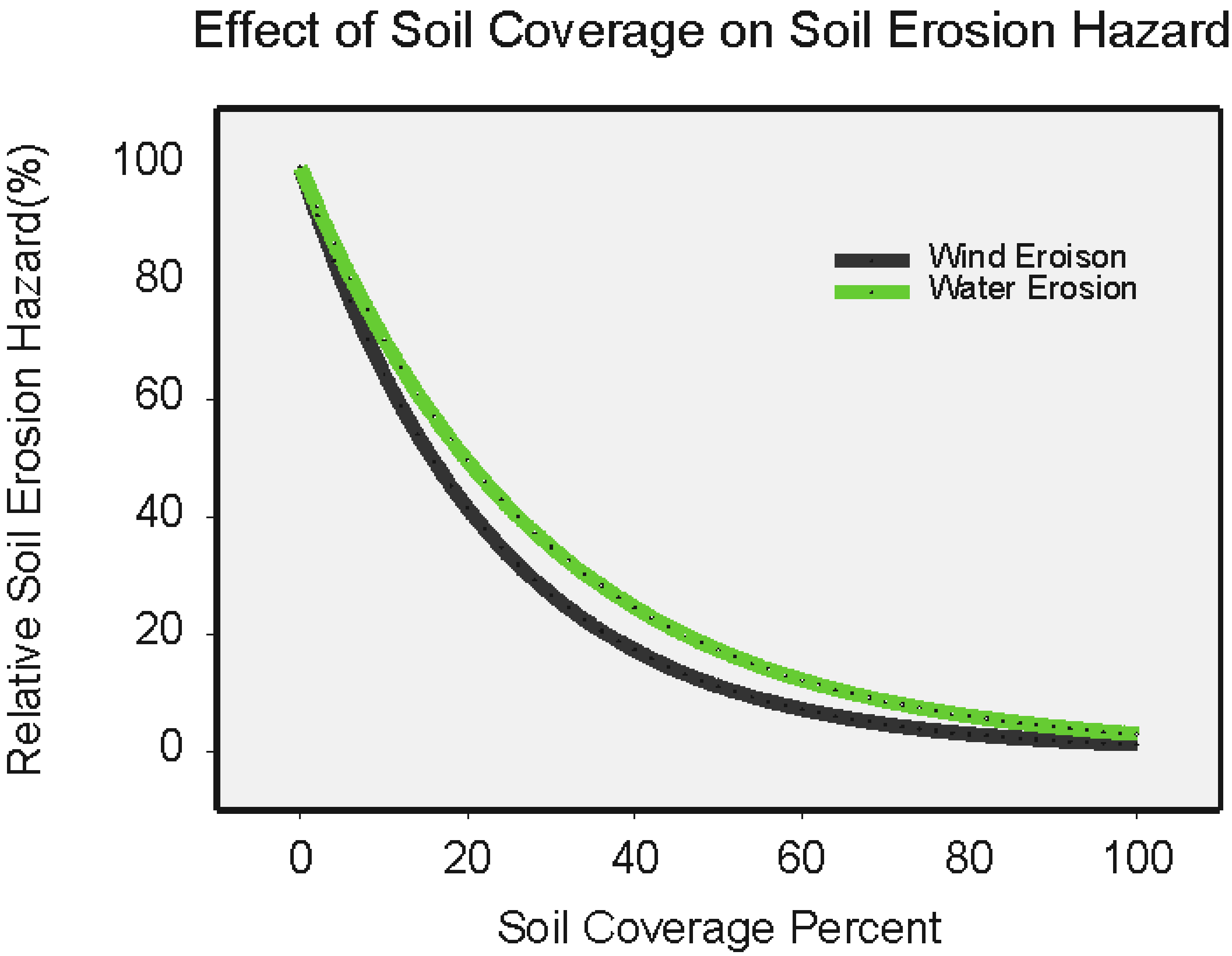

Figure 3: The relative effect of soil residue coverage on wind and water erosion potentials. The wind ersoion function is taken from the Revised Wind Erosion Equation (RWEQ) model and the water erosion function comes from the Revised Universal Soil Loss Equation (RUSLE) model.
(Merrill, et al, 2002)

Research conducted in Brazil (Roth, 1985) also shows, that **the percentage of soil covered with plant residues is the most important factor that influences water infiltration into the soil**. While virtually all water from a simulated rainfall of 60 mm/hour infiltrated when the soil was 100% covered with plant residues, in the case of bare soil 75 to 80% of rainwater left the plots as runoff (Figure 4). Similar results have been obtained by researchers in many parts of the world (see also Figure5).

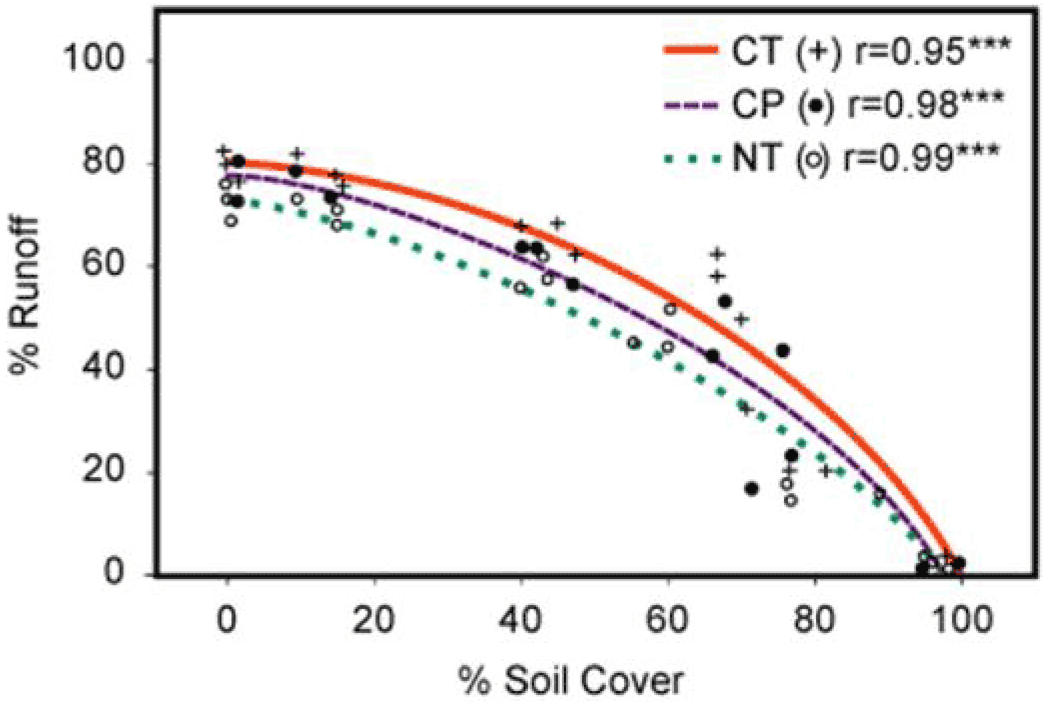

Figure 4: Total runoff after 60 minutes of simulated rainfall as affected by % soil cover and tillage system (CT: conventional tillage, CP chisel plough, NT: no-tillage).
(Roth, 1985).

Therefore it is important to maintain the soil covered with plants or with plant residue all year round, avoiding exposure to climatic agents. Any attempt to control runoff and erosion via bare soil, burying plant residues with tillage implements and maintaining the soil surface loose and uncovered, will sooner or later lead to failure.
For this reason t**he no-tillage system under cover of crop residues or green manure cover crops** is the most efficient and adequate method for the prevention and control of erosion, and should be the "par excellence" technology promoted and diffused all over the world.
Not tilling the soil, crop rotation combined with the use of cover crops, and not burning plant residues are the most important agricultural practices that make it possible to achieve the goal of permanent, year-round soil cover.
Conservation agriculture using the no-tillage system offers the most effective strategy and affordable methods available today to control soil erosion, and in this way achieve a sustainable agriculture. Sustainable agriculture is a necessary step to achieve sustainable rural development, and only with sustainable rural development can global sustainable development be achieved.

When afterwards the trays where turned on a canvas, the tray with bare soil (Nr. 3) showed, that water had only infiltrated about 1 inch, while at the bottom the soil was dry. The other trays showed a wet soil from top to bottom

From left to right: 1) 100% soil cover, little runoff and no sediments. 2) 30% soil cover, more runoff and some sediments. 3) Bare soil, no cover, resulting in a huge amount of runoff and the dark color of water shows also a lot of sediments. 4) Pasture with 100% soil cover and undisturbed soil. Even less runoff than under 1.

No-tillage appears to be essential for the maintenance of soil structure and productivity in many tropical soils. The long-term gains from widespread conversion to no-tillage could be greater than from any other innovation in third world agricultural production (Warren, 1981).

While most of the numerous advantages of the no-tillage system come from the permanent cover of the soil with plant residues, there are several advantages coming from not tilling the soil. Tillage destroys the vertical pore system created by roots, earthworm and other soil animals, destroys soil structure, accelerates organic matter mineralization (depletion) and reduces aggregate stability. Fields that are many years under no-tillage will be expected to further increase water infiltration as the vertical pore system builds up and organic matter increases. In this way, no-till with abundant soil cover allows for both the natural rebuilding of soil structure and porosity, as well as protecting the soil from damaging raindrop impact.

Besides increasing water infiltration and controlling erosion, soil cover has a major impact in reducing soil temperature, reducing evaporation, increasing available water for plants, enhancing soil's life and biological activity, contributing to reduce soil compaction and soil crusting as well as having positive effects on soil chemical physical and biological properties. All this is advantageous for the farmer and leads to higher productivity. Furthermore, permanent cover systems are essential to achieve long term agricultural sustainability.

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