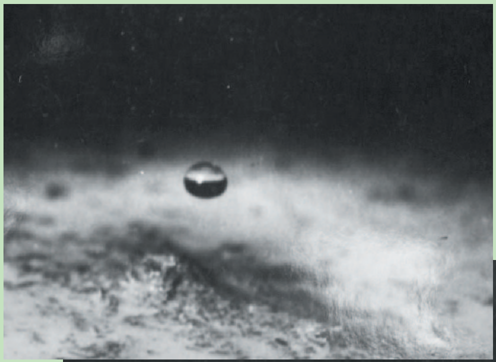
Understanding The Process of Water Infiltration

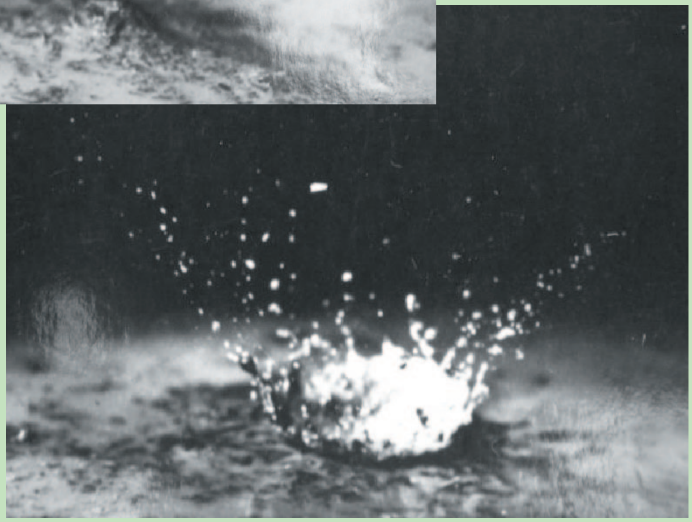
by Rolf Derpsch

Introduction

Soil erosion is caused by non-infiltrated water that runs off a field. It is astonishing that often the process of water infiltration into the soil is not well understood by farmers, but also is not well understood by extension workers and scientists. Pictures showing the raindrop's impact on a bare soil surface and information explaining the mechanisms of water infiltration into the soil go 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 runoff is often accepted as an unavoidable phenomenon associated with agriculture on sloping land. But soil loss by 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 locally 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 drier climates.





Photos by USDA.

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.)

Photo by Doug Palen.

Rolf Derpsch explains methods for keeping an adequate soil cover.

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 local conditions (slope, rainfall intensities) results in runoff, soil erosion and soil degradation. Thus, the consequence of traditional cultivation methods is the gradual loss of soil and fertility until the land becomes unproductive.

Research shows that the percentage of soil covered with plant residues is the most important factor influencing water infiltration into the soil.

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, is a silent testimony 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.

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

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

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 dynamite (50 t/ha). 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).

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).

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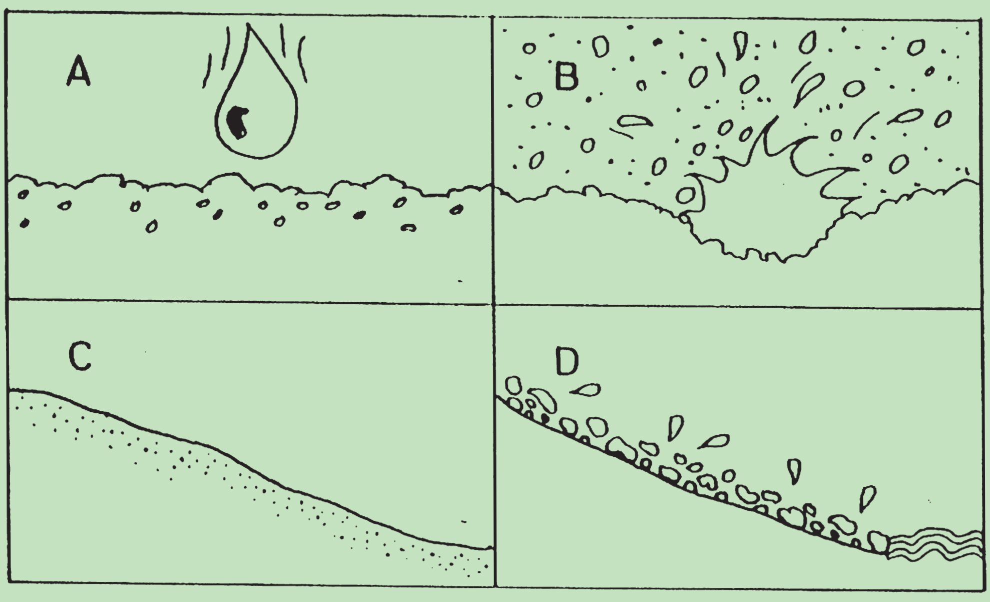

Figure 2: Phases of the erosion process: The impact of raindrops on the bare soil surface (A), causes the detachment of small soil particles (B), that clog the pores and form a surface sealing (C). The water that runs off carries soil particles, which are deposited down-slope when the runoff velocity is reduced (D). (Derpsch, et al., 1991)

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.

Therefore it is important to maintain the soil covered with plants or with plant residue all year round, avoiding soil exposure to climatic agents. Any attempt to control runoff and erosion via bare soil, by burying plant residues with tillage imple-

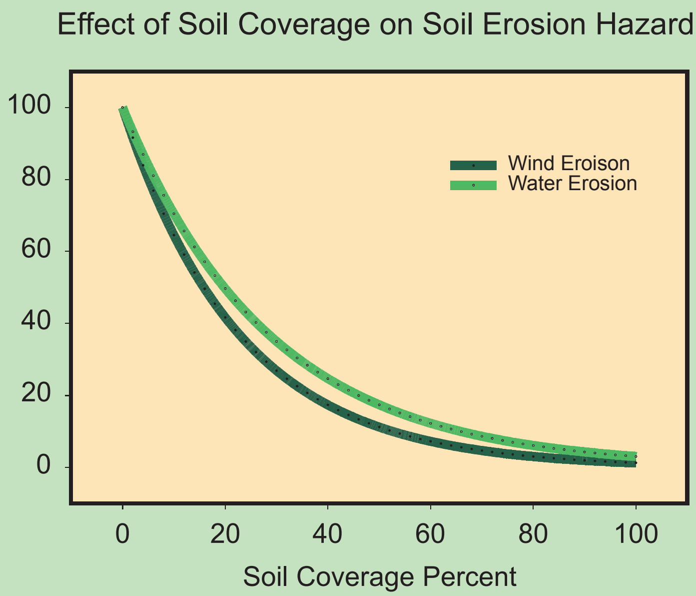

Figure 3: The relative effect of soil residue coverage on wind and water erosion potentials. The wind erosion function is taken from the Revised Wind Erosion Equation (RWEQ) model and the water erosion function comes from the Revised Universal Soil Loss Equation (RUSLE) model. (Merrill, et al., 2002)

ments and maintaining the soil surface loose and uncovered, will sooner or later lead to failure.

For this reason the 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.

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 additional advantages deriving from not tilling the soil. Tillage destroys the vertical pore system created by roots, earthworms, and other soil animals. Tillage also 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 moderating soil temperature extremes, reducing evaporation, increasing available water for plants, enhancing soil's life and biological activity, and reducing soil compaction and soil crusting, as well as having positive effects on soil chemical, physical, and biological properties. All this leads to higher productivity. Furthermore, permanent cover systems are essential to achieve long-term agricultural sustainability.

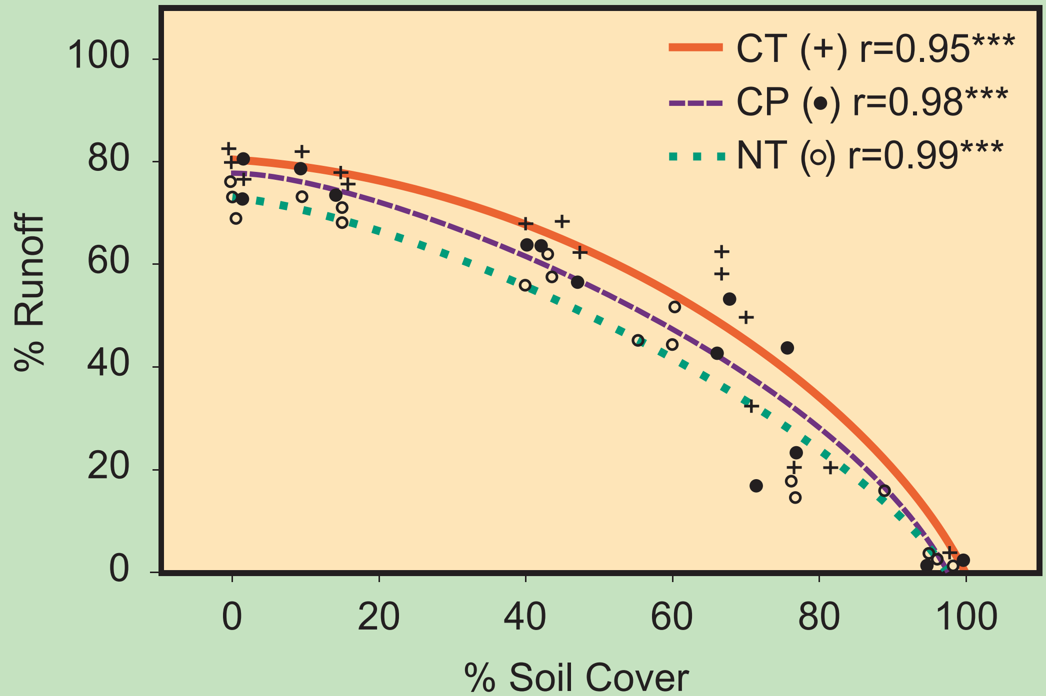

Figure 4: Total runoff after 60 minutes of simulated rainfall as affected by % soil cover and tillage system (CT: conventional tillage, CP: chisel plough, NT: no-tillage). (Roth, 1985)

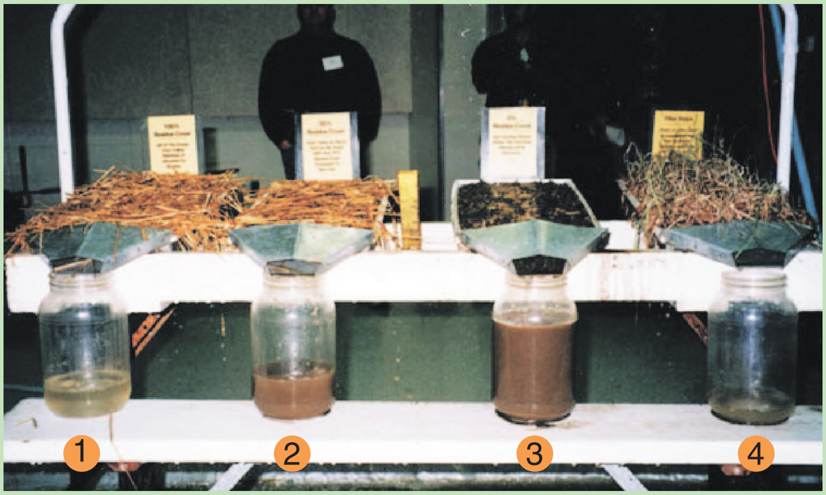

Photo by Rolf Derpsch.

Figure 5: Rainfall simulator demonstration performed at the No-Till on the Plains Winter Conference in Salina, Kansas. From left to right: 1) 100% soil cover, little runoff, and clear water indicating very few soil particles in suspension, 2) 30% soil cover, more runoff and some soil in suspension, 3) bare soil, no cover, resulting in a huge amount of runoff and the dark color of water shows also a lot of soil particles in suspension, 4) pasture with 100% soil cover and undisturbed soil, even less runoff than under #1.

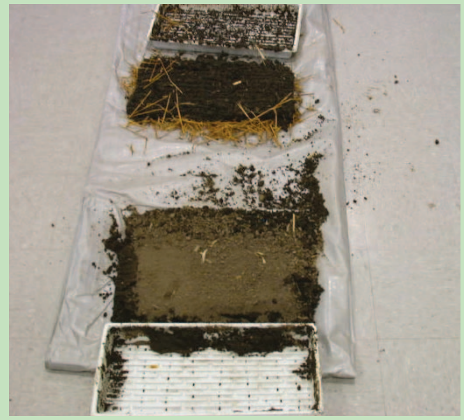

Photo by Rolf Derpsch.

When afterwards the trays were turned on a canvas, the tray with bare soil (#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.

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Acknowledgement:

The author thankfully acknowledges the revision, inputs and improvement of the original manuscript by Matt Hagny, Salina, Kansas, USA, as well as the revision by Melissa McDonald, Asuncion, Paraguay.

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