Improving soil moisture with conservation agriculture

José Benites and Antonio Castellanos

Irregular or insufficient rainfall can be a serious limitation to agricultural production, causing low yields and even crop failure. This is particularly true in drylands, where productivity levels are generally very low. In most cases, a great deal can be done to improve the efficiency of rainwater use. Conservation Agriculture is one way of improving soil moisture management.

Soil moisture management

A significant cause of low production and crop failure in rainfed agriculture is lack of water in the soil. This is caused by a combination of low and erratic rainfall, and poor utilisation of the water that is available. Soil moisture management is, therefore, a key factor when trying to enhance agricultural production.

Increasing the amount of water stored in the soil can result in:

- Improved yields (if there are also enough nutrients)
- Reduced risk of yield losses due to drought
- Recharge of groundwater, securing the water level in wells and the continuity of river and stream flows.

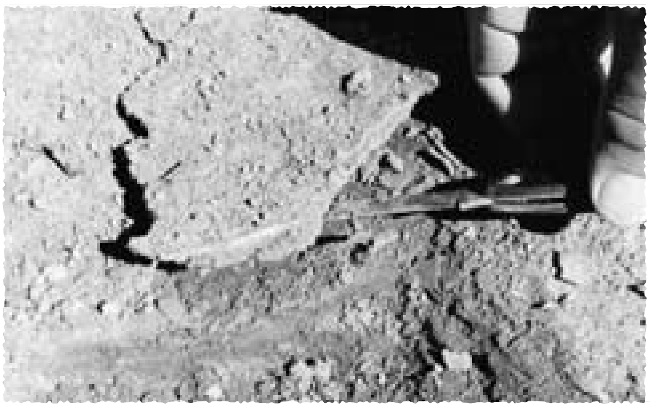
As little can be done to increase the amount of rainfall or the number of rainfall events, we should focus on improving the capture of rainfall, the availability of water in the soil and water use efficiency in rainfed agricultural lands. This means that the amount of water that enters the soil (infiltration) must be increased and that the moisture lost through runoff and evaporation must be reduced. Increasing soil cover and better soil management can help achieve this. Soil should be disturbed as little as possible, there should be permanent soil cover and the amount of organic matter should be increased.

Sub-surface compaction by continuing tillage has resulted in structural degradation and runoff. Photo: T.F. Shaxson.

Treasure hunting in drylands

When rain falls on the soil surface, part of it will infiltrate into the soil to replenish soil water or flow through to recharge the groundwater. Another part will run off as overland flow, and the remainder will evaporate directly from unprotected soil surfaces and from plant leaves.

The amount of water that can be held in the soil and made available for crop use is not only determined by the amount of rain that falls, but also by the chemical and physical properties



A thin surface crust caused by raindrop impact on a bare soil with poor structure. Photo: T.F. Shaxson.

of the soil. When most people think about soil, they think about the solid part. But the pore spaces or the structure of the soil are just as important.

Soils differ in their capacity to hold water and make it available to crops. This depends on:

- Soil texture (the proportions of sand, silt and clay)
- Soil depth (shallow soils hold less water than deep soils)
- Soil structure (pore spaces)
- Organic matter content (more organic matter means more water is held)
- Biological activity (earthworm holes, for example, greatly increase the possibility for water to enter the soil).

Pore spaces

The number, size and connections between pore spaces play a crucial role in determining the amount of water that can infiltrate into the soil, and the amount of water that the soil can absorb, hold and supply back to plants.

It is important to have many interconnected pores of a wide range of sizes, particularly at the soil surface. This improves infiltration, reduces runoff and benefits crop growth.

The number, size and connections between soil pores vary according to the type of soil and the way it is managed. Little can be done about the type of soil, but good land management can have a great impact on restoring, improving and protecting soil porosity. This in turn will increase available soil water content, and the interconnected pores will minimise any potential risk of waterlogging.

Crop water stress

Crop water stress develops when the plant cannot extract water from the soil through its roots as fast as it loses moisture from the surfaces of its leaves. To ensure that the crops will be able to utilise the available rainfall, we must understand the causes of poor soil structure, at the surface as well as below the surface.

At the soil surface, the impact of raindrops on a bare soil surface can decrease porosity through the formation of surface seals and crusts. These limit the rate of infiltration, leading to increased runoff. Runoff is responsible for soil erosion and peak-river flows. However, it is a consequence of soil degradation, not a primary cause. Physical structures like contour banks do slow down runoff and protect the soil from erosion, but do not resolve the problem of soil degradation as they do not increase the porosity of soils.

Any traffic in the field, such as machinery, ploughing, or the impact of human feet or animal hooves, can put pressure on the sub-soil, especially when the soil is in a moist condition. Pressure destroys pore spaces, in particular the interconnected pore space. The soil becomes compacted and water infiltration and storage capacity is reduced. Plant roots have difficulty in penetrating compacted soil and their root systems do not develop well.

Tillage, in particular turning over the soil by ploughing, can also lead to a decline in soil fertility. It decreases organic matter content and has a negative effect on soil biological activity, for example by destroying the burrows of earthworms.

The role of Conservation Agriculture

The four basic principles of Conservation Agriculture can help achieve and maintain an absorptive and biologically rich soil. These four principles are:

Maintaining permanent soil cover

Permanent soil cover, either plant residues or growing crops, protects the soil surface from the negative effect of raindrop impacts. It reduces crust formation and susceptibility to erosion, and enhances porosity on the soil surface. It also reduces direct water loss through evaporation from the upper layers of the soil and establishes better conditions. It also maintains a continuous food supply for soil organisms – from microbes to earthworms.

Minimising mechanical soil disturbance

Reducing or stopping tillage means that the soil is not disturbed and that the moisture loss and soil compaction that follows tillage is avoided. This increases the infiltration and percolation of water through the soil, leading to better root development and crop growth. Decomposition of organic matter and subsequent loss to the atmosphere is also reduced. Sometimes a once-only de-compaction is required to bring the soil back into a better starting condition. One of the most important impacts of minimising soil disturbance is that it improves the living conditions of beneficial organisms and so enhances their activity. Crop roots and soil organisms are responsible for the creation of a network of interconnected pores. These organisms undertake biological tillage and improve soil structure. In addition, biological activity ensures that crop residues are incorporated into the soil.

Controlling in-field traffic

It is vital to ensure that in-field traffic follows permanent tracks. In this way soil compaction is restricted to defined areas, year after year. When this is combined with zero or reduced tillage, the rest of the field is free of compaction. Soil porosity and water infiltration are maximised, earthworms and other soil animals prosper and organic matter is not lost but becomes closely bound and integrated with the soil. The overall impact is a productive soil system, able to carry crops through dry conditions because of the enhanced soil water store, the deep rooting of the crops, the biological activity and the high content of organic matter.

Crop rotation

The use of crop rotation and cover crops helps to increase soil organic matter, reduce erosion and bring biological diversity back to the soil. The rotation of different crops, with their different root systems, optimises the network of root channels in the soil, leading to increased water penetration, increased water holding capacity and more water being available for crop use, to deeper soil depths. Crop rotation also enhances biological diversity and helps reduce the risk of pest or disease outbreaks.

Monitoring soil moisture

We cannot know in advance how much rain will fall during the growing season. It is possible, however, to find out how much plant-available soil water is present before sowing the crop. Knowing how much plant-available water is present in the soil can help in making a wise decision about which crop to plant.

Measurements of soil water content can be made with a variety of equipment but most farmers will have to make an estimation based on the feel and appearance of their soil. This will vary with soil texture and moisture content, but with experience soil moisture can be estimated to an accuracy of about five percent.

Alternatively, a soil moisture probe can be used to determine the amount of water that is available for plants. This is estimated from the depth of insertion of the probe. Again, it has to be interpreted with knowledge of the soil texture.

Different rates of infiltration under zero tillage (left) and conventional tillage (right). Photo: Bruce Radford.

Conclusion

The four basic principles of Conservation Agriculture work together to create a soil that has a greater capacity to absorb rainwater. Although there is no single recipe to suit all conditions, Conservation Agriculture improves the physical and biological condition of the soil. A soil that is porous, absorptive, and rich in organic matter and biological activity is able to support maximum crop production for every drop of water it receives.

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