Int. Agrophysics, 1999, 13, 1-5

ASPECTS OF RED SOIL PROPERTIES AND WATER MANAGEMENT IN CHINA*

Z.Cao, X. Zhu

Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, People's Republic of China

Accepted January 30, 1998

A b s t r a c t. This paper is a brief reviev of studies on red soil water properties and its management in the tropics and subtropics of China. Although annual precipitation is more than evaporation, there is still seasonal draught in the area because of the uneven distribution of both rainfall and evaporation. Red soil structure is another reason for the seasonal draught. Several measures for alleviating this damage are also discussed in the paper.

K e y w o r d s: soil water, red soil in China

INTRODUCTION

There are large areas of red soil distributed in southern China. Approximately, the covering area of red soil is 2.03 million km^2, about 20% of the total land of this country. So, red soil is an important resource for the exploitation and utilization of agriculture and forestry in the tropics and subtropics of China. The hydrothermal conditions in this region are favourable, with an annual precipitation of 1200-2000 mm, which is usually more than the annual evaporation rate. However, the distribution of rainfall in a year is uneven due to the effect of southeast Asia monsoon weather. There is always flooding and low temperatures in spring, and severe drought and high temperature in summer and early autumn, which becomes one of the main limiting factors for agricultural production. Thus, how to efficiently use water resource for agriculture is an important issue in this region. In the past several years, great efforts have been made to study soil water properties, its balance and management in this above mentioned red soil hilly region [2,4-6]. This paper is a brief introduction of the research results.

CLIMATE CONDITIONS

Rainfall

Figure 1 shows the average monthly rainfall during 1955-1994. It can be seen that rainfall distribution in a year is extremely uneven in this region. The maximum precipitation is in May. The rainfall from April to June amounts to

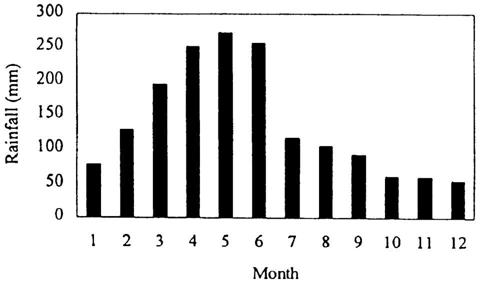

Fig. 1. Average monthly rainfall during 1955-1994.

*Paper presented at 6 ICA

781.36 mm, which is only 46.6% of the average annual precipitation. The rainfall from July to September is only 315.06 mm, 18.8% of the annual precipitation. In agricultural practice in this region, spring planting season happens at the beginning of April when the rainfall is excessive, which is adverse to seeding emergence. The maximum water demand for the staple food crops in this region is from July to September when the rainfall is insufficient, therefore, it becomes one of the main limiting factors for agricultural production.

Evaporation

The average monthly evaporation during 1955-1994 is shown in Fig. 2. Obviously, the evaporation rate is uneven in a year too. However, it is quite different from rainfall for its maximum is in July, later than the maximum rainfall (May). From June to September is the period with high evaporation, the accumulated in these four months amounts to 658.1 mm which is 53.5% of the total annual evaporation rate. So, during later summer and autumn, there is insufficient rainfall and high evaporation in the region, thus water managament becomes very critical in order to get high production.

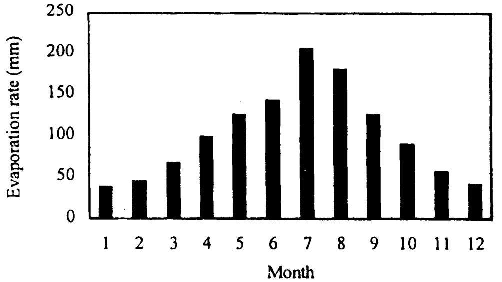

Fig. 2. Average monthly evaporation rate during 1995-1994.

SOIL WATER

Soil water content mainly depends on rainfall, evaporation and plant growth. Soil water problems in this region are dependent on its special water resource characteristics, soil structure and topography of land.

Water resource

According to the climate data showed above, although the total annual rainfall is insufficient during July to September when water is highly consumed by crops. However, rainfall is more than evaporation from November to June of next year especially during March to June, the excessive water can be harmful to seedlings emergence and plant growth, and also can cause runoff which makes the losses of water and the erosion of soil. While from July to October, rainfall is much less than evaporation. Thus, it is very important to develop soil management measures which can store more rainfall during rainy season for dry season.

Soil water properties

The soil we are discussing here is red soil derived from Quaternary red clay and the soil layer can be to a depth of two to three meters with uniform pore size distribution. Clay (<0.001 mm) content in 160 cm deep soil profile can be more than 40% except the first 20 cm layer (36.2%), thus the water retention capacity is very high, moisture content can reach to 40-50% at -2 KPa water potential, 30-40% at -10 KPa and 25-30% at -30 KPa (Fig. 3). However, the soils are well aggregated with a large amount of water stable aggregate, which makes the shape of the red soil water characteristic curve not like other clay soil, but similar to sandy soil due to the existence of macropores between aggregates. Thus, available water content of the soil is rather lower in spite of high water retention capacity, and soil water retained

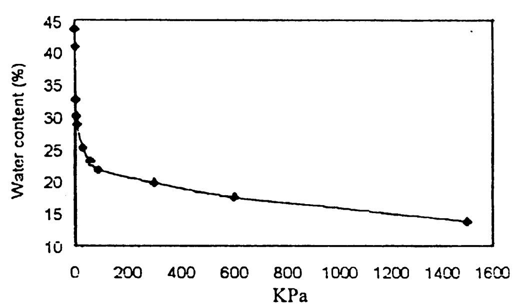

Fig. 3. Water characteristic curve of a red soil.

within aggregates is hard to relief even when crops are sufferi ng from drought.

Water characteristic of red soil and its ability to defeat drought is closely related with the soil capacity to accept rainfall, holding capacity of available water and absorbing ability of crop roots. According to the determination, the total porosity is about 50% and uniformly distributed in the soil profile, which means that although red soil has a high capacity to accept rainfall except there exists crust on surface layer. Usually crust happens in uncultivated red soil especially with slope topography where there is large amount of runoff in rainy season. If we take water content at water potential of -30 KPa as field capacity and -1.5 MPa as wilting water content, then the difference between the two water content is defined as available water content. It is reported that available water content of red soil is in the range of 6.4-11.6% only, while the black soil, which with similar soil texture as red soil, is amount to 25% [5], it does make the red soil liable to drought in spite of the large rainfall.

Water infiltration of soil is another important physical factor affecting water storage in red soils. Generally, it is favorable in clayey red soils because there are a great deal of water stable aggregates and the aeration pore space in these soils. The saturated hydraulic conductivity (K_{10}) is high and changed in a range of 2.3-14.7 cm/h, while that in clayey soils distributed at the plain of northern China ranges only 0.8-1.1 cm/h. However, once the crust is formed on the surface soil resulted from destruction of soil structure or the fine soil particles slaked from aggregates are leached down to block the transmission pores, the infiltration rate can be reduced apparently. In that case K_{10} in surface layer of red soils amounts only to one third of that in undisturbed sublayers of the same profile. Therefore, preventing the surface soil from crusting, maintaining better soil permeability and increasing infiltration rate are the most powerful ways to increase the effective use of water resources in this region.

Water supplying from sublayer mainly depends on unsaturated hydraulic conductivity. Although red soil is of high saturated hydraulic conductivity, unsaturated hydraulic conductivity decrease rapidly with the decrease of soil water potential (Fig. 4), which should be beneficial to prevent water loss from subsoil. Therefore, how to prevent the water retained in macropores from evaporation becomes very important. Mulching after rain maybe a useful way to meet the said requirement.

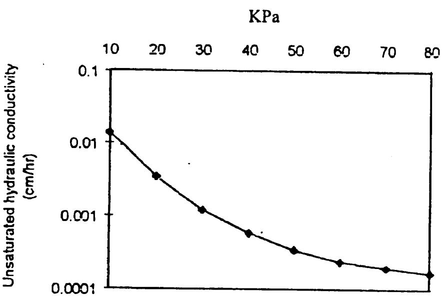

Fig. 4. Unsaturated hydraulic conductivity of a red soil.

Water storage in soil profile is obviously unevenly distributed with its typical of large amount soil water storage in spring and much less from Summer to middle Autumn. Usually, in the first half of a year, soil water content in the field is often near or even more than field capacity, but it declines from July till the end of the year. In the period of July to September, sometimes to October, water retained in the first 50 cm layer is very limited and the available water storage often appears to be negative. Occasionally, a negative value can be found even for the 50-100 cm layer. However, there is still available water retained in the 100-200 cm and 200-300 cm soil layers, the amount could be about 100 mm for each layer. Water storage in deep layer of red soil during the drought season is probably related with the feature of its high soil saturated hydraulic conductivity and rapid decrease of unsaturated hydraulic conductivity as the decrease of water potential. Because the former is good for soil to accept rainfall and the later is beneficial to decrease soil water loss by surface evaporation. The amount of water storage in red soil profile also varies with land utilization patterns. For example, water storage in tea garden and orange orchard is much more than in upland crop field during the dry season (July to September). Therefore, how to use the water stored in deep layer of red soils plays an important part in the alleviation of the drought occurring in summer and autumn.

SOIL WATER MANAGEMENT

The seasonal drought appears in the red soil region of subtropical China as the result of the integrated effect of uneven distribution of annual precipitation, easy loss of water by runoff, low available water capacity and poor water supplying properties of red soil.

It is necessary to improve management measure in order to alleviate drought. Research has been done to increase rainfall acceptance by surface mulch and to add water by micro-sprinkler during dry season in orange orchard [6]. The results pronounced that mulch and micro-sprinkler both could increase soil water storage in 0-50 and 0-100 cm layer during the dry season (Fig. 5). The average water storage in 0-50 cm layer for the plot of CK, mulch and micro-sprinkler during the dry season were 89, 101 and 115 mm, respectively, while the value for 0-100 cm layer were 214, 239 and 263 mm. It is also reported that the unavailable soil water storage in 0-50 cm and 0-100 cm layers are 110.4 and 212.6 mm. So, even if the soil surface was mulched with crop stem, there was still not enough available water in the first 50 cm layer for healthy crop growth. Thus, irrigation is essential to add water for crop growth. Of course, mulch is also a good measure for water management when irrigation system is not available bacause it can increase 25 mm available water storage in the 0-100 cm layer during the dry season. Irrigation also could increase orange fruit size and improve the quality. Therefore, irrigation and surface mulch are both efficient water management measures for the red soil. Another research regarding efficiently

a

b

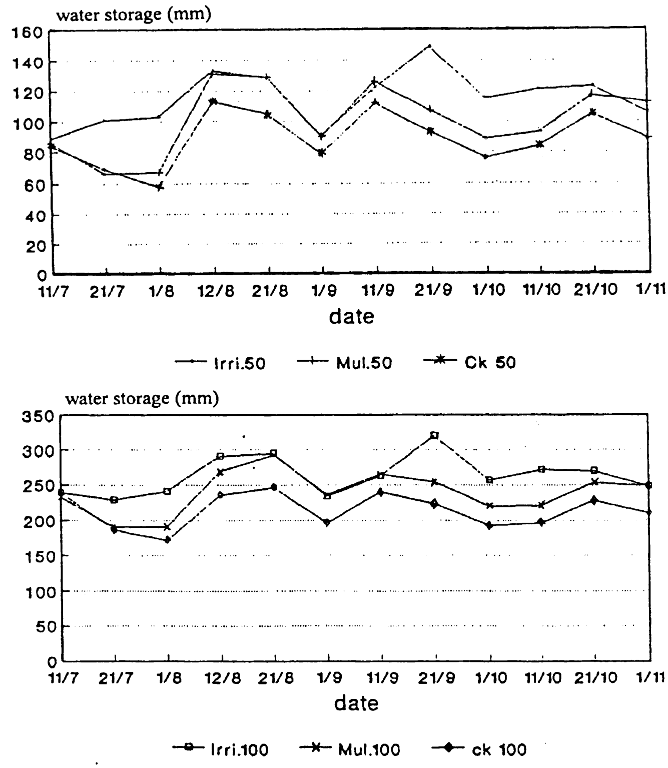

Fig. 5. Water storage in 0-50 cm (a) and 0-100 cm (b) layers (1991).

use of deep layer soil water was done by tree and upland crop intercropping [1]. Results showed that tree root can deep to as 80-90 cm which made the better use (33.7 mm more) of soil water stored in 0-100 cm soil layer.

CONCLUSIONS

1. Red soil physical properties are of high clay content, more macropores like sandy soil and many micropores within the aggregates, low available water and high unavailable water content, high saturated hydraulic conductivity and rapid decrease of unsaturated hydraulic conductivity with the decrease of soil water potential, which makes the soil with low water supply capacity and liable to drought.

2. The uneven distribution of rainfall and evaporation brings about the severe seasonal drought which is harmful to crop production and efficiently water use.

3. Irrigation is essential for good upland crop growth in red soil region, while mulch is only of limited value. Thus, more water management patterns and cropping systems need to be developed in order to alleviate the seasonal drought and for better use of deep layer water storage.

REFERENCES

1. **Wang M.Zh., Zhang J.B., Zhao Ch.Sh., Tan Q.M., He Y.Q.:** Study on temporal and spatial heterogenity of water resources and its comprehensive utilization in Low-hilly red soil region. Research on Red Soil Ecosystem, 243-282, 1995.
2. **Xu X.Y., Yao X.L.:** Physical properties of red soils and its effect on water availability. Trans. Int. Symp. "Development of Grasses in the Region of Red Soils of Southern China", 1991.
3. **Yao X.L.:** Recent advance in studies on physical properties of red soil in China. Int. Agrophysics, 7, 61-67, 1993.
4. **Yao X.L., Yu D.F.:** The volumetric capacity of red soil and its effect on the drought resistance. Research on Red Soil Ecosystem, 262-268, 1993.
5. **Yu D.F.,Yao X.L.:** A preliminary study on the range of available water in red soil. Research on Red Soil Ecosystem, 269-274, 1993.
6. **Zhu X.H., Yao X.L.:** Water properties and its management of citrus orchard soil in red soil of hilly region. Research on Red Soil Ecosystem, 275-282, 1993.