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Assessment and utilization of soil water resources

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Abstract: Based on the analyses of water interactions and water balance, this paper discusses the issues on the assessment and regulation of soil water resources, which lays the scientific basis for limited irrigation and water-saving agriculture.

Assessment and utilization of soil water resources WANG Hui-xiao, LIU Chang-ming, YANG Zhi-feng (State Key Laboratory of Water Environment Simulation, Beijing Normal University, Beijing 100875, China) 1 Introduction It is well known that the major problem of water resources at present is water shortage in the North China Plain. The development of agricultural production certainly increased the water consumption, so level of groundwater table declined year by year. Crop use water directly from soil water, while rainwater, surface water, and groundwater should be firstly transformed and changed into soil water and then be used by crops. Therefore, water interactions, water balance and soil water management will first affect the status of soil water resources, and then affect groundwater as well. These issues are analyzed in this paper. 2 Water interactions and water balance 2.1 Water interactions Water interactions are involved in a water cycle with a series of hydrological processes such as rainfall runoff (Rs), evapotranspiration (ET), infiltration and replenishment of subsurface water in the unsaturated zone and the saturated zone (W and G, respectively). Soil water participating in runoff (surface water, Rs) through interflow (F); groundwater draining in the form of underground flow (Rg) or involved in the base flow of runoff, soil water and upward groundwater movement by capillary actions contributing to evaporation (E) and transpiration (T) are just cases. This is so complex that many hydrological states in transformation are linked to each other. Figure 1 shows the water interactions in an agricultural field system, with the irrigation water (I) as a man-made water input of the system. For a flatland system, the inputs are P (precipitation) or I, the outputs are Rs, Rg (ground water flows), F (interflows) and ET comprising evaporation of surface retention water (ETa), soil water (ETb) and ground water rising to the unsaturated zone (ETc). Obviously, the throughput of the systems will be FI and FS, in other words, storable water in the subsurface zones. This water is of great significance for agricultural activities in terms of agricultural water management. Apparently, the subsurface water is the key research subject, which plays an important role not only in the processes of water interaction, but also in laying a base for the optimal conjunctive use of agricultural water. Figure 1 Water interactions of an agricultural field system Subsurface water includes soil water and groundwater. In another way, it is divided into unsaturated zone or aeration zone and saturated zone according to its water regimes. Extremely frequent water exchange exists between soil water/unsaturated water and groundwater/saturated water. The movement of subsurface water is only a part of water cycle. Movement of precipitation water (P) and irrigation water (I) into the subsurface water zones involves other processes of water cycle, such as runoff (Rs) and evapotranspiration (ET). Obviously, this is an extremely complex water process with the following characteristics: (1) water exchanges in both vertical and horizontal directions; (2) mass flows are reversible, but unequal; (3) water flows up and down with different characteristics, for example, downward water infiltration and percolation and upward water movement through capillary action and evapotranspiration contain a phase of transformation; and (4) water exchange process includes both energy transformation and the changes in water quality. 2.2 Water balance The main characteristics of the above processes are of great significance in understanding the movement and balance of soil water. Subsurface water balance consists of soil water balance and groundwater balance. Field water balance is the basis for the evaluation of field soil water resources. 2.2.1 Soil water balance The horizontal exchange of soil water in the North China Plain is extremely weak. Therefor e, P-Rs+CN+Eg=E+T+Fg+?W1 (1) where Rs is surface runoff; CN is condensation water; Eg is upward water from groundwater table to soil layer through capillary action, Fg is percolation water to groundwater table; and ?W1 denotes variation in soil water storage. 2.2.2 Groundwater balance The output (Fg) of soil water balance is the major input of groundwater. Considering other inputs, an equation of groundwater balance can be written as: Fg+Fr+Fs+FI=Eg+Rg=?W1 (2) where Fr and Fs are the percolation of rivers/canals and that of water-storing bodies, respectively. Fi is irrigation return water to groundwater; Eg and Rg are the vertical discharge and horizontal discharge of groundwater, respectively, and ?W2 denotes variation in groundwater storage. 2.2.3 General equation of subsurface water Merging equations (1) and (2), the equation of subsurface water balance will be expressed as follows: ?WG=?W1+?W2=P-R+CN-E-T+FR+FS+FI (3) where R is runoff including Rs and Rg. The terms ?W1 and ?W2 can be ignored in terms of many years. The experimental results in Haihe Plain showed that P, ET and Fg are the major elements of subsurface water balance. Therefore, the vertical water exchange takes a dominant position. 3 Assessment on soil water resources Soil reservoir is the place for storing soil water, i.e. the unsaturated zone. In the light of crop water use, it could be defined as the soil water in crop root zone. Like surface reservoir, it has its water input sources (precipitation, irrigation and capillary water from groundwater) and outputs (evapotranspiration, deep drainage). Soil reservoir has the regulating effects on the inputs and outputs through soil water infiltration and crop use. And the agronomic measurements could be used to control the soil reservoir to meet the water requirement and also to create the fitful environments for crops. The regulating capacity of soil water reservoir could be calculated from the common soil water constants: saturated water content, field capacity, and wilting point corresponding to the maximum, dead, and effective capacities of soil water reservoir, in which the effective capacity has the regulating effects on soil water supply to crops. And the regulating amount of soil water has a close relationship with the calculating period, crop growth season, evapotranspiration, climate, and groundwater level. Soil water is an important water source for crops. It is reasonable that soil water is taken as a natural resource for crop growth, which is involved in the interactions between the four surface renewable fresh waters. The unsaturated water body?oil water as the basic source ensuring field water requirement is an essential part of land water cycle. The main input of land water cycle system is atmospheric precipitation which finally transforms into surface water, soil water and groundwater. The structure of land water resources is shown in Figure 2. Figure 2 Systematic structure of land water resources Through many years?study, the identical understanding of the assessment on surface water and groundwater resources has already been achieved, which successfully laid the scientific basis for water sector. Though soil water has been paid great attention, there is no common idea of whether soil water belongs to water resources and how to evaluate it quantitatively. At the beginning of the 1980s, soil water resources began to be studied both in Russia and in China almost at the same time. Assessment on soil water resources has been carried out at regional or crop? level. Catchment water balance is the basis for evaluating regional soil water resources. The total evaporation of a catchment or evapotranspiration is the quantitative evaluation of regional soil water resources. Field evapotranspiration including crop transpiration and soil evaporation could give the structure of soil water resources. 4 Water regulation for groundwater Regulation and management on water interactions, especially on soil water could finally control groundwater table, and maintaining groundwater level is a necessary condition for the development of sustainable agriculture. For example, limited or controlled irrigation should be an effective way for regulating groundwater, because the main irrigation method in this region is pumping groundwater. Mulching in the field could prevent soil evaporation and then could reduce the irrigation frequency. WAVES (Water Vegetation Energy Solute Model) is used to simulate field water balance and crop growth. The simulating results of long sequence (1984-1996) under different crops, precipitation conditions, and irrigation regimes were shown that carrying out the limited irrigation is reasonable in the North China Plain. Irrigation management is of great importance for controlling the declination of groundwater table. During the process of modelling, deep drainage is defined as water flux at the lower boundary. Only considering the gravitational water movement, deep drainage could be estimated as: D = ??ks (4) where D is deep drainage at the lower boundary; ks is the saturated soil water conductivity of the soil layer near the lower boundary; and ? is a parameter between 0-1 determined by the character of lower boundary. Figure 3 Simulation of soil water consumption (W2-W1), evapotranspiration (ET) and deep drainage (D) under different irrigation regimes The simulating results under different irrigation regimes were shown that the drainage at the lower boundary (2m) was determined by irrigation water (Figure 3). Within the irrigation water of 120 mm, there was almost no change in the drainage, but the drainage changed greatly when irrigation was beyond this value which was the threshold value for controlling the deep drainage. Limited irrigation could effectively control the deep drainage and increase soil water use efficiency. 5 Summary Soil water is an important component of water balance, so analyses on water interactions and water balance are the basis for further assessment on soil water resources. Soil water is involved i

n the interactions between the four renewable fresh waters: atmospheric water, surface water, soil water and groundwater and soil water is the key part of the water interactions. Soil water is an important water source for crops, and soil water can be taken as a natural resource for crop growth. The unsaturated water body?oil water as the basic source ensuring crop water requirement is an essential and key part of land water cycle. Catchment water balance is the basis for evaluating regional soil water resources. The total evaporation of a catchment or evapotranspiration is the quantitative evaluation of regional soil water resources. Field evapotranspiration including crop transpiration and soil evaporation could give the structure of soil water resources. Regulation and management on water interactions, especially on soil water could finally control groundwater table, and maintaining groundwater level is a necessary condition for the development of sustainable agriculture. References

关键词： soil water resources; assessment; water interactions; water balance

