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Effect of apple production base on regional water cycle in Weibei upland of the Loess Plateau

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Abstract: Weibei upland, located in southern part of the Loess Plateau, is a commercial apple production base in China. The enlargement of apple-planting area has a great impact on the regional water cycle. The effects of different land use on hydrological parameters are compared and studied in this paper. The main results are as follows: (1) The initial and steady infiltration rates in apple orchard are higher than those in other land use types such as grassland, idle land and farmland. Their initial rates of infiltration are 0.823 cm/min, 0.215 cm/min, 0.534 cm/min and 0.586 cm/min in apple orchard, grassland, idle land and farmland respectively. Their steady infiltration rates are 0.45 cm/min, 0.038 cm/min, 0.191 cm/min and 0.155 cm/min respectively. (2) There is no runoff generated in plot of apple orchard in all 8 storm events in observed natural rainfalls, while runoff is generated in winter wheat plot, corn plot and alfalfa plot with runoff coefficients of 2.39%, 1.58% and 0.31% respectively. (3) The transpiration of apple trees is strong and thus soil moisture is gradually depleted. The average soil water contents in 3-9 m soil profile in Changwu plots with apple trees of 14 and 32 years in age are 11.77% and 11.59% and in Luochuan plots with those of 15 and 28 years in age are 11.7% and 11.59% respectively, which are nearly 9.0% of wilting moisture of Changwu soil and 8.6% of wilting moisture of Luochuan soil. The pathway of rainfall percolating to groundwater is hindered by dry soil profile.

Effect of apple production base on regional water cycle in Weibei upland of the Loess Plateau HUANG Ming-bin1, HE Fu-hong2, YANG Xin-min1, LI Yu-shan1 (1. Institute of Soil and Water Conservation, CAS, Yangling 712100, China; 2. Northwest Sci-tech University of Agriculture and Forestry, Yangling 712100, China) Weibei upland of the Loess Plateau containing Xianyang city, northern part of Weinan city, southern part of Yan'an city and a part of Tongchuan city covers a total area of 30,000 km2 with an elevation of 900 to 1500 m above sea level and annual average precipitation is from 550 to 600 mm. The Luochuan and Changwu uplands are two of those large uplands in Weibei region. These uplands have been identified as a commercial apple production base for its special features of topography and climate which are suitable for apple plantation. The apple planted area has been developed quickly in recent years. For example, the total arable land of Luochuan county is 350 km2, of which 200 km2 have been turned into orchard since 1995. The rest of the arable land has been planned to plant apple trees gradually before 2010. Owing to the high yield and biomass, water demand of apple trees is higher than that of other crops such as winter wheat and corn. The conflict between water supply and water demand in this region will be intensified if apple orchard is enlarged. In addition, the regional inter-relationships among precipitation, infiltration and runoff will also be affected because of leveling, deep ploughing and meticulous management of the due to changes in underlying surface. This will eventually lead to changes in regional pathways of water cycle. Therefore, we should concern the changing trend and predict regional water cycle. This research of impacts of human activities on regional water cycle has been undertaken in the way of simulation, monitoring and evaluation[1-5]. The objective of this study is to analyze the effect of apple production base on regional water cycle in Weibei upland of the Loess Plateau. 1 Features of topography and water cycle in Weibei upland The ground surface crisscrossed by loessic yuan (tableland), liang (ridge) and gullies and valleys constitutes the topographic features of Weibei upland. The tableland is covered by loess soil with a thickness of 50 to 100 m and a slope of 3o-5o. The area of ridges and gullies accounts for about 47% of the total area and the gully density is over 2-3 km/km2. The depth of a gully is from 80 to 200 m. The bottom of gully dissects deeply into base rocks[6]. The featu

res of regional water cycle are as follows: (1) Precipitation infiltration through soil layer is the sole water sourc e supplied to groundwater, and the water from stream flow is very small and can be neglected[7]; (2) stream flow is c omposed of surface runoff of tableland, ridges and gullies as well as base flow from groundwater; (3) groundwater tab le is very deep (Changwu, 70 m and Luochuan 100 m) which can not directly join vertical water exchanges; and (4) the main phenomena in hydrological cycle of upland is vertical cycle in the soil-plant-atmosphere system, and the amount of runoff and percolation which joins regional hydrological cycle is small. The annual amount of evapotranspiration i s about 80-100% of the total precipitation[8]. The features of regional water resource is that surface runoff from pr ecipitation and groundwater is the solely usable water. Table 1 Data of hydrology and soil at Changwu and Luochuan up lands in detail Table 2 Parameters of runoff plots in Chuangwu upland 2 Materials and methods This research was condu cted at the Changwu and Luochuan uplands in 1996 and 2000. Experimental measurements included the infiltration rates and the relationship between precipitation and runoff in different types of land use and soil water distribution in 1 0 m profile. The main data of soil characteristics in Changwu and Luochuan uplands are shown in Table 1. The infiltra tion rates of different types of land use in Changwu upland are measured in double-loop equipment[9]. The main measur ed site included soil types of harvested winter wheat, corn, alfalfa, and apple trees for 12 and 3 years in age as we ll as bare fields. The runoff of different types of land use in Changwu upland is collected by multi-tubs water tank and observed by technicians, and plots which consist of winter wheat, corn, alfalfa fields and apple orchard of 12 ye ars in tree age (Table 2). Soil water content is measured by gravimetry at farmland and orchards of Changwu and Luoch uan uplands by sampling soil from each plot on Sept. 10-11, and April 26-27, 2000, respectively. Soil samples are tak en from soil depths in 10 cm increments from the soil surface to 100 cm, and 20 cm increments from 100 cm to the 10 m. 3 Results and discussion 3.1 Infiltration of apple orchard in upland The effect of different land use on infiltrat ion is indicated in Figure 1. Data of the experimental result are regressed with Horton's equation[10] shown in Tabl e 3. Owing to good regression coefficients, the Horton's equation is regarded as a good one to simulate the process of infiltration in Weibei upland. From Figure 1 and Table 3, we find that the infiltration rate in apple orchard is m uch higher than other land use types as idle land, winter wheat, corn and alfalfa. The reason is that there is smalle r soil density in orchard than other land use for its deep ploughing. The steady infiltration rate in apple orchard f or trees of 3 and 12 years in age are 0.45 cm/min and 0.276 cm/min, respectively. But this value in farmland with har vested winter wheat and growing corn is only 0.155 cm/min and 0.130 cm/min respectively. The great infiltration capac ity in orchard could absorb all precipitation, therefore no surface runoff is generated although rain-splash and grou nd surface crusting can drop the rate of infiltration to a certain extent. Figure 1 Infiltrating processes of differe nt land use in upland Table 3 Infiltrating parameters of different land use in Changwu upland 3.2 Low surface runoff rate in apple orchard The data of precipitation and runoff of eight storm events for four experimental plots in 1996 are listed in Table 4. We can find that no runoff is generated from orchard in all of the eight storm events, but th e total amount of runoff from the plots of other crops is rather large. For example, the total amounts of runoff fro m 404 mm precipitation in plots of harvested wheat and growing maize are 9.647 mm and 6.377 mm, respectively. Beside s soil infiltration capacity, the main influential factor to surface runoff generation is land surface coverage statu s in the condition of similar slope. The rainy season in the Loess Plateau is from June to September when winter whea t accounting for 82% of the arable land in the Loess Plateau is just harvested, and this part of bare land is benefic ial to runoff generation and concentration. The corn field is also easy to generate runoff for its smaller infiltrati on capacity. If these parts of arable land are changed into apple orchard, the surface runoff generated will be reduc ed due to its high infiltration capacity and good coverage. Table 4 The relationship between rainfall and runoff in d ifferent land use of upland 3.3 Soil water distribution in the 0-10 m profile Soil water distributions in the 0-10 m profile of orchard in Changwu and Luochuan uplands are shown in Figure 2. The age of apple trees in Changwu upland i s 8, 14 and 32 years, respectively, and in Luochuan upland it is 8, 15 and 28 years. In Figure 2, soil water content s in the 0-10 m profile are obviously lower than that of farmland. The average soil water contents in 3-9 m soil prof ile in Changwu plots with 14- and 32-year apple trees are 11.77% and 11.59%, and in Luochuan plots with 15- and 28-ye ar apple trees, 11.7% and 11.59% respectively. Soil wilting moisture of the former is 9.0% and that of the latter, 8.6%. The results show that the strong evapo-transpiration of apple orchard consumes not only its total annual precip itation, but also previously effective soil water storage. This caused dry soil layer further deeper. The observed da ta show that the annual amounts of evapotranspiration from farmland with crops and bare soil in upland are 546 mm an d 571 mm respectively[8]. There are about 36.1 mm and 11.3 mm of rainfall respectively stored in soil in the conditio n of average 582.3 mm of precipitation (1977-1981). With average precipitation of 530.9 mm (1992-1999), 549.4 mm (198 5-1999) and 588.5 mm (1972-1999), the amounts of evapotranspiration from apple orchard with tree age of 8, 15 and 28

years are 552.5 mm, 600.3 mm and 616.6 mm, respectively. The amounts of over depletion of soil water storage are 15 1.0mm, 762.9 mm and 785.6 mm respectively, and the dry soil layer is further developed. The drying trend becomes mor e serious with the increase of tree age and this drying process would be ended with the depletion of effective soil w ater storage. The water demand for growth will depend on natural precipitation, and yield of apple will fluctuate wit h the amount of precipitation. The relationships between apple yields from trees of 28 years in age and precipitatio n in a certain year are analyzed. Result shows that there is no obvious effect on apple yield when annual precipitati on changes before the existence of dry layers. After dry soil layer formed, this effect is quite remarkable. About 2 0% of the production yield, on the basis of average 37500 kg/hm2 of apple orchard, appears close relation to precipit ation variation. The dry soil layer in the profile affects the transforming process of rainfall percolation to ground water. Even though the supply amount of rainfall percolation to groundwater is very limited, this pathway is the sol e source supplying groundwater in Weibei upland. From soil water distribution in the 0-10 m profile of farmland, soi l water content is close to field capacity in the 3-10 m profile, and rainfall could percolate to groundwater in wet year. But this pathway is hindered by dry soil layer in apple orchard with tree age over 14 years, for soil water con tent in the 3-9 m profile is near to the wilting point. The main mechanism of rainfall percolation in the Loess Plate au includes gravitational force and soil water potential gradient. The factor of rainfall percolation by gravitationa l force is that the total amount and depth of infiltration exceed soil water deficit. The gravitational function does n ' t work since the observed depth of infiltration is less than 3 m. The pathway of rainfall percolation by soil wate r potential gradient is also hindered for the negative gradient in the 3-10m profile[8]. Therefore, the expansion of apple-planting area in Weibei upland will lead to decrease of ground water supply amount and renewing period. 4 Concl usions Weibei upland has been a commercial apple production base in China. The enlargement of apple-planting area ha s a great impact on regional water cycle, and so the effects of different land use here on hydrological parameters ar e compared and studied. The initial and steady rates of infiltration in apple orchard are higher than those in grassl and, idle land and farmland. Runoff in apple orchard was not generated in the 8 events of observed rainfalls, but wa s generated in winter wheat, corn and alfalfa plots with runoff coefficients of 2.39%, 1.58% and 0.31% respectively. The transpiration of apple trees is very strong and gradually depletes soil moisture, so the pathway of rainfall perc olating to groundwater is hindered by dry soil profile. References

关键词： Loess Plateau; Weibei upland; water cycle

