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Spatiotemporal Variability of Soil Moisture under Different Agroforestry Landscape in Jinghe River

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Abstract：Measured the cover soil water content in soil layer 0~30cm of different agroforestry landscape types in Jinghe river with TDR, the landscape types including sloping cropland, apple orchard, apple-clover system, land under forest and grass changed from grain crop and black locust forest. Analyze the distribution characteristic and spatiotemporal variability of the cover soil water. The result showed that the soil water has renewed in a certain extent after a rain period in 1.5 m soil profile; the soil water content is gradually increased from the top of to the bottom of the slope under the affection of the slope location and plant category. The theory model of semivariogram for cover soil water content before rain season and after season, the value of nugget is changed no obviously , and they are 0.25 and 0.30; ranges is 99.7 m and 87.6 m. And the results indicated that soil moisture exhibited high fractal dimensions and clear spatial autocorrelation. The fractal dimensions are 1.71 and 1.74, variogram is main autocorrelation. During rain season the theory semivariogram model is linear, the spatiotemporal variability of soil water content becomes higher with the increase in distance, and its fractal dimension is 1.40.

Jing river is a major tributary of the he middle reaches of the Yellow River, a total length of 483km, the basin area of 45421km2, of which water and soil loss area of 33220 km2, accounting for73.1% of the total area. According to the landform types in the basin can be divided into Loess Hilly and gully region, the gully area of the Loess Plateau hilly region, soil, loess hilly area and loess terrace area. The hilly and gully area of Loess Plateau and gully region of loess plateau area occupies the entire basin81% (Guo Dongbin,1999). Most of the farmland without irrigation, agriculture and animal husbandry to obtain natural precipitation becomes the main water source. Land use and land topography is the impact of spatial and temporal distribution of soil moisture is the important factor (Crave,1997), in the area of soil moisture is not only the process of soil erosion (Jiang Dingsheng,1997), plant growth (Yang Wenzhi,1992) and vegetation restoration (Zhu Zhicheng,1993) and the main influence factors of land, is an important index in the evaluation of (Fu Bojie,1991). Due to the heterogeneity of the soil itself (Fu Bojie,1991; Wu Qinxiao,1998), at the same time as in the semiarid area of loess plateau gully slope position, under different planting patterns influence, will increase the spatial variability of soil moisture. The soil moisture spatial variability and its affecting factors made a lot of research (Li Yushan,1990; Fu Bojie,1999; Liu Mei,1990; Wang Jun,2000; Pan Chengzhong,2003), of the slope soil water study is the main target of gentle slope land in or on a steep slope, woodland, and for the different land use patterns in spatial and temporal distribution of soil moisture characteristics research. This study chooses the gully area of the Loess Plateau Watershed with different land use way, on the different position of slope, vegetation type under the influence of surface soil moisture content determination, to study the temporal and spatial distribution characteristics, designed for gully region of Loess Plateau Watershed of agricultural production, the restoration of vegetation and rational use of land to provide some guiding significance, to for a period of adaptation in Jinghe River basin economy and protection of ecological environment coordinated development 's needs, for the construction of agroforestry landscape optimization configuration model provides a scientific basis.

1. General situation of test area

Test area is located in the Jinghe River Basin in Shaanxi province in Yongshou county. Yongshou county is located in Weibei Dry plateau West, is a typical hilly and gully region of Loess Plateau, elevation of about 1000m. Experimental zone location which is sub-humid warm temperate continental monsoon climate, the average annual temperature of 10.8 degrees, rainfall interannual variability, over the average rainfall rainfall mainly in600.2mm,7-9, accounting for about more than 60% of the annual precipitation. In the studied area, the main soil types in loess parent material developed cinnamon soil, deep soil, tillage good. The groundwater buried depth, without irrigation conditions, implementation of Rainfed agriculture. The natural vegetation is destroyed, cultivate breed index is high, land use types to slope farmland, orchard, Guo Mu, retreat return n cultivated land forest land and forest land compound mainly.

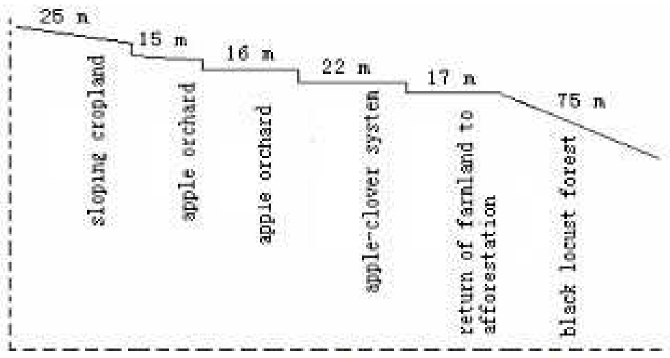

fig.1 The site sketch map of different types on the slope

2 Materials and methods

Selection includes different agricultural landscape slope from top to the bottom of the slope, agroforestry models were: Wheat (start test have been harvested), apple orchards, apple - alfalfa intercropping, retreat return n cultivated land forest and Robinia pseudoacacia Plantation (see Figure 1, figure number length). Among them, the apple tree spacing of 3m x4m,6 years old; Robinia pseudoacacia forest secondary forest (sprouting seedling),8 years old, diameter4-5cm, high 5-6m; returning cultivated land to woodland has cultivated a year, Robinia pseudoacacia seedlings planted. Using Trime-FM3with TDR surface moisture probe in the determination of the water content of soil surface 0-30cm, from top to bottom layout along the line transect sampling bandwidth,24m, long 168m, will be kind with grid for3m x 3m grid, the grid intersection measuring water content, a total of 504 points. Determination of time before the rainy season, and after the rainy season, June 18, 2004 to August 24th, to determine date respectively and in October 29th. In order to reduce the error, measurement probe in measuring point according to the three direction on the measured value of the mean.

Statistical analysis was performed using geostatistics theory and method, the principle and method in many literatures have more detailed description (Matheron,1963; Webster,1985; Robertson,1993), here no longer. For variant function formula:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[Z(x_i + h) - Z(x_i) \right]^2 \qquad (1)$$

$N(h)$ Is the distance equal to h point log， $Z(x_i)$ Is the kind of point Z at position x_i measured values， $Z(x_i + h)$ Is the x_i distance of h sample values。Suitable soil moisture variation function model often have spherical model and exponential model.

The fractal dimension D calculation by the variation function and the step ^{k} to determine the relationship, is：

$$2\gamma(h) = h^{4-2D} \quad (4)$$

On the type and double logarithm, the double logarithm curve by linear regression, the regression slope of a straight line *k* The fractal dimension can be used to estimate the slope *k*：

$$D = \frac{1}{2}(4-k) \quad (5)$$

The fractal dimension D size, said variation function curve curvature. On the different variable D value comparison between, can determine the degree of spatial heterogeneity.

This paper uses GS^{+} for windows calculation and analysis software the semivariance function and fractal dimension, the sample points are on the same slope, so we assumed that there is no anisotropy, analysis using isotropic model.

3 Results and analysis

3.1 Soil water distribution characteristics and its influencing factors

Fig.2 before and after the rainy season and the rainy season from top to bottom of the slope soil water content on average, table 1 for the soil surface water content of the average value and variation characteristics of. From Fig.2 and table 1can be seen, in different seasons, different land use patterns in different slope position and soil moisture are different. Among them, before and after the rainy season and the rainy season in the surface soil moisture change of average larger presence, rainy season, different land use types in the average surface water content in 14.9% ~ 17.9%,25% ~30.9% and17% ~21.4%.

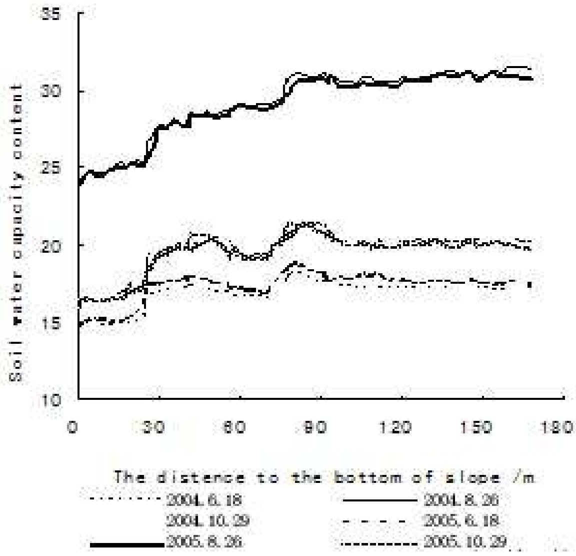

Fig.2 The change of 0～30 cm soil water content in different times

But from different seasons, soil water content from top to bottom slope change tendency is consistent.

From the soil moisture variation coefficient (see Table 1), say on the whole, the farmland, orchard hill in the coefficient of variation is downhill retreat farmland and woodland, which may be due to human cultivation increased moisture content variability. In different periods of water content variation is also different, the rainy season before and after the rainy season water content coefficient of variation of less than, and in rainy season with high coefficients of variation. The utilization of soil water content in the rainy season, the coefficient of variation were 2.24% ~ 5.82%,1.92% ~ 3.40%,2.68% ~ 5.41%, which may be due to the rainy season in the surface soil moisture are added, after the rainy season due to consumption of plants and soil evaporation and increase soil moisture variation.。

Tab.1 The average value and its variation characterize of 0～30 cm soil water content of different land types

Year	Land use types	No. of plot	Before the rainy season			In the rainy season			After the rainy season		
			Mean (%)	Change range(%)	Coefficient of variation (%)	Mean (%)	(%) Change range	Coefficient of variation(%)	Mean(%)	Change range(%)	Coefficient of variation (%)
2004	Sloping cropland	81	14.9	12.7～16.7	5.82	25.0	23.0～26.6	2.63	17.0	14.9～20.0	5.41
	Orchard（up）	45	16.9	14.7～17.9	3.90	27.4	25.6～29.4	3.40	19.7	17.6～20.9	3.86
	Orchard（down）	45	17.1	15.7～18.3	3.61	28.4	27.0～30.1	2.71	20.5	18.7～21.7	3.75
	Agroforestry	72	16.8	15.5～18.5	3.53	29.2	28.0～31.4	2.71	19.9	17.9～22.0	5.05
	Returned farmland	45	17.9	17.0～18.6	2.24	30.9	29.4～32.2	1.94	21.4	20.3～22.5	2.68
	Black locust forest	216	17.4	15.4～18.6	3.37	30.9	29.4～32.5	1.92	20.6	20.6～22.5	3.55
2005	Sloping cropland	81	14.9	13.9～17.3	5.13	23.2	21.3～26.6	2.75	16.6	13.9～19.3	5.21
	Orchard（up）	45	16.9	16.1～19.9	4.23	26.9	23.1～28.2	3.27	18.3	16.8～19.5	4.04
	Orchard（down）	45	17.1	15.5～19.3	3.78	27.1	26.2～28.9	2.56	19.3	18.6～21.2	3.81
	Agroforestry	72	16.8	14.9～18.9	3.79	28.9	27.9～30.3	3.01	18.4	18.3～21.6	4.87
	Returned farmland	45	17.9	18.3～20.5	2.43	28.9	28.1～30.4	1.86	19.9	19.1～20.7	2.66
	Black locust forest	216	17.4	16.7～19.4	3.56	29.3	28.7～30.3	1.89	18.9	18.9～20.7	3.43

From the measurement data, in the watershed of loess plateau area, effect of soil water distribution in the main factors include precipitation, topography, land use.

3.1.1 Precipitation

Test area is located in arid highland of Loess Plateau soil moisture, rainfall is the only source, changes of soil moisture and precipitation has the very big relations, Experimental Zone in 2004 and 2005 rainfall, see table2. In 2005 and 2004, is a flat water year,2004 and2005rainy season (7-9in355.9mm and 331.4mm) respectively, rainfall, accounted for62.2% and 57.6%, soil moisture content is larger; the rest of the relatively small amount of precipitation, soil moisture and low.

Tab.2 Distribution of annual precipitation in the plots mm

year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
2004	0.6	14.7	43.6	13.1	25.1	58.4	86.1	143.7	125.7	33.3	17.4	9.5
2005	0	10.3	9	13.5	92	58.2	79.4	137.3	114.7	35.2	16.9	8.7

3.1.2 Land use patterns

From Figure 1 and table1 also shows that, different land use patterns on soil water content has a great influence on. In addition to compound mode, both before and after the rainy season and its ascent to descent from the water content increases gradually, the highest downhill locust forest, orchard moisture content of farmland moisture, minimum. In different ways of land use, because the vegetation types for the distribution of soil water is mainly influenced by the root depth and density has great difference, thus soil evaporation and vegetation transpiration is different, in the rainy season and after the rainy season, plants are the main growth period, crop transpiration than the tree is much smaller, at the same time due to the rainy season, precipitation in the slope of the redistribution, the downhill moisture ratio on high. But in the downhill part of the orchard intercropping plants due to the increase in plant, water consumption, the moisture content than the upper part of the water content and low pure orchard. Therefore, in the Loess Plateau orchard intercropping plants, should be careful.

3.1.3 Terrain

The influence of topography on the soil moisture is mainly due to the intensity of solar radiation, wind speed and temperature and other environmental factors of different. The farmland in the uphill, the intensity of solar radiation, wind speed and air temperature in the strong geometric downhill (high), causing evaporation than in downhill, makes the surface water content ratio in the low hill. In the middle of the orchard, the landscape through measures such as land leveling, relatively flat, relatively reducing surface runoff and soil water redistribution of downhill, this has certain effect to soil and water conservation.

3.2 Spatiotemporal variability of soil moisture

Table 2is based on the soil water content of variogram theory model of corresponding parameters and fractal dimension, figure 3 is the representative soil moisture variation function diagram. Theoretical model and experimental variogram fitting is very good, the coefficient of determination in 0.88 ~0.99 between, annotations available theory variation model reflecting soil moisture spatial structure. Before and after the rainy season water content in surface soil of semi-variogram function showed a spherical model, and show the base value, reflecting the soil moisture in the studied area has a stable characteristic or nearly stationary properties of (Andrew,1998). Before the rainy season the water content of surface soil in the nugget is 0.25, its independent spacing of 99.7m, after the rainy season of surface soil moisture in the nugget is 0.30, its independent spacing of 87.6M. Before and after the rainy season gold values of 0.25 and0.30, did not change significantly. Nugget is usually indicated by experimental error and smaller than the experimental sampling scale (the minimum sampling scale 3m) induced variation, larger block square difference showed a smaller scale on a process should not be neglected. Our results show that although the nugget effect at the origin, but its value is small (Table 2), which reflects less than 3 m scale effect of water process is less important, if increase sampling density does not substantially increase soil moisture spatial structure information. Base value is usually expressed in system total variability including structural variation and random variation, therefore, nugget and sill value ratio of random component elicited by spatial heterogeneity accounted for the total variation in the proportion of space, can be used as a factor related to classification based on. If the ratio is less than 25%, belong to the strong spatial autocorrelation, explanatory factor have good spatial structures; if the ratio of 25% ~ 75%, belong to moderate spatial autocorrelation; if the ratio is greater than 75%, which belongs to the weak spatial correlation, reflect the random component elicited by spatial heterogeneity degree plays the major role in (Cambardella,1994). Our results show that, before the rainy season was produced by random factors of spatial heterogeneity of the total spatial heterogeneity in 10.63%, after the rainy season total spatial heterogeneity in 16.03%, suggesting that their variation were primarily by spatial autocorrelation in part caused by. Soil moisture has a strong spatial correlation (Table 2), mean soil moisture in this scale has obvious spatial autocorrelation and pattern. This point will be in the fractal dimension of size has been verified. Spacing and semi variance double logarithm curve has a good linear correlation, the correlation coefficient in 0.88 ~0.99between, indicating that soil moisture has good fractal characteristic. Before and after the rainy season the soil moisture with higher fractal dimension, respectively 1.71 and1.74, and mean by spatial autocorrelation in part caused by spatial heterogeneity of high (Li Habin, etc.,1998).

Tab.2 The best-fitted semivariogram models of 0～30cm soil moisture parameters and fractal dimensions

Date	Smivariogram model	Nugget	Sill	Nugget/Sill(%)	Range(m)	Correlation coefficient	Fractal
2004-6-18	Spherical	0.25	1.54	16.03	99.7	0.89	1.74
2004-8-26	Linear	$\gamma = 0.0927x$				0.99	1.40
2004-10-29	Spherical	0.30	2.79	10.63	87.6	0.88	1.71
2005-6-21	exponential	0.26	2.00	13.00	63.1	0.88	1.69
2005-8-22	Linear	$\gamma = 0.0896x$				0.97	1.42
2005-10-26	Linear	$\gamma = 0.0379x$				0.92	1.61

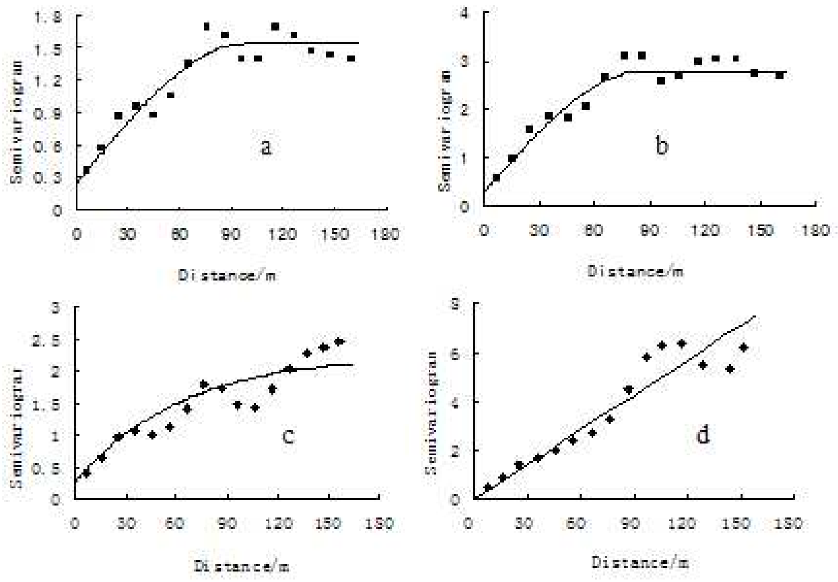

Fig.3 The semivariograms of 0～30cm soil moisture
（a and b, c and d is for 6.18，2004.6.18and10.29，2005.6.18 and 10.29.）

In the rainy season (August 24th determination, semi-variogram are not given) soil moisture spatial variability semivariance model is not spherical and exponential models, and linear model, spatial variability of soil moisture showed increase with distance. The reason is because it is in humid conditions, soil moisture patterns from the soil bulk density and porosity control, followed by the topography and land use effects (Wang Jun, etc.,2000).

4 Conclusion

Based on watershed slope farmland, apple orchard, agroforestry system, returning farmland to forest land, locust forest forestry model in5phase before and after the rainy season and the rainy season of surface soil moisture distribution and its spatial and temporal variability of research shows that, due to the influence of slope and vegetation types, uphill downhill from the soil moisture increased gradually, agriculture and forestry composite pattern due to orchard soil moisture decrease to execute intercropping. Surface soil moisture before and after the rainy season the semivariogram models for the spherical model, before and after the rainy season gold values did not change significantly, its values are 0.25 and0.30. Before the rainy season was produced by random factors of spatial heterogeneity of the total spatial heterogeneity in 10.63%, after the rainy season total spatial heterogeneity of soil moisture in 16.03%, with a strong spatial autocorrelation, variation is mainly determined by the spatial autocorrelation in part caused by. Spacing and semi variance double logarithm curve has a good linear correlation, the correlation coefficient in 0.88 ~0.99between, there is very good fractal characteristics, fractal dimension is high, respectively 1.71 and1.74. Due to wet conditions, soil moisture pattern soil bulk density and porosity as well as the effects of topography, the rainy season in the semivariance function into the linear model, fractal dimension of 1.40, spatial variability of soil moisture showed increase with distance. This requires that the future agricultural production, forestry ecological engineering, ecological environment construction, consideration should be given to the spatial distribution of soil water characteristic, thus for Watershed Agricultural production, restoration of vegetation and rational use of land to provide help.

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