Scientia Horticulturae 207 (2016) 65–72

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Comparative analysis on spatial variability of soil moisture under different land use types in orchard

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ARTICLE INFO

Article history:
Received 22 January 2016
Received in revised form 21 May 2016
Accepted 25 May 2016
Available online 6 June 2016

Keywords:
Geostatistics
Land use types
Soil moisture
Spatial variability
Kriging interpolation
Orchard

ABSTRACT

Spatial variability of soil moisture under different land use types of orchard in Weibei rainfed highland of China was investigated by means of geostatistics. Classical statistical analysis showed that the average soil moisture content of clean tillage, grass land and straw land ranged from 9.36 to 20.86, 8.78 to 23.37 and 10.84 to 20.49, respectively. In 0–40 cm soil layer, $10\% < CV\% < 100\%$, which belongs to moderate variability. Depth in 120–160 cm and 160–200 cm, $CV \leq 10\%$, which belong to weak variability. And with the increasing of depth, coefficient of variation decreased. S-W test values pointed out that the distribution of soil moisture content accorded with normal distribution.

The results of variation function analysis indicated that the ranges of grass land were larger than clean tillage. Spatial autocorrelation in surface soil was weaker than that of the bottom soil. The reason was that surface soil was more easily influenced by exterior factors. Fractal dimension value decreased with the increasing of soil depth. While the average content of soil moisture showed the opposite trend. According to kriging interpolation, the high-value areas of clean tillage mainly concentrated in (13.4, 27.8), (28.0, 32.5) and (27.0, 10.4), and low-value areas were in (13.8, 6.6). However, the high-value of grass areas mainly focused on around (11.5, 11.5), and low-value were in (11.2, 11.2) and (25.5, 25.5). The change of the other areas' soil moisture were not obvious in a wide range. It has a good consistency. Therefore, in the dry season, it was advisable to choose straw mulching, and reduce grass cultivation, to achieve the goal of improving soil moisture content.

1. Introduction

The loess plateau is one of the two apple optimal production areas in China. The development of Weibei apple can directly affect apple industry of shaanxi. Therefore, it plays an important role in the construction of economic and social development of shaanxi province (Li et al., 2008a,b, 2009). In recent years, the quality of weibei apple has a downward trend. And the reason may be that it was severe lack of soil moisture which caused by continuous drought. So comprehensive systematic analysis of soil moisture spatial variation characteristics has great significance for scientific management of soil moisture in the orchard.

Soil moisture is a dynamic part of the soil properties, and a crucial factor in soil fertility. The variation of soil moisture has randomness. Research on spatial variability of soil moisture is of great significance for soil moisture dynamic monitoring, understanding the orchard water balance, and scientific and efficient irrigation (Gao et al., 2002).

At present, the research on spatial variability of soil moisture has been one of the hot topics (Wang and Franz, 2015; Zhu et al., 2012; Zhang et al., 2013; Brocca et al., 2012). Compared with the traditional analysis, geostatistics pay more attention to the space of variable factor, considering the spatial distribution characteristics and spatial autocorrelation. It has been proved that analysis of soil moisture spatial characteristics and its variation regularity, was one of the most effective methods (Du et al., 2007). Geostatistics was introduced by many scholars at home and abroad into the spatial variability of soil properties. Such as Herbst and Diekkruger (2003) analyzed and simulated Germany Berrensiefen watershed spatial structure and spatial variability of soil moisture. Guo et al. (2013) studied the spatial variability of soil moisture scales in Heihe oasis farmland surface. Yantai orchard spatial variation regularity of surface soil moisture was discussed by Liu et al. (2006). Similarly, Hu et al. (2001) analyzed spatial variation of 0–100 cm soil moisture content. Based on a model for random fractal Brownian motion or fractal dimension of function, irregular and randomness

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http://dx.doi.org/10.1016/j.scienta.2016.05.017
0304-4238/

Table 1
Statistical characters of soil moisture content and normal testing.

Date	type	soil layer(cm)	Number of sample	Minimum[a]	Maximum[a]	Mean[a]	Std. deviation	Coefficient of variability	Skewness	Kurtosis	S-W test value P
Jul-29	clean tillage	0–40	40	1.92	15.92	9.57	2.66	0.28	−0.57	−0.28	0.17
	40–80	40	3.53	20.74	12.09	3.01	0.25	−0.60	−0.24	0.15	
	80–120	40	7.90	21.04	12.37	2.11	0.17	−0.54	0.52	0.49	
	120–160	40	12.14	23.96	15.32	1.89	0.12	−0.16	−0.17	0.86	
	160–200	40	16.98	25.86	20.72	1.82	0.09	0.44	0.23	0.66	
	Grass land	0–40	40	3.02	12.69	8.78	2.10	0.24	−0.41	0.84	0.58
	40–80	40	5.24	16.52	11.19	2.66	0.24	0.32	−0.10	0.07	
	80–120	40	7.16	17.65	13.17	1.55	0.12	0.16	0.05	0.74	
	120–160	40	14.25	19.22	15.92	1.21	0.08	0.69	−0.19	0.15	
	160–200	40	19.88	25.80	23.26	1.47	0.06	−0.30	−0.41	0.79	
	Straw land	0–40	10	9.58	12.87	11.24	0.10	0.09	−0.07	−0.52	0.97
	40–80	10	11.83	13.99	12.75	0.70	0.06	0.42	−0.75	0.74	
	80–120	10	12.62	15.80	13.62	0.90	0.08	−0.01	−0.24	0.51	
		120–160	10	13.38	16.09	14.72	0.90	0.06	−0.03	−1.24	0.81
	160–200	10	17.92	22.09	20.34	1.16	0.06	0.82	−0.14	0.58	
Aug-08	clean tillage	0–40	40	1.63	15.26	9.36	2.75	0.29	0.06	0.98	0.48
	40–80	40	3.43	24.36	12.15	3.05	0.25	−0.68	−0.08	0.11	
	80–120	40	10.79	24.69	12.57	2.39	0.19	−0.03	−0.17	0.92	
	120–160	40	12.76	25.58	15.41	1.77	0.12	−0.05	−0.41	0.95	
	160–200	40	17.98	26.23	20.86	1.71	0.08	0.26	−0.57	0.69	
	Grass land	0–40	40	2.74	13.07	8.87	2.2	0.25	−0.08	−0.24	0.75
	40–80	40	5.87	16.61	11.12	2.56	0.23	0.31	0.16	0.18	
	80–120	40	7.85	18.58	11.22	1.5	0.13	−0.11	0.55	0.59	
	120–160	40	13.97	19.08	16.01	1.25	0.08	0.64	−0.05	0.23	
	160–200	40	20.46	25.99	23.37	1.46	0.06	−0.12	−0.68	0.68	
	Straw land	0–40	10	9.67	12.22	10.84	0.93	0.09	0.52	−0.93	0.47
	40–80	10	10.05	12.64	11.46	0.76	0.07	0.76	−0.93	0.19	
	80–120	10	11.70	13.53	12.40	0.65	0.05	−0.43	−0.09	0.82	
	120–160	10	12.48	15.99	14.49	1.08	0.07	−0.65	−0.35	0.59	
	160–200	10	18.29	21.44	20.49	1.03	0.05	−0.66	−0.53	0.44	

Notes: P > 0.05 shows data conform to normal distribution.
[a] The basic unit of soil moisture content is%, the same below.

of soil properties in space has been experimentally measured by some academics (Feng et al., 2009; Li et al., 2008a,b).

Currently, related research on spatial variability of soil moisture in apple orchard was still rare. The existing research on spatial variability of soil moisture more focused on the discussion of the topography (Lu et al., 2009; Luo et al., 2009; Tang et al., 2011; Zhu and Lin, 2011), soil texture (Zhang et al., 2009; Gao et al., 2003), the stability of soil moisture spatial variability (Zhu et al., 2000; Zhou and Shimada, 2003) and spatial autocorrelation of soil moisture (Yun et al., 2010). Based on the foregoing examination of the literature, the paper focused on analyzing spatial variability of soil moisture in apple orchard by geostatistics. Therefore, the main intention of this study was to reveal the regularity of spatial variation of soil moisture in orchard and improved the productivity of fruit trees.

2. Materials and methods

2.1. Site description

The experimental site is a 5-year-old apple (*Malus pumila* Mill; Fuji on M26) orchard of the Northwest A&F University apple experimental station in the Baishui county (35°21′N, 109°30′W; elevation 850 m; Located in Weibei Loess Plateau), Shaanxi Province, China. The soil at this site is a thick layer of loessal soil. The average annual rainfall and temperature were 577.8 mm and 11.4 °C with a large variability. Topography was minimal. The planting density was 1 m × 2 m.

Three different treatments were established as a randomized complete block design with three replications to measure spatial variability of soil moisture in orchard. Grasses were sown in a 4.5-m trip between two tree rows at 0.75 g/m^2 after a deep tillage. Every 25 m^2 (about 20 apple trees) was a plot. For grass treatments, the grass was mowed 2–3 times a year. And for the clean tillage treatment, weeded 5 times a year. Fertilization and pest control were depending on the requirements of apple trees.

2.2. Experimental design

Sampling points included 9 lines 11 columns, a total of 90 monitoring points. These sampling soils moisture content were got from 0 to 300 cm and 15 times every 20 cm. Additionally, the abnormal points were deleted and the rest can be used for data analysis. In the studies, the soil depths were divided into three layers, shallow (0–40 cm and 40–80 cm), middle (80–120 cm) and deep (120–160 cm and 160–200 cm) with sequential cluster method. Soil moisture content was measured by the German TRIME-TDR System, whose probe for measuring is a depth of 22 cm. In addition, determination of values for the soil is volumetric moisture content (%). Experimental time in this paper was classified as two times in July 29th and August 8th, the former has a small degree of rainfall.

2.3. Statistical analysis

Spatial variation of soil moisture was measured mainly using the methods of classical statistics and geostatistics. Statistical analysis was performed with SPSS version 19.0 and GS$^+$ software. The statistical analysis divided into two steps: firstly, Shapiro-Wilk (W test) method is used to test the normal distribution of soil moisture; and then the variation function is simulated, calculated and tested (Wang et al., 2000). W values showed that the majority of the original soil moisture data conformed to normal distribution, and little part accorded with the nearly normal distribution.

Experimental data were analyzed by statistics software GS$^+$ 9.0 in variation function analysis, Morans' I coefficient analysis, fractal