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Spatial and Short Time Variability of Some Soil Properties in a Nursery Garden Experimental Site Irrigated with Low Quality Water

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Soil salinity can arise eventually whenever irrigation occurs since almost all water consists of some dissolved salts, making drainage crucial to leach salts out of the plant root zone. The development of salination can be hastened in the cases of irrigation with low quality water, especially in arid and semi-arid regions. This research was conducted with the aim of determining the spatial and short time variability of the electrical conductivity (EC) together with soil organic matter (OM) and pH in spruce (*Picea pungens*) nursery garden soils. The site was not tilled for seven years and irrigated with low quality water for a full growth period after it opened to the nursery. A good understanding of short time variability in soil salinity development in the site would help evaluate the problem and take measures promptly if necessary, for producing high quality seedlings. A total of 396 disturbed soil samples were taken with regular intervals of 5 × 5 m and represented the depth of 0-30 cm for four different sampling periods with 45 d time interval in a 40 m × 50 m plot. The soil samplings, which were at May 1st, June 15th, August 1st and September 15th, were made immediately on the same sampling points before the soil tillage applied during the growth. Analysis of variance showed that there were significant differences among the period means of EC and OM. EC and OM values, respectively increased and decreased as the irrigation and soil tillage progressed. pH changes among the periods were not as significant as those of EC and OM. Spatial analysis additionally revealed the development of the soil salinity and the decomposition of organic matter over the study site within a short growth period of 5-month. Especially, in the sampling periods of P3 and P4 the coverage for EC values between 2.74 and 3.25 dS m^{-1} diminished severely or completely vanished (0.0 and 6.1 and 0.0 and 0.2 %, respectively) and those between 2.50 and 3.75 dS m^{-1} attained the value of 70.0 %. Spatial coverage of OM between 0.81 and 1.20 attained the value of

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93.25 % at the end period (P4) revealing important OM losses. There was 31 % reduction in OM content from P1 to P4. The results showed that soil degradation was increased in five months becauce of the irigation program and conventional agricultural practices, which could affect production quality and quantity.

Key Words: Soil salinity, Organic matter, Irrigation, Spatial variability, Land use change.

INTRODUCTION

In arid and semiarid regions, one of the most important problems is the difficulty of finding good quality of irrigation water. Irrigation programs have been intensively applied at the stage of producing of seedlings in arid and semiarid region. However, the limited water resources have led the expected use of saline water for irrigation purposes resulting in a risk of salt accumulation in the root zone and accordingly damage to crop production and soil fertility[1,2]. In other terms, irrigation by low quality water generally caused the soil salinity and reduced quality and quantity of the production[3,4]. Additionally, Chhabra[5] gives such factors of the salt accumulation, rather than the improper irrigation by the low quality water, as capillary rise from shallow groundwater or from sea water intrusion in coastal areas.

A good understanding of variation and proportion of the salinity and the soil degradation by its effects is very important to evaluate the problem and to take measures. Many researchers used the conventional statistics to assess the extent of soil salinity, which may develop under the irrigated agriculture[6-8]. Utset *et al.*[9] emphasized the importance of selecting optimal sampling design to make soil salinity maps. In recent years, the geostatistics and GIS were increasingly used to determine of the spatial variability of the salinity in relation to the different soil properties and tillage and irrigation techniques in small and large plots[9-11]. Determination of the extent of the salinity problem and rate of deterioration was the basic information needed to evaluate the severity of the problem and to make the ameliorative recommendations[12].

Geostatistics provides descriptive tools in selecting sampling design and characterizing the spatial pattern of continuous and categorical soil properties[8,13]. In this stage, the kriging interpolation assumes that the distance or direction between sample points reflects spatial correlation that can be used to explain variation in the surface[14]. An important contribution of the geostatistics is the assessment of the uncertainty about un-sampled values, which usually takes the form of a map of the probability of exceeding critical values for the soil quality[15]. This uncertainty assessment can be combined with expert knowledge for decision making such as description of degraded areas where amendment measures should be taken or areas of good soil quality where specific management plans can be developed[16].

The objective in this research was to determine the spatial and seasonal variability of the EC, OM and pH in a spruce (*Picea pungens*) nursery garden soils irrigated with low quality water by using the classical satatistics, the geostatistics and GIS for a full growth period.

EXPERIMENTAL

Study site is located in Cankiri at an altitude of 750 m above sea level and north of Ankara, Turkey. The region has terrestrial climate. The highest and the lowest temperature determined during a growth period were on July and May (25.2 and 16 ºC, respectively) and the highest and the lowest precipitation were on May and July (38.3 and 15.6 mm, respectively). In the selected site, spruce (*Picea pungens*) seedlings have been produced for one year. It could be significant to note that there have been no agricultural activities in the site for 7 years. Mean EC of the irrigation water was 1.7 dS m^{-1} through the irrigation season. Soil texture of the research area was clay (C). Organic and inorganic fertilizers were not used in the study area during the research. Some important properties of the irrigation water used in the study are given in Table-1.

TABLE-1
SOME IMPORTANT PROPERTIES OF THE IRRIGATION WATER USED IN THE STUDY

		Cations	me/lt	Anions	me/lt
EC	1.70	Ca^{2+}	4.96	CO_3^{2-}	0.00
Na (%)	18.93	Mg^{2+}	8.73	HCO_3^-	6.25
SAR	1.23	Na^+	3.22	SO_4^{2-}	8.74
pH	7.90	K^+	0.10	Cl^-	2.02
		Total	17.01		17.01

EC = Electrical conductivity; SAR = Sodium absorption ratio.

Soil sampling and analyses: Total of 396 disturbed soil samples were taken with regular intervals (5 × 5 months) (Fig. 1) and represented the depth of 0-30 cm for four different sampling periods with 45 d time interval (P1, P2, P3 and P4, respectively) in a 40 m × 50 m plot. Soil samples were analyzed for EC by conductivemeter[17]; for clay, silt and sand contents by hydrometer method[18]; for soil organic matter (SOM) content by the method of Nelson and Sommers[19]; for pH with glass electrode in a 1:2.5 soil/water suspension[20].

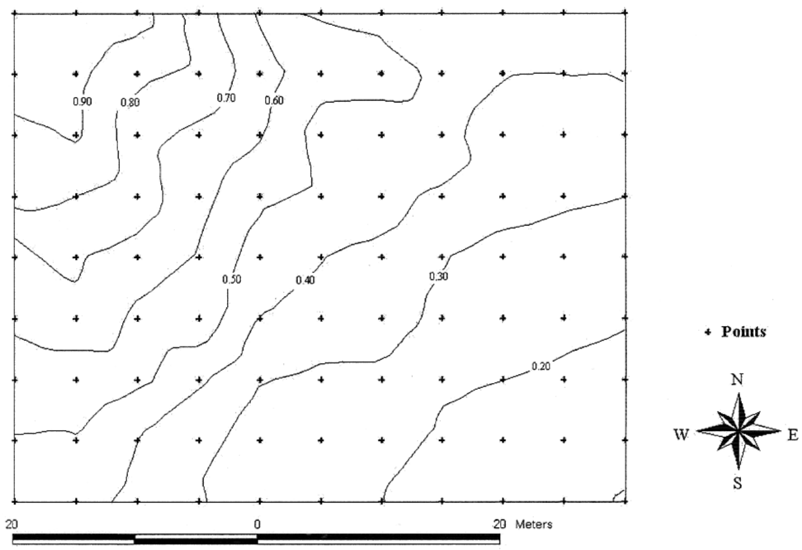

Fig. 1. Study site (Dots show sample points)

Data of the soils were evaluated by methods of both geostatistics and classical statistics. The analysis of variance with repeated was performed and temporal variations were examined at four levels (May 1st, June 15th, August 1st and September 15th, respectively). The soil tillage applied in the site by the cultivator with duck-foot sweeps for every 45 d to mechanically kill the weeds emerging determined the periods of taking soil samples such that immediately before the tillage the soil was sampled. Also, the repeated hoeing with 15 d interval was performed to eradicate weeds mechanically and prevent weed establishment.

Statistical analysis: Descriptive statistics were used to express the overall variability within the study area and spatial variability in the soil properties was defined using geostatistical methods. The Kolmogorov-Smirnov test was conducted for conformance to a normal distribution and analysis of variance were performed. The SPSS 10.0 were used to calculate those statistical parameters.

Differences in the means of EC, OM and pH values were compared by using Benferroni test. Geostatistics analysis and kriging interpolation were performed with GS +7 geostatistical software[21].

Experimental semivariograms were developed to determine the spatial dependence of soil properties using the following equation given by Journel and Huijbregts[22] and reviewed by Trangmar *et al.*[23]:

$$\gamma^*(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left(z(x_i) - z(x_i + h)\right)^2 \quad (1)$$

where γ(h) is the semivariance; N(h) is the number of experimental pairs separated by a distance h; $z(x_i)$ is the measured sample value at point x_i; and $z(x_i + h)$ is the measured sample value at point $x_i + h$.

RESULTS AND DISCUSSION

The one-sample Kolmogorov-Smirnov test was confirmed the normal distribution of the variables ($p < 0.05$). The descriptive statistics for the values of the EC, OM and pH are given in Table-2 for the sampling periods of P1, P2, P3 and P4, which were representative of May 1st, June 15th, August 1st and September 15th, respectively. CV of the P1-EC_e (18 %) was significantly different from those of P2-EC, P3-EC_e and P4-EC (11, 10 and 10 %, respectively), which showed the effect of the irrigation water on variation of EC: As exposure time to the low quality irrigation water of the site increased, its homogeneity in terms of the EC increased making the CV values almost similar. This suggested that the EC of the site significantly extended with the sprinkler irrigation. Miyamoto *et al.*[24] and Clercg and Meirvenne[25] indicated the similar effect of irrigation on CV values of EC. The greater CV value of the P1-EC could, however, be linked to the differentiation in EC over the site due to the winter precipitations, micro-topography and various clay and organic matter contents of the study site.

TABLE-2
DESCRIPTIVE STATISTICS OF THE SOIL PROPERTIES

	Depth	Mean	SD	CV	Skewness	Kurtosis	Min.	Max.
P1-EC	0-30	3.17	0.57	18	1.80	5.20	2.27	6.01
P2-EC	0-30	3.29	0.36	11	0.47	0.34	2.31	4.39
P3-EC	0-30	3.52	0.36	10	0.78	1.04	2.89	4.76
P4-EC	0-30	3.58	0.37	10	0.62	1.05	2.82	4.85
P1-OM	0-30	1.54	0.21	14	0.61	1.39	1.05	2.36
P2-OM	0-30	1.38	0.25	18	0.57	-0.45	0.91	2.10
P3-OM	0-30	1.27	0.37	29	1.01	1.69	0.36	2.55
P4-OM	0-30	1.06	0.37	34	-0.06	-0.81	0.32	1.97
P1-pH	0-30	8.26	0.12	1.5	0.22	-0.47	8.00	8.62
P2-pH	0-30	8.21	0.11	1.4	0.37	-0.07	8.00	8.56
P3-pH	0-30	8.26	0.10	1.3	0.08	-0.25	8.03	8.54
P4-pH	0-30	8.27	0.09	1.1	0.82	3.58	8.08	8.72

P1, P2, P3 and P4: Sample periods; EC = Electrical conductivity (dS m^{-1}); OM = Soil organic matter (%); SD = Standard deviation; CV = Coefficient of variation.

The CV of the OM increased as irrigation progressed from P1 to P4. Values were 14, 18, 29 and 34 % for P1, P2, P3 and P4, respectively (Table-2). Mean values of the OM, on the other hand, decreased with the irrigation progression and the values were 1.54, 1.38, 1.27 and 1.06 %, respectively for P1-OM, P2-OM, P3-OM and P4-OM. These decreases were most likely because the OM significantly decreased with the soil tillage applied in the site for mechanically killing the weeds by duck-foot sweeps for every 45 d and by the repeated hoeing with 15 d intervals. It attained its lowest value at the sampling period of P4.

Similar to that of the EC, the CV of the pH in the site tended to decrease with the progression of irrigation from P1 to P4. Values were 1.5, 1.4, 1.3 and 1.1 % for P1, P2, P3 and P4, respectively (Table-2). Generally, the CV of the pH had lower variation than those of the other soil properties[26-30]. This was commonly linked to the fact that pH values were mostly measured on log scale of proton concentration in soil solution.

Also, for better fitting, using the skewness and kurtosis coefficients in order to describe the shape of data distribution, the model data frequency distribution was compared to a normal distribution. The results indicated that there were no significant right or left tails in the distributions and only distributions of the P1-EC and P4-pH were positively kurtotic (Table-2). This suggested that a few extremely large values of those were observed in the distributions.

Differences of the EC, OM and pH among the sampling periods of P1, P2, P3 and P4 are tabulated in Table-3. The mean of P1-EC was significantly different from P3-EC and P4-EC and this was statistically insignificant when compared with the mean of P2-EC ($p < 0.05$). The mean of P2-EC was statistically different from those of P3-EC and P4-EC and those of P3-EC and P1-EC were statistically similar at the level of $p < 0.05$. Decisively, the analyses of variance indicated that EC progressively and considerably increased with the progression of the irrigation with the low-quality water (Fig. 2a). The results also implied that the soil samples representing the last 90 d and covering periods of P3 and P4 did not noticeably change in terms of EC and it became steady depending on the quality of the irrigation water and clay content and exchange capacity of the soil. Totally, soil salinity increased by 13 % in the course of the irrigation in the research site.

When means of the OM among the different periods were compared, there were significant differences among the period means except those between P2-OM and P3-OM, whose means were statistically identical ($p < 0.05$) (Table-3). Fig. 3b shows the trend of variation in OM among the periods and there was a regular decrease towards the final sampling period. Reduction in OM was by 31 % from P1 to P4 and this was greatly ascribed to the mechanical tillage activities for weed control carried out in the nursery garden.

TABLE-3
DIFFERENCES OF THE SOIL PROPERTIES BETWEEN THE SAMPLING PERIODS

	P1-EC_e	P2-EC	P3-EC
P2-EC (dS m^{-1})	0.103^{ns}	–	–
P3-EC (dS m^{-1})	0.336*	0.234*	–
P4-EC (dS m^{-1})	0.394*	0.291*	0.057^{ns}
	P1-OM	P2-OM	P3-OM
P2-OM %	0.157*	–	–
P3-OM %	0.265*	0.108^{ns}	–
P4-OM %	0.474*	0.317*	0.209^{*}
	P1-pH	P2-pH	P3-pH
P2-pH	0.058*	–	–
P3-pH	0.009^{ns}	0.049*	–
P4-pH	0.004^{ns}	0.058*	0.005^{ns}

*The mean difference is significant at the 0.05 level and ns is not significant at the level of 0.05; P1, P2, P3, P4: Sample periods; EC = Electrical conductivity (dS m^{-1}), OM = Soil organic matter (%).

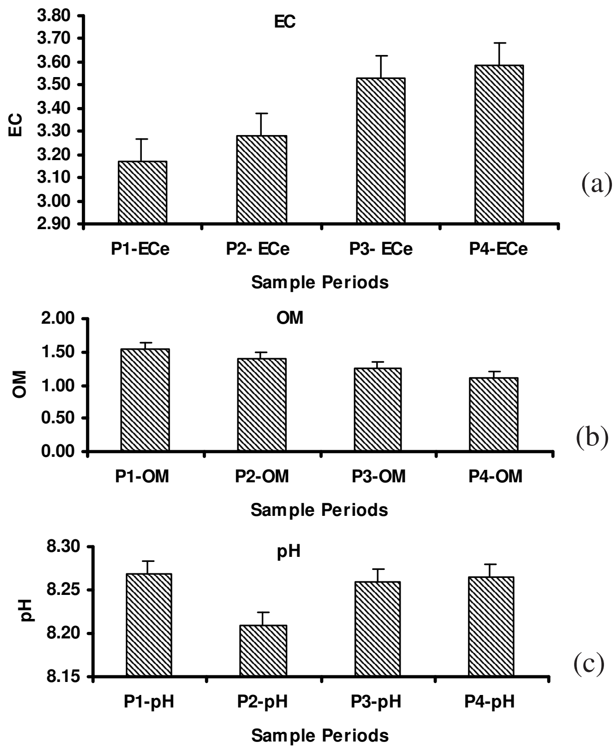

Fig. 2. Mean soil properties for different periods a) EC b) OM c) pH P1, P2, P3, P4; Sample periods, EC = Electrical conductivity (dS m^{-1}), OM = Soil organic matter (%)

In the same way, the differences of the mean pH values for different periods were given in Table-3. Differences between P1-pH and P2-pH, P2-pH and P3-pH and P2-pH and P4-pH were statistically significant ($p < 0.05$) although those between P1-pH and P3-pH, P1-pH and P4-pH and P3-pH and P4-pH were statistically insignificant. On average, the periods caused differences of 0.01 and 0.05 pH units among means. At the beginning of the irrigation depletion of 0.05 units in pH was observed. This could be linked to the pH of the irrigation water (Table-1) and rapid mineralization of OM, but it soon recovered and attained the previous value in the period of P3 depending on buffering capacity of the soils and after this, change in pH was very slight and not statistically significant.

Geostatistical analysis: The empirical semivariograms were estimated by raw data and were directionally calculated at the angles of 0º (N–S), 45º (NE–SW), 90º (E–W) and 135º (SE–NW) for each soil property. This directional examination of the variogram surfaces indicated no severe anisotropy for variation of soil EC, OM and pH measured and therefore, only omnidirectional variograms were obtained by using the best fitting model by the least squares regression method and modeled with isotropic functions. This was significant to make the spatial structure analysis by kriging and to find a view of changes in the soil properties affected by the low quality irrigation water, soil tillage and other effective ecological factors that were expected to vary with the irrigation. Generally, the spherical model provided the best fit for all soil properties except for P4- EC, P4-OM and P2-pH which showed pure nugget effect. In those cases, all the samples had the same weight, 1/n with n being number of samples inside the search neighbourhood. Accordingly, kriging interpolator reduced to a simple averaging for P4-EC, P4-OM and P2-pH. The spatial statistics obtained from the semivariograms and the models used are summarized in Table-4.

The geostatistics indicated that the soil EC values of the different periods examined were spatially dependent to the different degrees. The range of spatial dependence for EC increased from 18 to 29 m as the periods progressed from P1 to P3 showing a clear effect of the low quality irrigation water on EC. Electrical conductivity became more homogenized as its heterogeneity spatially decreased over the test site due to the intensive irrigation with sprinklers. Obviously, through the end of the irrigation season, more salt accumulation occurred at the soil depth of 30 cm and horizontally extended by the continuous sprinkle irrigation. This very much agreed with the CV values given in Table-2.

The smaller nugget variance of P1-EC, when compared to those of P2, P3 and P4-EC, suggested that the sampling scheme used was sufficient for this period. However, larger nugget variances observed for P2-EC, P3-EC and P4-EC indicated a high variance of EC at short distances[31]. This implied that, although the sampling scheme used was satisfactory at the beginning of the irrigation, it turned out to be insufficient as the irrigation moved on. This short range variability in EC of P2, P3 and P4 was barely discernible with the CV values of Table-2 for the CV values tended to decrease with the irrigation periods. Conclusively, the irrigation increased the short range variability of EC in the research site and this could be because of non-uniform application of water caused by wind during the irrigation, slope, micro-topography, impermeable layer close to surface, soil texture, hydraulic conductivity and soil tillage applied during the seedling production[13].

TABLE-4
VARIOGRAM MODELS AND PARAMETERS

Soil properties	Model and Parameters						
	Depth	Model	Nugget effect (Co)	Sill (C) (Co+C1)	Co/(Co+C1) (%)	a (m)	r^2
P1-EC	0-30	Spherical	0.020	0.025	80	18	0.979
P2-EC	0-30	Spherical	0.090	0.120	75	28	0.791
P3-EC	0-30	Spherical	0.100	0.130	77	29	0.853
P4-EC	0-30	Nugget	0.130	0.130	–	–	–
P1-OM	0-30	Spherical	0.031	0.044	70	31	0.743
P2-OM	0-30	Spherical	0.050	0.069	72	29	0.866
P3-OM	0-30	Spherical	0.110	0.130	85	18	0.422
P4-OM	0-30	Nugget	0.230	0.230	–	–	–
P1-pH	0-30	Spherical	0.012	0.017	71	28	0.880
P2-pH	0-30	Nugget	0.014	0.014	–	–	–
P3-pH	0-30	Spherical	0.007	0.011	63	10	0.507
P4-pH	0-30	Spherical	0.006	0.009	66	33	0.627

Co = Nugget variance; C1 = Partial sill; C = Sill; a = Range (m); P1, P2, P3 and P4: Sample periods; EC = Electrical conductivity (dS m^{-1}); OM = Soil organic matter (%).

In contrast to that of EC, the range of spatial dependence for EC significantly decreased from 31 to 18 m as the periods progressed from P1 to P3 (Fig. 3). The highest spatial correlation was determined for the period of the P1-OM (31 m) although the lowest was found out for the period of the P4-OM (1 m), which had the pure nugget effect. This was greatly in agreement with the CV values of Table-2 and spatial variability and dependence, respectively increased and decreased as the periods proceeded together with the soil tillage. Different mineralization rate of the OM by the intensive soil tillage over the test site could be expected to be a good reason for this variability. Also, drying and re-moistening by the irrigation cycles could affect the variability of OM and microbial activity in the soil may change rapidly upon changes in the water content or with the irrigation, leading temporal changes in the OM among the periods.

The nugget variance, similar to that of EC, increased for P3-OM and P4-OM (0.031 and 0.05, respectively) when compared to those of P1 and P2 (0.11 and 0.23, respectively) and contrary to that of EC. This short range variability in OM of P3 and P4 was easily evident with the CV values of Table-2 for the CV values tended to increase with the irrigation periods, particularly in those of P3 and P4. The irrigation progression increased the short range variability of OM in the research site.

The pH values of the different sampling periods showed variable spatial correlations. Pure nugget effect was observed with the P2-pH and the spatial correlation was 1 m although this was 28 m with the P4-pH. Evidently, by the start of the irrigation pH variability over the site drastically increased. After this very low spatial correlation, the range of pH had a tendency of increasing in the periods of P3 and P4 (10 and 33, respectively). To the rapid changes in the land use of the site and intensive use of irrigation and soil tillage, pH responded promptly, however, it spatially became more correlated, implying that the soil had the better ability to buffer the changes in pH possibly resulted from the pH of the irrigation water and the rapid mineralization of the OM. The nugget variances of pH for all periods were fairly small that the sampling scheme used was acceptable.

Cambardella *et al.*[32] and later Bo *et al.*[30] suggested that the nugget-to-sill ratio could be used to classify the spatial dependence of soil properties for short distances. Authors considered a variable had a strong, moderate and weak spatial dependence if the ratio was < 25 %, between 25 % and 75 % and >75 %, respectively. Accordingly, the nugget-to-sill ratios mostly showed a weak spatial dependence for EC, OM and pH. For P1-OM, P2-OM, P1-pH, P3-pH and P4-pH there was a moderate spatial dependence, but, with the percentages closer to the upper bound of the class (70, 72, 71, 63 and 66 %, respectively, when compared to 75 %) (Table 4). As observably stated above, this weak spatial dependence could be explained by the different response of the research site to the change of land use elevated by the low quality water use and intensive soil tillage for a period of five months.

Kriging of soil properties: Evaluation of a spatial structure of soil properties could help to solve particular problems associated with the irrigation management. Kriging based on variogram models and raw data values for each variable at 8736 locations (104 × 84) over a regular grid were used to directly find the spatial changes of soil properties by interpolation for locations where soil samples were not taken.

The cross-validation procedure was used to accurate the kriging maps. The result indicated that the mean reduced error close to zero and average ratio between the square error of prediction and the estimation variance close to unity showing a good fit of the semivariogram model. Fig. 3 shows kriging interpolations of the EC for four irrigation periods. For P1, the kriging interpolation generally predicted the low EC distribution over the site except some parts of it, which were located at the northern and western part, with high salinity (Fig. 3a). This gives some insight to understand the EC nature of the site before the change of land use from non-agriculture to the production of spruce seedlings with low quality irrigation water and where the salinity started stretching out over the site. In this period, differences in micro-topography, soil texture and the hydraulic conductivity might be the reason why certain spots were more affected than others[11,13]. In the site for P2, soil salinity to some extent increased towards eastern part (Fig. 3b) and this movement of the salinity matched with the prevailing slope (Fig. 1); encroachment of the salinity followed the slope down to lower parts of the site. This was more obvious in the periods of P3 and P4 with larger EC values, mostly greater than 3.00 and 3.25dS m^{-1}, respectively (Fig. 3c and 3d). Also, although continuous irrigation could vertically wash salts deep enough in the soil, the results indicated that capillary rise of the salts by evaporation from soil surface between irrigations in these periods was sufficiently strong to accumulate salt on the upper 30 cm of the soil. Ayers[33], van Hoorn and van Aart[34], Beltran[35] and later Cetin and Kirda[11] indicated that irrigation water with EC of 1.7-4.9 dS m^{-1} might cause soil salinity.

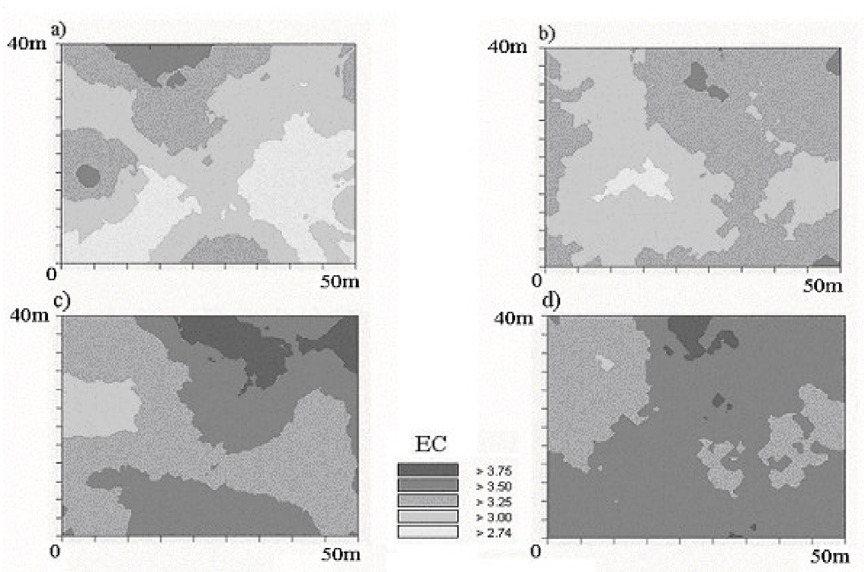

Fig. 3. Kriging maps of the EC values. a) P1, b) P2, c) P3 and d) P4

Kriging maps of OM for the different sampling periods were given in Fig. 4a-d showing those of P1, P2, P3 and P4, respectively. The OM values > 1.50 covered nearly entire of the northern part of the study site and made the gradient through the south-west direction for P1 (Fig. 4a). Gradually, OM values spatially decreased as the periods advanced and the control of the irrigation and soil tillage over OM became plain (Fig. 4b and c). Sparling *et al.*[36], Haynes[37] and Shepherd *et al.*[38] explained in detail that cultivation detached soil aggregates and exposed previously inaccessible organic matter to microbial attack and accelerated the decomposition and mineralization of OM. At the end of the sampling period the content of P4-OM values were between 0.81 and 1.20, covering almost the entire study site except some small spots with OM values greater than 1.20 and 1.30 (Fig. 4d). There was a uniform and rapid breakdown of OM with the land use change in the site.

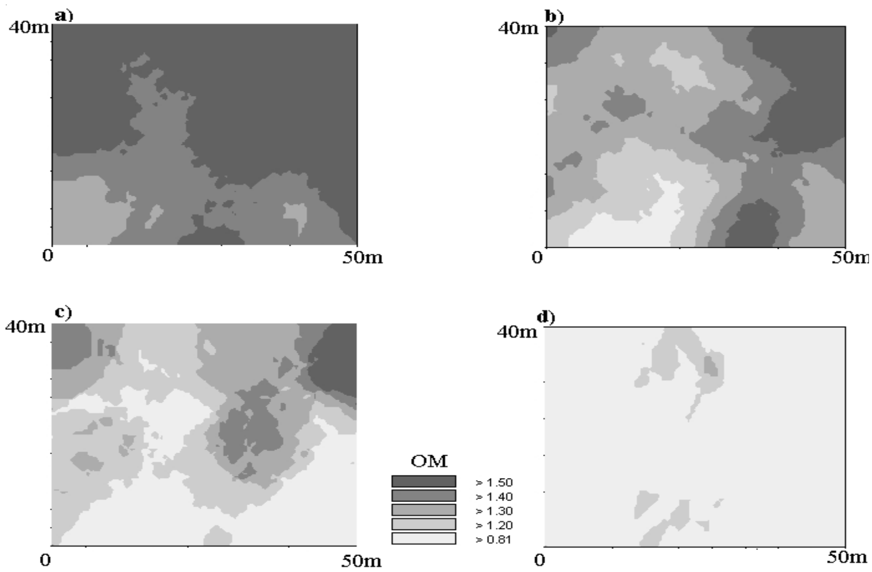

Fig. 4. Kriging maps of the OM values. a) P1, b) P2, c)P3, d) P4

Similarly, pH values of the sampling periods showed variability with the irrigation and soil tillage activities (Fig. 5). P1 had the changing pH over the site, having a pH gradient mainly from south-east to north east (Fig. 5a). In this direction pH varied from >8.40 to >8.00. Later, a uniform pH pattern was observed more from P2 to P4 (Fig. 5b-d). The pH value between 8.20 and 8.30 finally persisted covering the largest part of the site. This suggested that the pH gradient observed at the beginning of periods disappeared progressively by the movement of base cations with irrigation water.

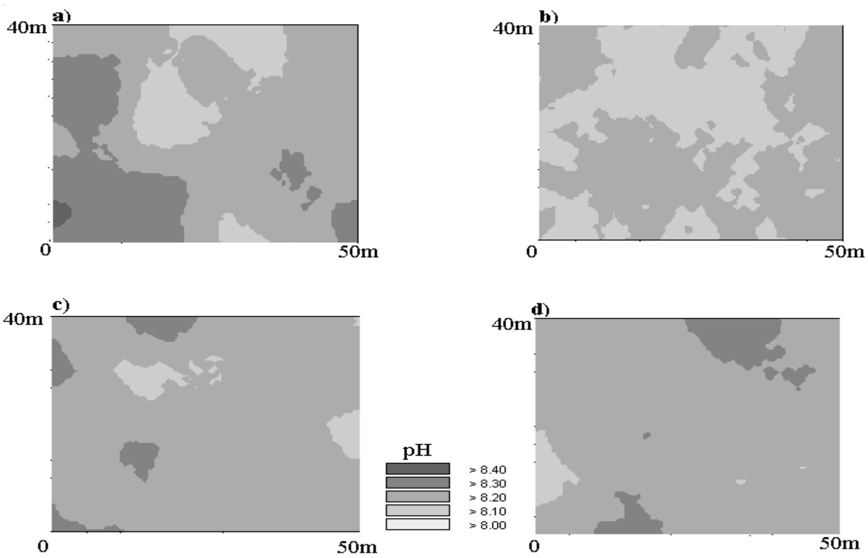

Fig. 5. Kriging maps of the pH values. a) P1, b) P2, c)P3, d) P4

TABLE-5
SPATIAL VARIATION OF THE SOIL PROPERTIES WITH RESPECT TO THE SAMPLING PERIODS

	P1		P2		P3		P4	
	(m^2)	%	(m^2)	%	(m^2)	%	(m^2)	%
EC								
>3.75	0.00	0.00	0.00	0.00	170.10	8.50	57.14	2.80
>3.50	95.68	4.80	25.25	1.30	760.13	38.00	1399.35	70.00
>3.25	497.67	24.90	1043.2	52.10	948.17	47.40	539.56	27.00
>3.00	892.36	44.60	891.69	44.60	121.59	6.10	4.00	0.20
>2.74	514.29	25.70	39.86	2.00	0.00	0.00	0.00	0.00
OM								
>1.50	1259.26	62.96	345.19	17.26	82.37	4.12	0.00	0.00
>1.40	592.00	29.60	456.00	22.80	202.37	10.12	0.00	0.00
>1.30	148.74	7.44	763.26	38.16	415.70	20.79	5.93	0.32
>1.20	0.00	0.00	318.22	15.91	642.07	32.10	128.59	6.43
>0.81	0.00	0.00	117.33	5.87	657.49	32.87	1865.48	93.25
pH								
>8.40	11.85	0.59	0.00	0.00	0.00	0.00	0.00	0.00
>8.30	511.42	25.57	0.00	0.00	104.29	5.21	170.66	8.50
>8.20	1216.88	60.85	1141.00	57.05	1800.88	90.04	1783.12	89.20
>8.10	259.85	12.99	859.00	42.95	94.83	4.75	46.22	2.30
>8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2000.00	100.00	2000.00	100.00	2000.00	100.00	2000.00	100.00

P1, P2, P3 and P4: Sample periods; EC = Electrical conductivity (dS m^{-1}), OM = Soil organic matter (%).

Table-5 summarizes spatial variations obtained by kriging in EC, OM and pH of the study site with respect to the periods. When P1-EC_e and P4-EC were compared, the coverage area of EC_e between 3.50 and 3.75 dS m^{-1} drastically increased from 4.8 to 70.0 %. Especially, in the sampling periods of P3 and P4 the coverage for EC values between 2.74 and 3.25 dS m^{-1} diminished severely or completely vanished (0.0 and 6.1 and 0.0 and 0.2 %, respectively).

Along with EC, OM was significantly affected from the irrigation and tillage practices. Spatial coverage of OM between 0.81 and 1.20 attained the value of 93.25 % at the end period (P4) revealing important OM losses. Compared with EC and OM and instead of respectively having a trend of increasing or decreasing with the periods, pH inclined to be uniform at the middle value of pH range of 8.20 and 8.30, which had the spatial coverage of 89.20 % at the end.

Conclusion

This research was carried out to determine the spatial and mountly seasonal variability of EC, OM and pH in the site that was recently opened to the agricultural activity for growing spruce (*Picea pungens*). In this semi-arid environment, irrigation program was applied with the low quality water by sprinkler irrigation because of the difficulty of finding better quality of water. A total of 396 disturbed soil samples were taken with regular intervals of 5 × 5 months and represented the depth of 0-30 cm for four different sampling periods with 45 d time interval in a 40 by 50 m plot. In addition to the analysis of variance, spatial analyses was performed with the collected data. The results showed that there were significant differences among the period means of EC and OM. However, pH changes among the periods were not as significant as those of EC and OM. Opening the site to the agriculture and irrigating it with the low quality water drastically decreased OM contents and increased the salinity as these activities advanced. Furthermore, the spatial analysis disclosed the breakdown of organic matter and the encroachment of the soil salinity over the study site within a short growth period of 5-month. Particularly, from the beginning to the end of the sampling periods, the coverage for EC_e values between 2.74 and 3.25 dS m^{-1} diminished severely or completely vanished (0.0 and 6.1 and 0.0 and 0.2 %, respectively) and those between 2.50 and 3.75 dS m^{-1} attained the value of 70.0 %. Spatial coverage of OM between 0.81 and 1.20 attained the value of 93.25 % at the end period (P4) revealing important OM losses.

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