ORIGINAL PAPER

THE SPATIAL VARIABILITY OF UREASE ACTIVITY OF SURFACE AGRICULTURAL SOILS WITHIN AN URBAN AREA

Tayfun AŞKIN[1], Rıdvan KIZILKAYA[2]

[1]Corresponding author: Assistant Professor, Karadeniz Technical University, Faculty of Agriculture, Department of Soil Science, 52200, Ordu/TURKEY phone: +90 452 230 05 56; Fax: +90 452 225 12 61, e-mail: tayfuna@ktu.edu.tr
[2]Assistant Professor, Ondokuz Mayıs University, Faculty of Agriculture, Department of Soil Science, 55139, Samsun/TURKEY

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ABSTRACT

Soil enzymes play a major role in the mineralization processes of organic materials. The soil enzymes originate from animal, plant and microbial sources and the resulting soil biological activity including the metabolic processes of all these organisms. Information on soil enzyme activities used to determine soil microbiological characteristics are very important for soil quality and healthy.

KEYWORDS: Spatial variability, soil urease activity, site specific management

INTRODUCTION

Biochemical actions are dependent on or related to the presence of enzymes. Many reactions involving soil organic matter transformations may be catalyzed by enzymes existing outside the microorganisms ([9]) and plant root system ([19], [7]). Each soil may have a characteristic pattern of specific enzymes as described by Kuprevich and Scherbakova ([10]). The differences in the level of enzymatic activity are caused primarily by the fact that every soil type ([4]), depending on its origin ([11]) and developmental conditions, is distinct from every other in its content of organic matter, in the composition and activity of living organisms inhabiting it, and consequently, in the intensity of biological processes. Obviously, it is probable that each type of soil has its own inherent level of enzymatic activity ([3], [12]).

Large proportions of the nitrogen in many soils are organically bound and the mineralization of these portions is of agricultural importance ([16]). Organic nitrogen compounds in soil can constitute huge amount percent of total nitrogen and the assimilation of this nitrogen by plants and microorganisms is preceded by soil enzymes. Several enzymes are involved in the decomposition of organic nitrogen compounds ([1]).

Soil scientists studied the variability of soil properties in conventional statistical terms. Classical statistical procedures assume that variation is randomly distributed within sampling units. Actually, soil properties are continuous variables whose values at any location can be expected to vary according to direction and distance of separation from neighboring samples. Recently, emphasis has been placed on the fact that the variations of a soil property are not completely disordered over the field and this spatial structure must be taken into account in the treatment of the data. Investigators have shown increasing interest in analyzing measured soil parameters for their interdependency over space, i.e., to study the dependency of a measured parameter on location in the field. Typically semivariograms and outocorrelogram have been used to study the spatial structure of soil properties. A literature search revealed limited published studies on spatial behavior of enzyme activity in soils.

The objective of this study was to assess the spatial variability of soil urease activity; analysis of the spatial structure was based on the semivariogram analysis under an urban area.

MATERIAL AND METHODS

Study Site and Design

The site selected for this study is on the urban area in Gümüşhacıköy, Amasya, in the northwest Turkey (Latitude, $40^0$53'N; longitude, $35^0$13'W). The study area is located in an urban area. The primary grid consisted of 39 points spaced 4500 by 4500 m (Figure 1).

The soils surface soils (0-20 cm depth) were sampled in the spring of 2001. Annual mean of precipitation is 400 mm and temperature is range from - 10 ^{0}C to 38 ^{0}C. Bulk soil samples were air dried and then crushed to pass through a 2 mm sieve.

Measurements

Selected soil physical and chemical properties were determined by means of appropriate methods: soil particle size distribution by the hydrometer method, pH in 1:2.5 (w/v) in soil: water suspension by pH -meter, soil organic matter by modified Walkley-Black method, $CaCO_3$ content by Scheibler calcimeter, cation exchange capacity (CEC) by Bower method and (0.5 M $NaHCO_3$ extractable at pH 8.5) by Olsen method ([14]).

Urease activity (UAc) was measured by the method

Table 1. Descriptive statistics for selected properties of soils (n=39)

Soil Properties	Mean	Min.	Max.	S_d	S_e
Sand (S), %	46.03	29.0	68.6	11.66	1.87
Silt (Si), %	24.07	14.6	33.3	4.96	0.79
Clay (C), %	29.91	12.8	43.2	8.27	1.32
pH (1:2.5 soil: water suspension)	8.06	7.30	8.60	0.34	0.05
Electrical conductivity (EC), dS m^{-1}	0.241	0.127	1.745	0.258	0.041
Lime content (LC), %	5.38	0.20	15.86	4.40	0.70
Organic matter content (OMC), %	2.23	0.38	5.02	1.10	0.18
Cation exchange capacity (CEC),	41.98	23.48	60.02	9.49	1.52
Available P, mg kg^{-1}	7.07	4.48	15.38	2.12	0.34
Urease activity (UAc), µg N g^{-1} dry soil	82.99	39.36	129.64	22.06	3.53

S_d; standard deviation, S_e; standard error

of Hoffmann und Teicher ([8]). A 7.5 ml citrate buffer (pH 6.7) and 10 ml of 10% urea substrate solution were added to 10 g soil, and subsequently the samples were incubated for 3 h at 37 °C. The volume was made up to 100 ml with distilled water at 37 °C. Following filtration through Whatman No. 42 filter papers, 1 ml of filtrate was diluted to 10 ml with distilled water, and 4 ml of sodium phenolate (12.5% (w/v) phenol + 5.4% (w/v) NaOH) and 3 ml of 0.9% sodium hypochloride were added. The released ammonium was determined spectrofotometrically at 578 nm. Three replicates of each sample were tested, and the control sample without urea was prepared. Results were expressed μ N g^{-1} dry soil.

Statistical Analysis

All geostatistical analyses were performed on a PC using GS^+ package program ([6]). Descriptive statistics were determined by SPSS package program ([17]).

RESULTS AND DISCUSSION

Soil Properties

Some descriptive statistical results for selected soil physical and chemical properties are given in Table 1. The results can be summarized as; soil samples have mostly moderate coarse in texture, alkaline in pH, moderate in organic matter (average of 2.23 %), low in lime content (average of 2.35 %), and free alkaline problem (ESP<15 %) ([15]) (Table 1).

Spatial Variability of Urease Activity

Distance on urease activity, pairs and semi variance values were presented in Table 2.

The spherical isotropic model was selected, had the smallest RSS value and the biggest r^2 value (Table 3), for spatial variability of the urease activity in the study area by GS^+ package program ([6]).

Table 2. Semi variance values for urease activity

Distance, m	Pairs	Semi variance
0	-	253.5
5366	114	394.2
10329	166	445.4
14775	152	543.1
18996	122	587.0
23602	101	475.2
28076	43	601.3

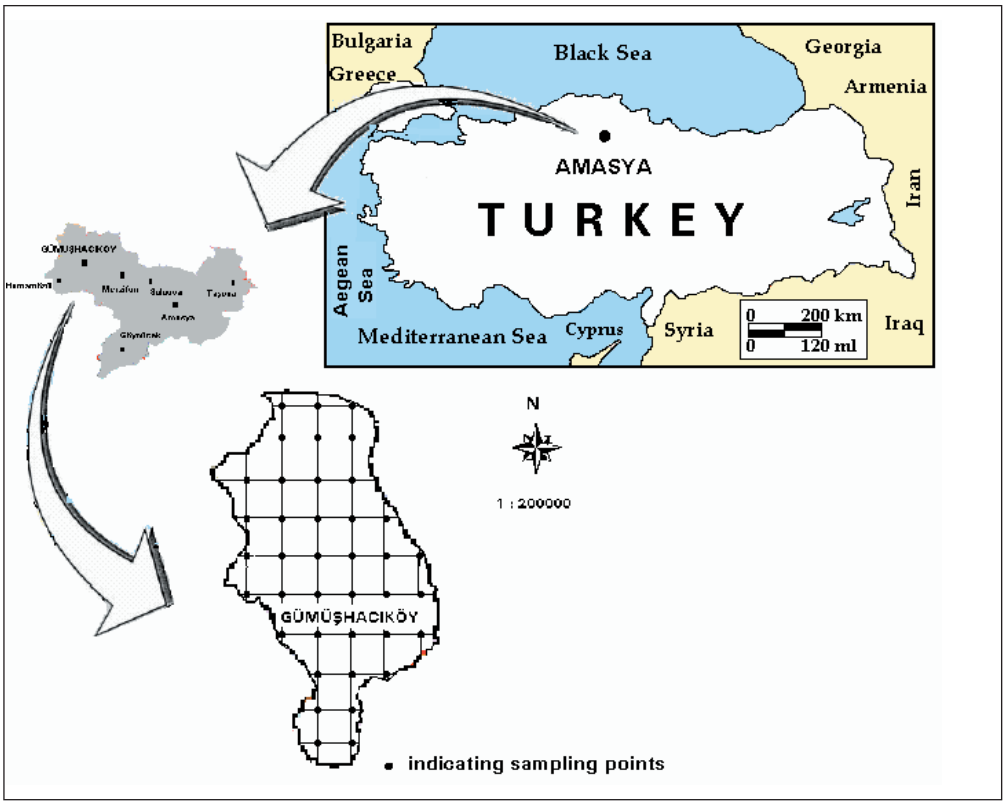

Figure 1. Location of the sampling sites in Gümüşhacıköy, Amasya

Table 3. Parameters of spherical isotropic model fitted to semi variance of UAc

	Nugget C_o	Sill C_o+C	A_0 or $3A_0$ m	C/C_o+C %	C_o/C_o+C %	r^2	Model
UAc	235.5	554.8	19350	68.7	31.3	0.69	Spherical

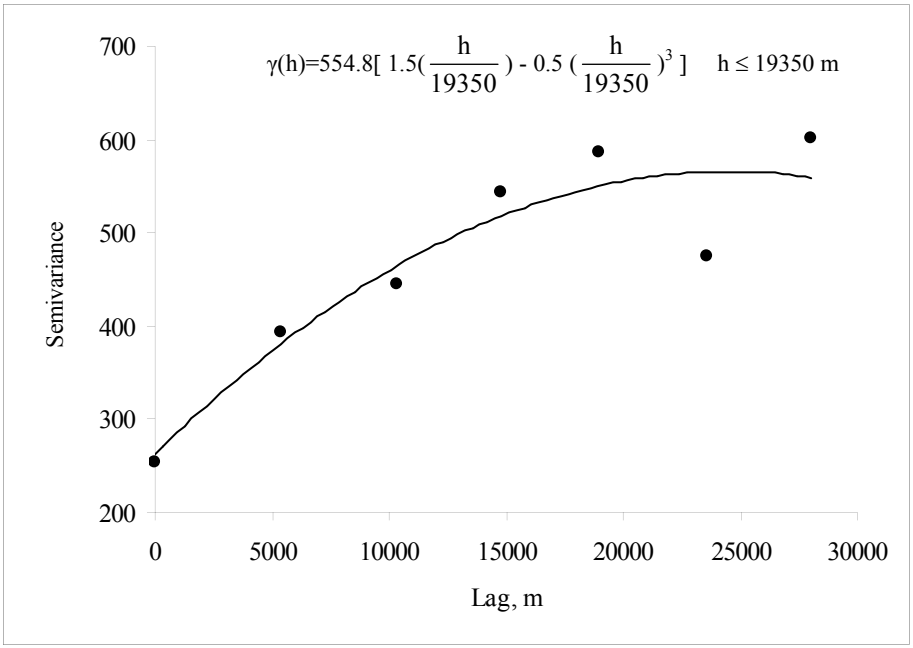

Figure 2. The estimated semi-variogram values for UAc.

The spatial distribution and model parameters of soil urease activity in the study area are schematically illustrated in Figure 2.

The zone of influence for urease activity was approximately 19.3 km (Table 3).

The urease activity was point-kriged, based on spherical isotropic model, on a 1x1 km grid (1008 locations) by using the ten nearest neighboring points. Descriptive statistics were presented in Table 4 on observed and point-kriged UAc values.

As shown in Table 4, not only the range of point-kriged urease phosphatase activity values was 36.59 to 112.18 μg N g^{-1} dry soil but also mean values was 84.34 μg N g^{-1} dry soil, somewhat narrower than the range and mean of the measured UAc values (39.36-129.64 μg N g^{-1} dry soil and 82.99 μg N g^{-1} dry soil). Also why standard deviation on kriged UAc values was lower than the measured selected model was true ([18], [13]). A point-kriged map of UAc was illustrated using the same 1008 points that was used to krige UAc in Figure 3.

Table 4. Descriptive statistics on measured and kriged of UAc values

Descriptive statistics	Measured	Predicted by Kriging
Number of samples (n)	39	1008
Minimum	39.36	36.59
Maximum	129.64	112.18
Mean	82.99	84.34
Standard deviation	22.06	8.45

CONCLUSION

Knowledge of the spatial variability of soil biological properties is one of the most important keys in further development of precision quality of agricultural areas. Reliable information on the range of spatial relationships enables defining the sampling strategy needed to carry out soil biological properties maps accurately. In this study, a spherical isotropic model was the best fit semi variogram model for urease activity. Also the range of model was 19.3 km. The nugget effect, representing the undetectable experimental error and field variation within the minimum sampling space, was quite large compared to the sill, which represents total spatial variation. The ratio of nugget variance to sill expressed in percentages can be regarded as a criterion to classify the spatial dependence of soil properties. If this ratio is less than 25%,

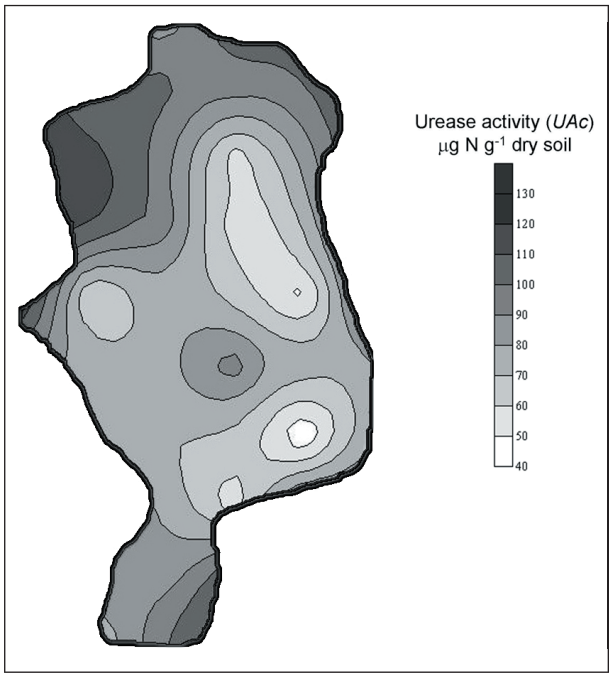

Figure 3. Kriged map of UAc

the variable has strong spatial dependence; if the ratio is between 25 and 75%, the variable has moderate spatial dependence; otherwise, the variable has weak spatial dependence ([5]). The ratio of nugget to total variation of UAc was 31.3 % indicating that the spatial correlation of UAc at the large scale was moderate dependence. The information of obtained from geostatistical techniques should be used to gain a better knowledge on spatial distribution of soil biological properties in an urban area. Also, this knowledge should be used as a literature for identifying the sampling strategies in large scale.

REFERENCES

[1.] Alexander, M., Introduction to soil microbiology. Second ed., John Wiley & Sons. New York, USA. 1977.

[2.] Aon, M.A., Colaneri, A.C., Temporal and spatial evolution of enzymatic activities and physico-chemical properties in an agricultural soil, Applied Soil Ecology (2001) 18:255-270.

[3.] Burns, R.G., Enzymes in soils: Some theoretical and practical considerations, in: Burns, R.G. (Ed.). Soil enzymes, Academic Press, London, UK. 1978, pp. 295 – 339.

[4.] Chhonkar, P.K., Tarafdar, J.C., Accumulation of phosphatase in soils. Journal of the Indian Society of Soil Science (1984), 32: 266 – 272.

[5.] Chien, Y.J., Lee, D.Y., Guo, H.Y., Houng, K.H., Geostatistical analysis of soil properties of Mid-west Taiwan soils, Soil Science (1997) 162: 291-298.

[6.] GS$^+$, Geostatistics for the environmental sciences, Gamma Design Software, Plainwell, Michigan, USA, 1998.

[7.] Haas, H., Redl, B., Friedlin, E., Stöffler, G., Isolation and analysis of the Penicillium chrysogenum phoA gene encoding a secreted phosphate-repressible acid phosphatase, Gene (1992) 113: 129 – 133.

[8.] Hoffmann, G. G., Teicher, K., Ein kolorimetrisches Verfahren zur Bestimmung der Urease Aktivitat in Boden, Z. Pflanzenernahr. Dung. Bodenk., (1961), 91: 55 - 63.

[9.] Hofmann, E., The analyses of enzymes in soils, in: Linskens, H.F., Tracey, M.V. (Eds.), Moderne Methoden der Pflanzenanalyse. Vol.VI. Springer Verlag, Berlin 1963, pp. 416 – 423.

[10.] Kuprevich, V.F.,Shcherbakova, T.A., Comparative enzymatic activity in diverse types of soil, in: McLaren, A.D., Skujins, J. (Eds.), Soil Biochemistry, Vol. 2, Marcel Dekker, New York, USA, 1971, pp. 167-201.

[11.] Ladd, J.N., Soil enzymes, in: Vaughan, D., Malcom, R.E. (Eds.). Soil organic matter and biological activity, Martinus Nijhoff Dr. W. Junk Publishers, Dordrecht, Netherlands, 1985, pp. 175 – 221.

[12.] Marinari, S., Masciandaro, G., Ceccanti, B., Grego, S., Influence of organic and mineral fertilizers on soil biological and physical properties, Bioresource Technology (2000) 72: 9-17.

[13.] Öztaş, T., 1996. Eğimli bir arazide erozyonla kaybolan toprak derinliğindeki değişimin Kriging analizi ile belirlenmesi. Tarım-Çevre İlişkileri Sempozyumu "Doğal Kaynakların Sürdürülebilir Kullanımı", s: 327-335, 13-15 Mayıs, Mersin.(in Turkish)

[14.] Rowell, D.L., Soil science: Methods and applications. Longman, UK, 1996.

[15.] Soil Survey Staff, Soil Survey Manuel, USDA Handbook No:18, Washington, 1993.

[16.] Speir, T.W., Ross, D.J., Soil phosphatase and sulphatase, in: Burns, R.G. (Ed.), Soil enzymes, Academic Press, London, UK, 1978, pp. 197-250.

[17.] SPSS, SPSS for Windows, Release 10.0.5, SPSS Inc., USA, 1999.

[18.] Trangmar, B.B., Yost, R.S. Uehara, G., Application of geostatistics to spatial studies of soil properties, Advances in Agronomy, Vol. 38, 1985, pp. 45-93.

[19.] Voets, J.P., Dedeken, M., Observations on the microflora and enzymes in the rhizosphere, Annls. lnst. Pasteur, Paris Suppl. (1966), No. 3: 197-207.