HORIZONTAL AND VERTICAL NITRATE-NITROGEN DISTRIBUTION UNDER DIFFERENT NITROGEN FERTILIZATION LEVELS

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Abstract: The importance of nitrate (NO_3^-) in the internal nitrogen cycle of arable soils has been widely recognized, especially because of accumulation of nitrate-nitrogen in the soil profile and its implications for the environment. In order to determine vertical and horizontal nitrate-nitrogen distribution, soil samples were collected from a long term experimental field located in central part of Croatia (Popovaca). Soil sampling was conducted during vegetation of maize (June, 2007) on four fertilization treatments (0, 100, 200, 300 kg N ha^{-1}) and at 8 depths (up to 2 m). Spatial variability was mapped using ArcView geographic information system (GIS). Ordinary kriging was used as interpolation method. To characterize spatial variability, spherical (with logarithmic transformation) model were fitted to calculate semivariograms. Also, results indicate that the content of nitrate-nitrogen significantly varied depending on the depth and treatment.

Keywords: soil, nitrate-nitrogen, micro spatial distribution

Introduction

Nitrogen (N) fertilization is very important for crop production from economic but also from environmental standpoint. Environmental impacts of N fertilization are becoming concern because N, not utilized by crop, when in nitrate form, may move with soil water from root zone to groundwater and surface waters. Vertical distribution of soil nitrate nitrogen (N-NO_3^-) was investigated all over the world: North America (Nance et al., 2007), South America (Álvarez et al., 2007), Asia (Lu et al., 2008) and Europe (Németh and Kádár, 1999). All studies indicate that N-NO_3^- content decrease with soil depth. Because the risk of nitrate loss, throughout Europe new environmental lows, based on Council Directive 91/676/EC (''Nitrates Directive''), are being implemented to limit N fertilization on arable land. One way to avoid N surplus and apply precision amount of fertilizer is to apply precise management strategies. For these strategies it is crucial to have variability maps of N (Lofton et al., 2010). Also, estimation of N variability is essential for making site-specific decisions on soil practice, which is a soil management at a smaller spatial scale then the whole field. Geostatistical methods are valuable tools for predicting the spatial structure of soil properties (Darwish and El-Kader, 2008). Considering that soil properties can vary greatly over small distances in every direction this resource was conducted to determine micro spatial horizontal analysis of N-NO_3^-, but also its vertical distribution.

Materials and methods

Research was conducted on experimental field located in Western Pannonian subregion of Croatia (45°33´N, 16°31´E). The soil type of trial site is drained distric Stagnosol. Experiment has 10 treatments but only four are taken into consideration in this paper: 1. N_0+P+K, 2. N_{100}+P+K, 3. N_{200}+P+K, 4. N_{300}+P+K (kg N ha^{-1}). Soil samples were taken from each treatment on the rectangle of 2 m^3 in volume (1m x 1m x 2m), at 16 surface points (each 25 cm × 25 cm in size) and at 8 depths (0-25 cm, 25-50 cm, 50-75 cm, 75-

 DOI:10.12666/Novenyterm.62.2013.suppl

100 cm, 100-125 cm, 125-150 cm, 150-175 cm and 175-200 cm) in maize vegetation (16th June, 2007). Grid sampling was applied to give detailed insight of true within-field spatial variability of soil $N\text{-}NO_3^-$ content after fourteen years of different N fertilization. Each sampling location was precisely defined using GPS (Trimble GNSS R8). $N\text{-}NO_3^-$ was determined by ion-chromatography method in water extracted solution. Spatial variability up to 0.25 m depth was mapped using ArcView geographic information system (GIS). Ordinary kriging was used as interpolation method. Spatial structure of soil parameter was analyzed by calculating semivariograms. Root-mean-square error (RMSE) of prediction was used as measure for the best model evaluation. Vertical distribution was analyzed by basic statistical model with effects of treatments and their linear and square trends regarding depths using SAS Institute 9.1.3 at $P \leq 0.05$.

Results and discussion

Summary table for analysis of variance is given in *table 1* and average $N\text{-}NO_3^-$ content per treatment and depth is presented in *Figure 1*. The highest significant differences between $N\text{-}NO_3^-$ content according to different nitrogen fertilization levels were recorded at the first depth (0-25 cm) and they ranged from 11.8 mg kg^{-1} in treatment with 0 kg N ha^{-1} up to 87.8 mg kg^{-1} in treatment with 300 kg N ha^{-1}.). Also, $N\text{-}NO_3^-$ content decreased with the increase of depth. Application of 100, 200 and 300 kg N ha^{-1} significantly influenced nitrate status at the first two depths (0-25 cm and 25-50 cm).

Table 1. Analysis of variance summary table: $N\text{-}NO_3^-$ content

Source	dF	SS	MS	F	Pr > F
D	1	1.938	1.938	608.8	0.0007
D x D	1	0.522	0.522	164.0	0.0032
T	3	1.617	0.539	169.3	0.0012
D x T	3	0.313	0.104	32.76	0.0010
D x D x T	3	0.110	0.036	11.47	0.0004

Source explanation: D = depth; D x D = Depth x Depth; T = Treatment; D x T = Depth x Treatment; D x D x T = Depth x Depth x Treatment

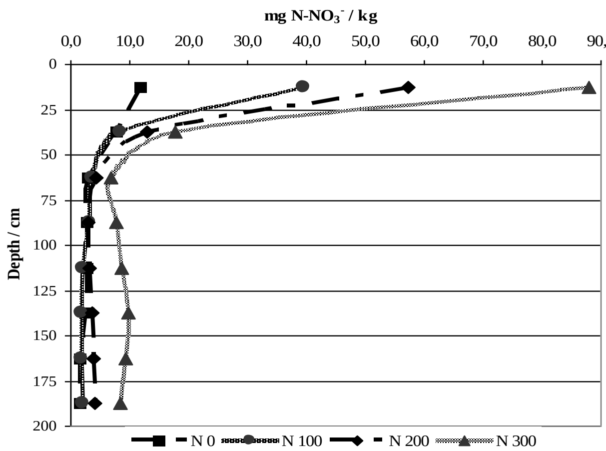

Figure 1. Vertical nitrogen-nitrate distribution

The coefficient of variation (CV) is very useful statistic for measuring the spatial variability of soil properties. CVs for N-NO_3^- were in the range from 31.1% to 58.9% (*Table 2*). To characterize horizontal spatial variability, spherical (with logarithmic transformation) models were fitted to calculate semivariograms. The range of spatial dependence for N-NO_3^- with increased N levels was 0.266 to 0.366 m. Root-mean-square errors (RMSE) were in the range of 3.90 mg kg^{-1} to 26.8 mg kg^{-1} depending on fertilization level. After constructing the variograms, corresponding kriged values were plotted to form contour maps of the spatial distribution of N-NO_3^- and to estimate N-NO_3^- values in unsampled location at sampling grid of $1m^2$ (*Figure 2 a-d*).

Table 2. Geostatistical parameters of soil N-NO_3^- content and RMS errors

N rate (kg ha^{-1})	Model	CV (%)	Stil (kg $ha^{-1})^2$	Range (m)	RMSE (kg ha^{-1})
0	spherical	32.2	0.111	0.356	3.90
100	spherical	58.9	0.286	0.276	24.7
200	spherical	31.1	0.099	0.266	18.5
300	spherical	32.1	0.862	0.366	26.8

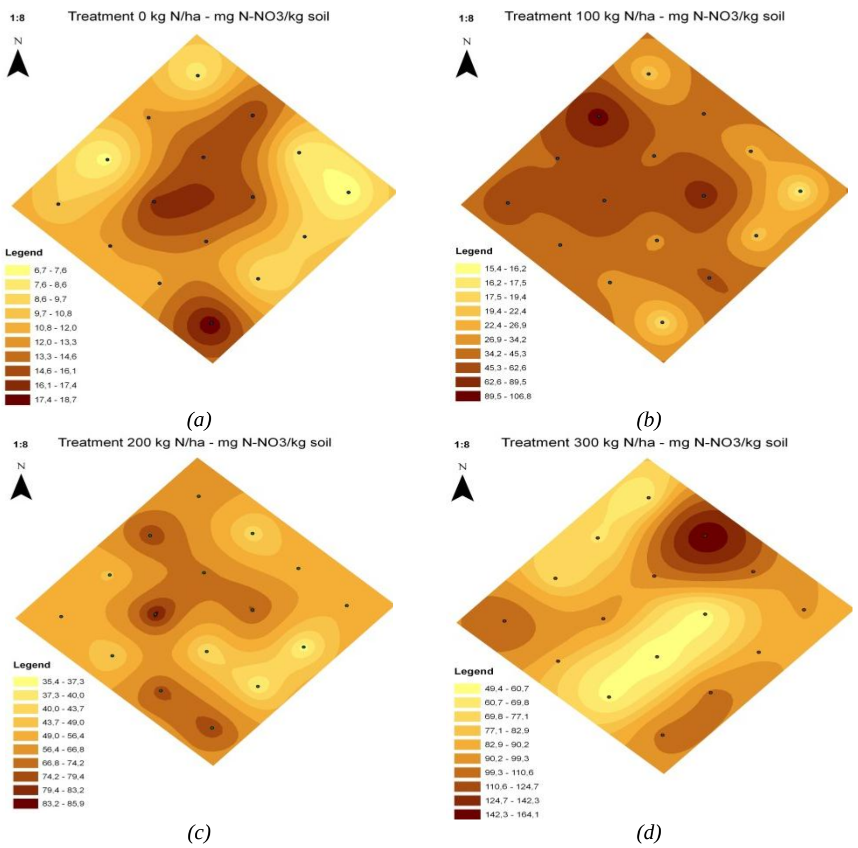

Figure 2. Nitrate-nitrogen maps generated by ordinary kriging under different fertilization levels for: (a) 0 kg N ha^{-1}; (b) 100 kg N ha^{-1}; (c) 200 kg N ha^{-1}; (d) 300 kg N ha^{-1}

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Fang et al. (2006) and Yin et al. (2007) also reported that increased levels of nitrogen fertilization significantly influenced on N-NO_3^- content and that N-NO_3^- content decreased with soil depth. Webster (1985) explains that semivariograms depend on the sampling scale, sampling design and support of the underlying data sets; there is no 'absolute' semivariogram for a soil property. Depending on the goal of the particular study, variation on the microscale (<60 m^2, Mohanty and Kanwar, 1994) or plot scale (<3000 m^2, Stenger et al., 2002) has been addressed and describe by spherical semivariograms. Spatial analysis of N-NO_3^- content and site-specific crop management based upon spatial variation of N-NO_3^- content can maximize crop production and minimized environmental impacts of nitrogen fertilization (Abu and Malgwi, 2011)

Conclusions

Results showed that the long term nitrogen fertilization effected on the variability of N-NO_3^- content within a square meter (CVs were from 31.3% to 58.9%). These distinct zones of high and low nitrogen content (contour maps) may provide useful information for variable-rate nitrogen management, better understanding nitrogen uptake by plant and plant nutrition in general. Also results indicate that grid sample is more accurate and representative than random sampling for better nitrogen fertilizer recommendations.

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