SPATIAL VARIABILITY OF BIOLOGICAL AND CHEMICAL PROPERTIES IN IOWA SOILS AND IMPLICATIONS FOR WATER QUALITY ASSESSMENTS

T.B. Moorman, C.A. Cambardella, and J.M. Novak, USDA-ARS, National Soil Tilth Laboratory, Ames, IA

The field-scale variability of soil-related parameters was examined at a 6.25 ha site in central Iowa. Total soil organic C content, nitrate concentration, atrazine sorption, microbial biomass C, and 2,4-D degradation are directly or indirectly related to processes important to pesticide and nitrate movement. Although considerable variability exists at the field scale, definite spatial trends exist, as determined by geostatistical techniques. Spatial distributions of these parameters were weakly related to soil map units. Variability of these parameters was as great within map units as at the whole-field level. Total organic C, atrazine sorption, and microbial biomass C were related to landscape position.

A large nationwide scientific effort is presently underway to identify the sources and extent of agricultural chemical pollution of surface and ground water. Estimates of potential leaching of pesticides and nitrates need to be evaluated within the context of soil and environmental conditions representative of important agricultural regions. Predictive tools have been used to estimate pesticide leaching range from simple rating functions, such as the attenuation factor (Rao et al., 1985), to sophisticated computer models. Each of these methods relies upon a core set of inputs including chemical concentrations, adsorption coefficients, and transformation rates. These parameters are largely soil dependent and can vary widely within farmer fields.

Some efforts to predict pesticide leaching at large scales have utilized soil taxonomic units to predict physical and chemical properties. Logue et al. (4) examined the variability associated with individual parameters such as organic carbon content or bulk density, within taxonomic groups and found that parameter variability decreased as taxonomic level was reduced from Order to Series. Variability in pesticide leaching potential, as rated by calculation of the attenuation factor (AF) was greater at the higher taxonomic categories than in lower categories. Logue et al. (4) concluded that the greatest uncertainty in estimating pesticide leaching was associated with organic carbon content and pesticide K_{oc}. Attempts to base pesticide risk-assessments on soil taxonomic groupings or map units clearly has a high degree of uncertainty. Improved or alternative methods are needed, as well as basic information at the field and watershed scales.

The Iowa Management System Evaluation Area (MSEA) located south of Ames, Iowa is an large, privately owned area largely devoted to agriculture. In many ways this area is typical of conventional farming systems within central Iowa. In the spring of 1992 we preformed an extensive evaluation of the spatial variability of several soil properties and parameters related to the prediction of water quality. These parameters were soil pH, texture, bulk density, C and N in microbial biomass and particulate organic matter (POM). Total organic C, total N, and inorganic N were also measured. Process-related measures included atrazine sorption (K_d, 2,4-D mineralization, and N-mineralization potential. These latter measurements are known to be of importance to predicting the movement of pesticides and nitrates to groundwater. Our research objectives were (1) to assess field-scale variability of soil-related properties and processes related to pesticide and nitrate transformations and leaching, (2) evaluate geostatistical methods for use in the assessment of potential pesticide and nitrate movement at large scales. Progress in these areas will be illustrated by our research results from the Walnut Creek MSEA Site in central Iowa.

METHODS AND PROCEDURES

The field site was a 6.25 ha area measuring 250 m on each side, which is farmed in a corn-soybean rotation. A total of 241 soil samples were taken from the surface 15 cm during the last week of April, 1992, just prior to corn planting. Soil biomass (mg biomass C/kg soil) was measured by the fumigation-extraction method (7) on duplicate samples. Biomass N was determined analyses of organic N in the extracts following fumigation (1). Inorganic N was determined by KCl extraction, filtration, and flow injection (Latchet) analysis. Total organic C and total N were determined by combustion methods. Carbonates were removed by pretreatment with dilute acid. Particulate organic C and N were determined by the methods of Cambardella and Elliott (2). Potentially mineralizable N and respiration were measured using aerobic incubation techniques modified from Keeney and Bremner (3). Atrazine sorption was determined by the batch equilibration method using 0.01 M $CaCl_2$ containing 1 mg/L atrazine as the equilibration solution. Atrazine was analyzed by HPLC. The mineralization of [^{14}C-*ring*] 2,4-D was determined on 45 samples using biometer flasks (5).

Data was analyzed to determine the relationship between the true spatial distributions of the experimental parameters, landscape positions, and soil map units. Sample locations were assigned to soil series based on the USDA Soil Survey map for Boone Co., Iowa. It is recogized that soil survey maps contain an inherent level of variability. Spatial variability was determined by fitting the data to appropriate semivariogram models and block kriging. The time required for 25% of added ^{14}C to be mineralized (T_{M25}), atrazine partition coefficients (K_d), soil organic C content, soil biomass C, and nitrate concentrations were used as inputs for the geostatistical procedures.

RESULTS AND DISCUSSION

Spatial relationships were examined by constructing semivariograms to show the relationship between variability and distance. All parameters examined showed some spatial dependence, although nitrate and 2,4-D mineralization had a lesser degree of spatial dependence than the other parameters. Kriged maps for soil organic C (Figure 1), 2,4-D degradation (Figure 2) and nitrate concentrations (Figure 3) show different patterns from the soil map units (not shown) at this site. Distributions of soil organic C, biomass C, and atrazine K_d all showed some similarity to the soil map units, while 2,4-D degradation rate (T_{M25}), and nitrate showed less similarity to the map units. Total N distributions were generally similar to organic C, but were not identical. The C in the POM fraction was closely related to total soil organic C.

Varaibility within map units, as estimated by the coefficient of variation, were as great as the whole-field variability for most parameters (Tables 1 and 2). In some instances, trends in mean values showed a soil type or landscape effect. Less microbial biomass C and total organic C were found in the upland Clarion soil than in the poorly drained pothole soil (Okoboji map unit). Other soil types which occupy the side slopes similar in their biomass C and organic C contents. Atrazine sorption correlated with organic C content, but there was no correlation between total microbial biomass and 2,4-D mineralization.

Understanding the distribution of soil factors and processes across landscapes and the variability associated with these estimates is important to assessing the impacts of agriculture on water quality. Areas of greatest risk for pesticide and nitrate leaching need to be identified. While additional information is needed for a complete assessment, our results show that soil properties and processes related to the movement and transformation of pesticides and nitrates vary considerably at the field-scale. Estimates of these parameters were improved somewhat by separating data according to map unit, but the level of variability was not reduced substantially. Map-unit-based approaches to modeling transport of pesticides and nitrates may need to consider the variability within map units. Geostatistical techniques allow the estimation of soil parameters over large fields and the identification of large areas where processes or properties differ from other areas, but these techniques are resource intensive. Research will continue to assess variability in these parameters at the field and other large scales.

REFERENCES

1. Brooks, P.C., A. Landman, G. Pruden, and D.S. Jenkinson. 1985. Chloroform fumigation and the release of soil nitrogen: a rapid direct extraction method to measure microbial biomass nitrogen in soil. Soil Biol. Biochem. 17:837-842.

2. Cambardella, C.A., and E.T. Elliott. 1992. Particulate organic matter changes across agrassland cultivation sequence. Soil Sci. Soc. Am. J. 56:777-783.

3. Keeney, D.R., and J.M. Bremner. 1966. Comparison and evaluation of laboratory methods of obtaining an index of nitrogen availability. Agron. J. 58:498-503.

4. Logue, K.M.,and R.E. Green. 1988. Impact of data-related uncertainties in a pesticide leaching assessment. Pages 98-119, In: D.W. Nelson and R.H. Dowdy (eds) Methods for Ground Water Quality Studies. Univ. of Nebraska, Lincoln, NE.

5. Moorman, T.B., and S.S. Harper. 1989. Transformation and mineralization of metribuzin in surface and subsurface horizons of a Mississippi Delta soil. J. Environ. Qual. 18:302-306.

6. Rao, P.S.C., A.G. Hornsby, and R.E. Jessup. 1985. Indices for ranking the pesticide contamination of water. Soil Crop Sci, Florida Proc. 44:1-8.

7. Tate, K.R., D.J. Ross, and C.W. Feltham. 1988. A direct extraction method to estimate soil microbial C: effects of some experimental variables and some different calibration procedures. Soil Biol. Biochem. 20:329-355.

Figure 1. Total organic C contents (%) in surface soils from a 6.25 ha field in central Iowa. Contours were produced from kriged data based on 241 soil samples.

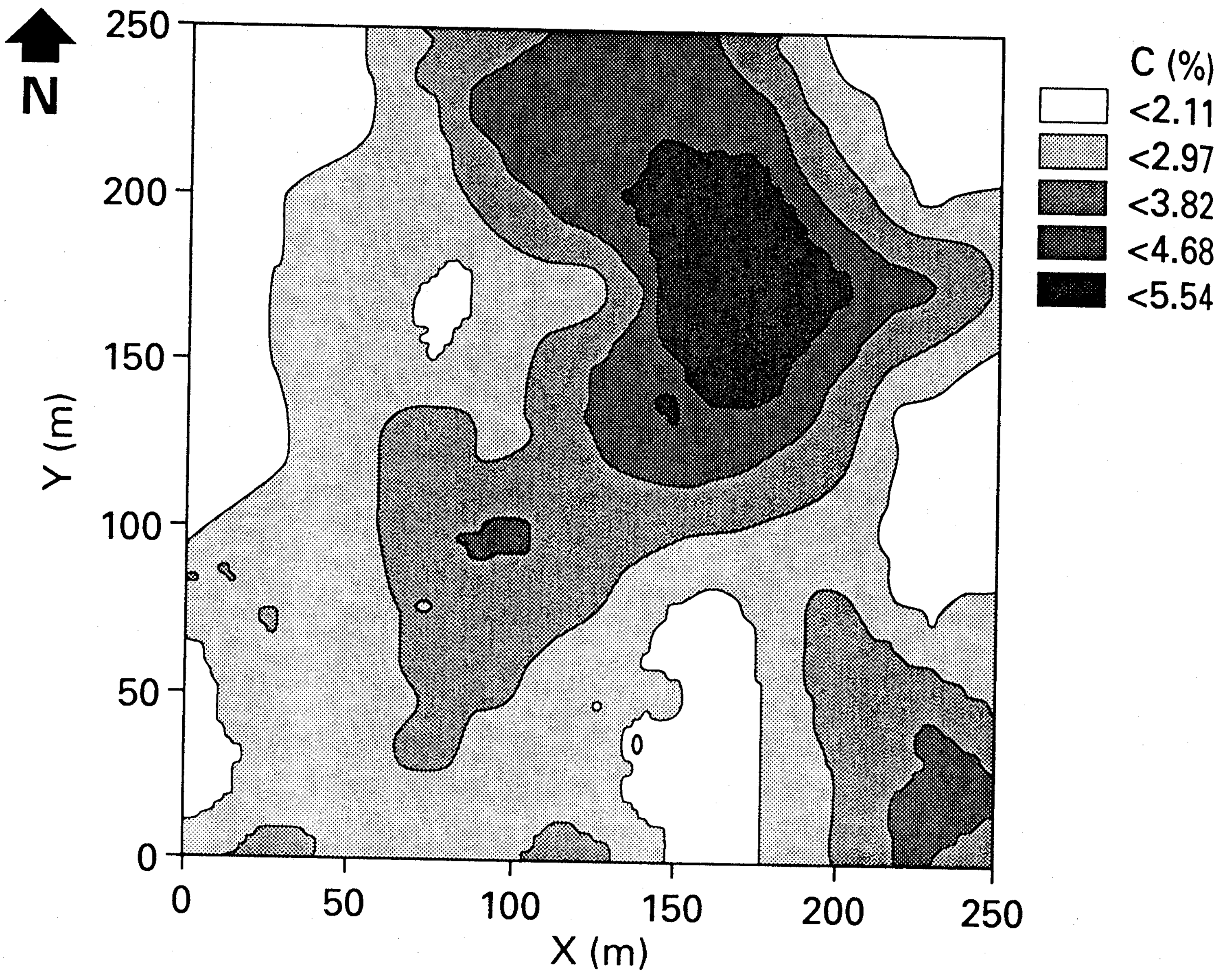

Figure 2. Degradation of 2,4-D in surface soils from a 6.25 ha field in central Iowa. Contours were produced from kriged data based on 44 soil samples. The index of degradation (T_{M25}) is the time (days) required to mineralize 25% of added [^{14}C] 2,4-D. The 2,4-D mineralization was assessed under laboratory conditions at -50 kPa water potential and 25 degrees C.

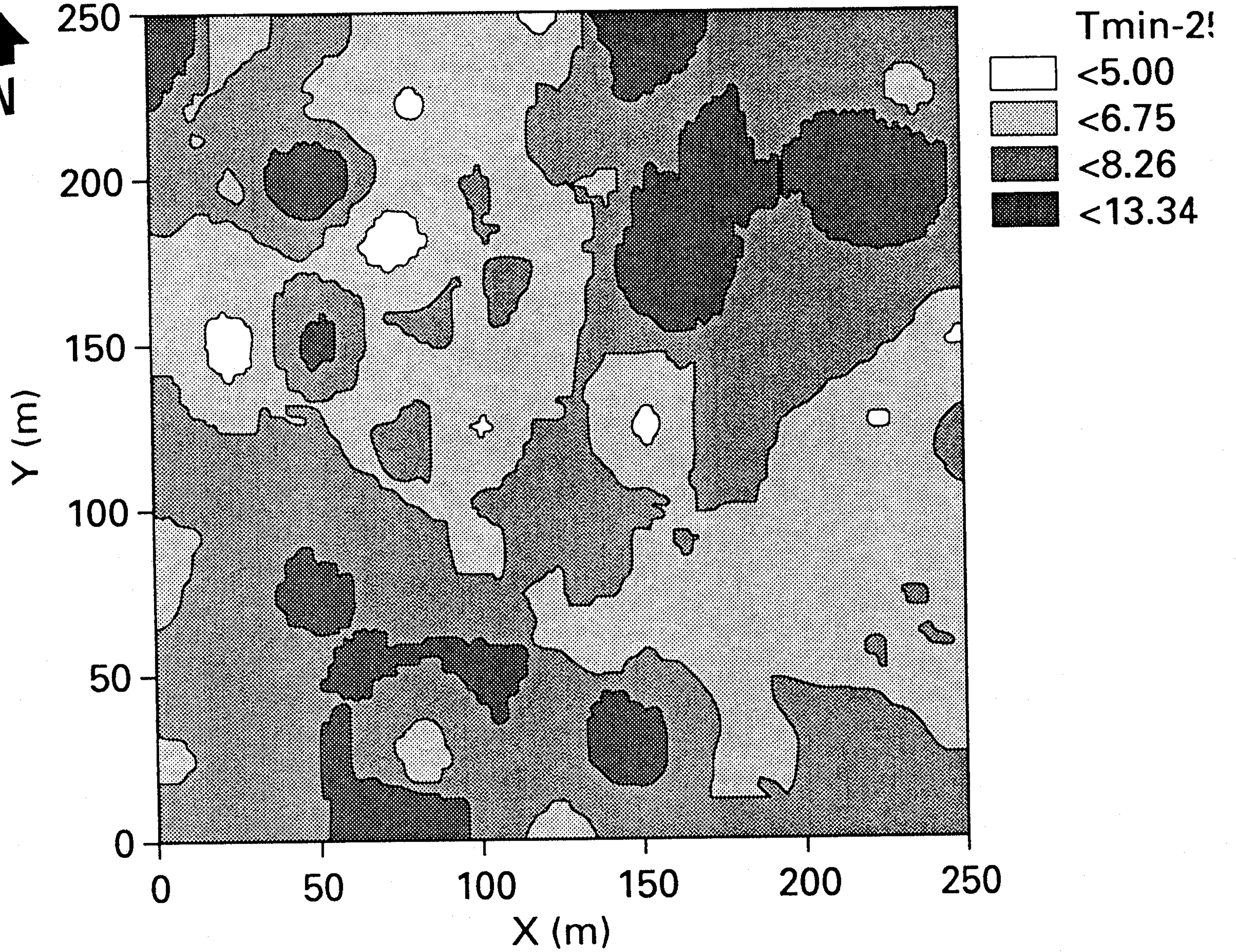

Figure 3. Total nitrate concentrations (mg NO_3-N/kg soil) in surface soils from a 6.25 ha field in central Iowa one week prior to corn planting. Contours were produced from kriged data based on 241 soil samples.