STUDIES ON SPATIAL SOIL HETEROGENEITY AND ITS INFLUENCE ON CROP RESPONSE TO FERTILIZER APPLICATION IN NORTHERN MALAWI

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Abstract

Soil quality that controls water transmission and plant nutrient availability is spatially heterogenous. Understanding the influence of spatial soil heterogeneity on crop response to fertilizer application is critical in sustainable crop production. In Malawi, fertilizer prices have significantly increased over years resulting into inability of smallholder farmers to access chemical fertilizers for crop production. The government of Malawi and its development partners are working to further enhance agricultural productivity while using minimal or no chemical fertilizers. In the northern region of Malawi, ecological sanitation (ecosan) toilets which produces ecosan manure and nutrient-containing urine as fertilizers for agriculture are used by selected farmers. The fertilizers from ecosan toilets have potential to improve yield among farmers in the region. However, the status of spatial soil heterogeneity, which likely affects urine fertilizer and manure application, remains unknown in the region. The overall objective of the study was to examine spatial soil heterogeneity and its influence on crop response to fertilizer application in northern Malawi. Two field studies were carried out on a 52-ha land with undulating topography of a village in Northern Malawi. The aim of the first experiment was to assess the spatial heterogeneity of soil physicochemical properties with attention to topography and soil fertility management. The second study analyzed the effect of soil texture on crop response to fertilizer application. To achieve the first objective, 115 geocoded surface soil samples were collected at 0–20 cm depth for physicochemical analysis. Remotely sensed images were captured using an unmanned aerial vehicle, processed, and analyzed to generate and visualize topographic data. Soil fertility management practices were described using field observations and questionnaire survey. The geostatistical analysis revealed spatial heterogeneity of most soil properties at a scale of 80–650 m. The spatial structure of soil pH, available phosphorus (P), total carbon (TC), total nitrogen (TN),

and clay showed strong spatial autocorrelation (Q value > 0.75). Calcium (Ca^{2+}) and potassium (K^{+}) had moderate spatial autocorrelations (0.25 < Q values < 0.75), whereas magnesium (Mg^{2+}), sodium (Na^{+}), sand, and silt had weak spatial autocorrelations (Q value < 0.25). The spatial heterogeneity in TC, K^{+}, Mg^{2+}, CEC, clay, silt, and sand was influenced by the area's topography, whereas pH, P, TN, and Ca^{2+} were influenced by soil fertility management practices. Increase in elevation and slope induced positive changes in CEC, K^{+}, Mg^{2+} and clay possibly due to formation of soil aggregates in highly elevated areas that are stable with protected sites for binding of positively charged ions. TN and P increased with the application of fertilizer, and manure, respectively. These results could be helpful in the development of site-specific fertility management in the village. Based on results of the first objective, three sites were selected in the farmers field for an experiment to quantify the maize response to the application of urine fertilizer on soils with contrasting clay content of 23, 15, and 10%, referred to as Clay, Intermediate, and Sand, respectively. Four treatments were used: chemical fertilizer (CF), urine fertilizer (U), Ecosan (E), and control (C), replicated three times in a completely randomized block design. The U and CF treatments brought nearly equal crop performance in the soil with a clay texture. Nonetheless, the maize yield at the Sand site showed a statistically significant difference between the CF and U treatments, with a higher yield in CF than U. The low water holding capacity of the Sand site result in increased losses of liquid urine fertilizer compared to Clay site leading to significantly poor maize performance in Sand. In conclusion, spatial soil heterogeneity significantly affects maize performance in the study village. Applying urine fertilizer according to the texture of the soil will greatly increase maize productivity by minimizing N losses through leaching.

Keywords: Geostatistics, maize yield, N leaching, nutrient uptake, soil fertility management, soil properties, soil texture, spatial autocorrelation, spatial heterogeneity, topographic factors, urine fertilizer