Spatial Variability of Soil Properties in a Dry Zone Soil Catena of Sri Lanka

F. Rosemary[1*], U.W.A. Vitharana[2], S.P. Indraratne[2] and S.V.R. Weerasooriya[2]
[*1]Postgraduate Institute of Agriculture, University of Peradeniya, [2]Department of Soil Science, Faculty of Agriculture, University of Peradeniya.

Abstract
Detailed information on spatial variability of soil properties is important for the decision making in site specific soil management and land use planning. Available coarse scale classical soil maps are insufficient to provide information for such requirements. Therefore, the soil variability needs to be investigated to provide detail soil information. The objectives of this study were to spatially characterize soil properties in a dry zone soil catena and to determine the impact of present land uses on the variability of soil properties. A dry zone catena consists of uncultivated lands and cultivated with paddy and vegetable lands was selected as a study area. Latin hypercube sampling technique was used to collect 58 soil samples. Soil samples were analyzed for pH, electrical conductivity (EC), cation exchange capacity (CEC) and texture. Summery statistics were calculated and statistical tests were performed to determine the land use impacts on soil properties. Semivariograms for each property were calculated and theoretical models were fitted using Variowin software. Continuous maps were constructed using ordinary point kriging interpolation technique. Normality test indicated that all the properties were normally distributed. Large coefficient of variation values indicated a considerable heterogeneity of soil properties within the catena. The relative nugget effect (RNE) values of pH (8.25 %), EC (7.41 %), sand (12 %), CEC (50.9 %), silt (50.5 %) and clay (29 %) revealed a high to moderate spatially structured variability for soil properties. Range of spatial dependencies of soil properties ranged from 193 to 650 m. Kriged maps further explained the variation of soil pH, EC and CEC in uncultivated and cultivated land uses and clay and silt enrichments were observed in vegetable lands and paddy lands, respectively.

Key words: Dry zone catena, Soil properties, Spatial variability, Variograms

Introduction
Understanding the degree of the variability of soil properties at the field scale is important in planning and implementing agricultural practices while minimizing environmental damages. Soil spatial variability is resulted by natural factors as well as by anthropogenic factors such as soil management. Earlier, scientists assumed that the variation of soil properties at short distances is random and therefore variation has been described using classical statistical models. Spatial dependencies were observed for soil properties those were sampled at greater distances rather than the samples collected very close to each other (Viera *et al.* 1981). Presently, the application of soil inputs is made based upon the blanket recommendation. In the presence of short-scale soil variability, parts of the field may expose to over and under applications. This can be resulted in losses and accumulations of soil inputs. However, in the most parts of the world, the short-scale soil variability of agricultural fields is unknown. Therefore, to improve the efficiency of present day crop management, soil variability of agricultural fields must be spatially characterized. This study was conducted to spatially characterize soil properties of a dry zone catena and to determine the impact of present land uses on the variability of soil properties.

Materials and Methods
A catena (94 ha) situated in a map unit in dry zone of Sri Lanka, was selected for this study (central coordinates 8° 7'57.07" N latitude and 80° 7' 51.22" E longitude). Land uses of the area were uncultivated, paddy fields and vegetable cultivation. Sampling was done using Latin hypercube sampling technique. All the sampling points were georeferenced using a GPS receiver (Garmin GPS etrex10). Collected 58 top soil samples (0 - 30 cm) were prepared for the laboratory analysis.

Soil pH (1:2.5 soil: 1 M KCl) and electrical conductivity (EC) (1:5 soil: water) were analyzed using pH and EC meters respectively, and the soil texture was determined using the pipette method. Cation exchange capacity (CEC) was determined using calcium as the index ion. Data analysis was performed using SPSS (V.13) statistical software. Summery statistics and normality test (Kolmogorov-Smironov test) were

***Corresponding author:** rosemary.fernando@gmail.com

performed for soil properties. The differences of soil properties across land uses were investigated by comparing means. Isotropic semivariograms for soil properties were calculated and theoretical variogram models were fitted using Variowin software. The Relative Nugget Effect (RNE) (nugget semivariance / sill semivariance) is used to explain the strength of spatial correlation (Camberdella *et al.*, 1994). Spatial distribution maps of soil properties were constructed using ordinary point kriging interpolation technique by GSLIB software.

Results and Discussion

The Kolmogorov-Smironov tests revealed that all the soil properties except EC were normally distributed. The clay, silt and sand content of the area ranged from 1.5 to 25.0 %, 2 to 26.6 and 57.4 to 84.0 %, respectively. Mean values of the pH, CEC and EC were 5.9, 5.94 cmol (+) kg^{-1} and 0.08 dS m^{-1}, respectively. Soil pH of the area can be classified as slightly acidic. Among the analyzed soil properties, EC showed the largest variation (CV= 107 %) where as the sand content showed the smallest variation (CV= 9.5 %). According to the classification of coefficient of variation by Hillel (1980) sand showed low (<10 %) variability, clay, silt, pH and CEC showed medium (10-100 %) variability while EC showed a large variability (>100 %). Different CV ranges suggested that soil properties different in the degree of heterogeneity within the catena.

The spatial behavior of soil properties can be evaluated through their semivariograms. Spherical model was found as the best model for experimental variograms of soil pH, EC, CEC and sand content. The spatial dependence of a variable occurs within the distance that explains by range. The range of spatial dependence for pH (598 m), EC (590 m) and sand (290 m) suggested strong spatial correlations. These properties showed a less variability over longer distance than the other measured properties. Relative Nugget Effect for pH (8.3 %), EC (7.4 %) and sand (12 %) indicated strongly structured spatial dependencies (< 25 %) (Cambardella *et al.* 1994). These strong spatially dependent properties may be controlled by intrinsic variation in soil characteristics such as mineralogy (Ayoubi *et al.* 2007). The RNE (50 %) value for CEC showed a medium level of spatial dependency. Exponential model was found as the best model for clay and silt. Ranges of spatial dependence for clay, silt and sand were 193, 290 and 290 m in distance respectively. Clay (RNE: 29 %) and silt (RNE: 50 %) are medium spatially structured (Cambardella *et al.*, 1994).

Soil pH in paddy soils in this particular dry zone catena ranged from 5.2 to 7.9. The higher content of exchangeable basic cations and high evaporation during dry season could contribute to the increase in soil pH in this area. Exchangeable basic cations in soil solution come up during dry season and could accumulate in surface soils.

The EC values in paddy (0.19 dS m^{-1}) soils were significantly (p = 0.05) different with uncultivated (0.06 dS m^{-1}) and vegetable (0.04 dS m^{-1}) soils. The critical level of EC for paddy is 0.12 dS m^{-1} as reported by Bandara *et al.* (2005). EC values in some parts of paddy grown areas were higher than the critical level. Soluble salts containing in irrigation water from Rajanganaya

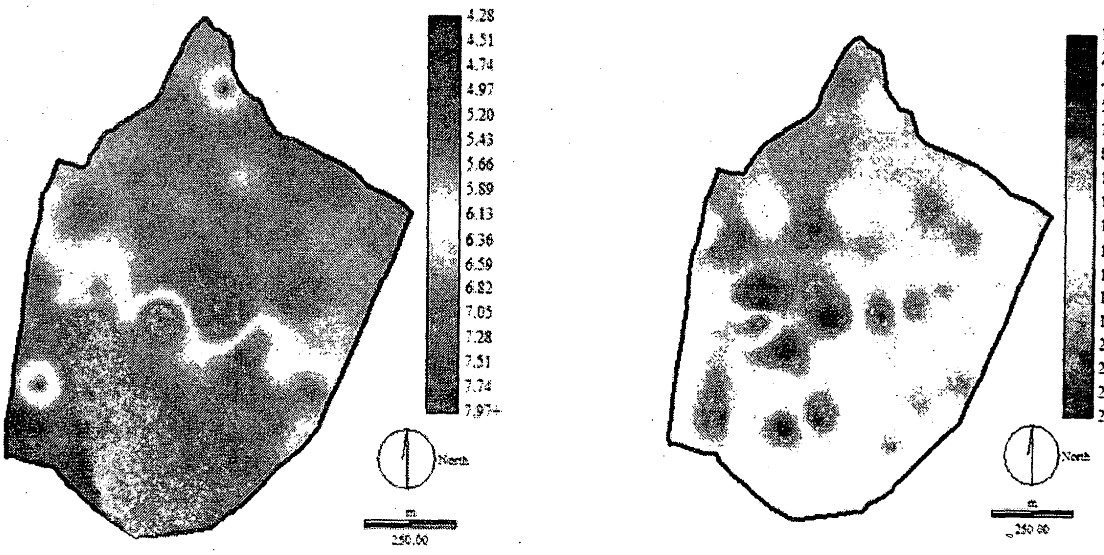

Figure 1. Kriged maps for (a) Soil pH (b) Clay content in the selected dry zone catena

catchment could have contributed to higher EC values in paddy lands of this catena compared with other land uses.

Kriged map of CEC showed higher values in paddy (7.1 cmol (+) kg^{-1}) soils than in the vegetable (4.8 cmol (+) kg^{-1}) and uncultivated (5.05 cmol (+) kg^{-1}) soils. Soil pH also followed the same spatial pattern. Significant differences were observed in CEC in uncultivated (5.05 cmol (+) kg^{-1}) and paddy soils (7.1 cmol (+) kg^{-1}), and paddy (7.1 cmol (+) kg^{-1}) and vegetable (4.8 cmol (+) kg^{-1}) soils ($p = 0.05$). Clay content (Figure 1b) of paddy soils (11.83 %) was lower than the vegetable (13.07 %) and uncultivated (14.82 %) areas. Sandy patches were observed in some of the vegetable and uncultivated areas. The silt content was higher in paddy fields. A slight slope was observed from middle part of the paddy fields towards to northern part of the area. Transport of silt towards the paddy lands and accumulate there. It might be the reason for silt enrichment in paddy lands. The RNE values demonstrated that soil pH (8.3 %), EC (7.4 %) and sand (12 %) are strongly spatially correlated while clay (29%), silt (50.5 %) and CEC (50.9 %) are moderately spatially correlated. Soil pH, EC and CEC showed a significant difference in paddy and vegetable cultivated lands. Kriged maps exhibited a spatial variability of soil properties further strengthening the variability revealed by variograms. This study showed a considerable short-scale variability of soil properties that have to be considered in determining the requirement of soil inputs for crop cultivation.

Acknowledgement

Financial support from NRC grant 11_166 is gratefully acknowledged.

References

Ayoubi, S., Zamani, S.M. and Khormali, F. 2007. Spatial variability of some soil properties for site specific farming in northern Iran. *International Journal of Plant Protection*, 1:225-236.

Bandara, W.M., Kumaragamage, J.D., Wickramasinghe, D.B. and Weerawarne, S.B.A. 2005. A site specific fertilizer management strategy to increase the rice yield in LCIZ. *Journal of Soil Science Society of Sri Lanka*, 17:32-44.

Cambardella, C.A., Moorman, T.B., Novak, J.M., Parkin, T.B., Karlen, D.L., Turco, R.F. and Konopka, A.E. 1994. Field scale variability of soil properties in central Iowa soils. *Soil Science Society of America Journal*, 58:1501-1511.

Hillel, D.1980. Applications of soil physics. Academic press, New York, 600pp.

Viera, S.R., Nielsen, D.R. and Biggar, J.W. 1981. Spatial variability of field measured infiltration rate. *Soil Science Society of America Journal*, 45:1040-1048.