Spatial Variability of Selected Soil Properties Under Different Pasture Grasses in Western and Central Kentucky

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Abstract

Spatial variability of soil chemical, physical, and biological properties such as soil organic matter, total soil nitrogen, soil nutrient status, pH, hydraulic conductivity, bulk density, aggregate stability, and macrofauna are greatly affected by the land use and land cover. The present work tries to address the spatial pattern of some selected soil properties under four different pastures in western and central KY. Soil samples were collected from three layers representing the depth from 0-30 cm in three transects (Orchard grass, KY 31 tall fescue, and Max Q tall fescue) in western KY, Murray State University (MSU). Each transect was 170 m with a 10 m lag distance between samples. A 4th transect, which represents the bluegrass region of central Kentucky passed through the center of large sinkhole and encompassed at least two soil catena. The 4th transect was 160 m long and was sampled every 5 m. Using classical and spatial statistical methods, we characterized and compared the spatial heterogeneity and spatial dependence between several soil properties under the different pasture systems. The work presented here focused on the spatial patterns of total nitrogen, total phosphorus , and dry aggregate mean weighted diameter MWD.

Introduction

Tall fescue (*Festuca arundinaceae* Schreb.) is a cool-season forage grass that dominates pastures in the southeastern United States. Kentucky 31 (KY 31) is a dominant cultivar in this region, but unfortunately suffers from infection by the endophyte *Neotyphodium* , which produces various ergot alkaloids that are detrimental to animal growth and productivity. Much effort is currently devoted to replacing KY 31 with alternate forage species. In western Kentucky, fragipans with poor drainage underlie many pasture soils. In central Kentucky, potential effects of forage transition are exacerbated by the underlying karst topography. Numerous sinkholes that develop in this landscape provide rapid conduits for surface contaminants into shallow groundwater resources. Karst topography creates soil environments dominated by multiple sinkholes that differ in width and depth. As a consequence, spatial variability of soil properties is likely to be influenced within very short distances. Characterizing the effect of forage species transition on spatially variable patterns of soil N and P as major indicators of soil fertility and soil quality would be informative. On the other hand, the association between soil structure as represented by aggrgate mean weighted diameter MWD and N and P in the soil as major non-source pollutants to surface and ground water needs to be studied to evaluate the environmental effects of forage transition on the environment. Eventually, these types of studies will help us predict the environmental response of soil ecosystems to this change.

The research reported here is part of an ongoing effort to assess the effect of forage species change on the soil processes beneath grass cover, their association with soil structure, and consequently their effect on soil and environmental quality.

The specific objective of the work presented here is to identify and compare the field scale spatial patterns of soil aggregate mean weighted diameter, soil total nitrogen, and soil total phosphorus under different forage species in western and central Kentucky, and to analyze the impact of underlying soil factors and forage species on the distinct spatial patterns of soil properties.

Material and Methods

The study was conducted on two locations representing western and central Kentucky. Fig. 1 shows the location, soil maps, and sampling transect orientation of the selected fields. Forage grasses at Murray, KY consisted of orchard grass (*Dactylis glomerata*, L.) and tall fescue (KY 31 or Max Q). The forage at Woodford Co. consisted of a mixture of KY 31 and KY bluegrass (*Poa pratensis* L.). Spatial structure and spatial variations of different soil properties were described using omnidirection semivariograms (Goovaerts, 1997; Deutsch and Journel, 1998; Chiles and Delfiner, 1999). Semivariogram values at each lag separation, ***γ(h)***, were computed as:

$$\gamma(h) = \frac{1}{2N(h)} \left\{ \sum_{i=1}^{N(h)} (A(x_i) - A(x_i + h)^2 \right\}$$

Where: N(h) is the number of pairs separated by a lag distance of h and A(xi) and A(xi+h) are the observations at position Xi and Xi+h. Visual and statistical approaches were used for variogram modeling as suggested by Webster and Oliver (2001). First, the variogram was plotted and inspected for general trends. Then, spherical, gaussian, and exponential models with and without nugget were fitted and based on the (RSS).

The cross correlation function (CCF) was used to visualize the spatial correlation between two variables and was calculated as follows (Nielsen and Wendroth, 2003):

$$\boldsymbol{\gamma}_{xy}(h) = C_{xy}(h)(\delta x \delta y)^{-1}$$

Where X and Y are the studied variables, and δx and δy are the standard deviation of X and Y, respectively. To study the effect of separation distance on the spatial patterns of the studied variables, the autocorrelation function ACF was calculated as described by (Nielsen and Wendroth, 2003). The general relative semivariance was used to compare the spatial patterns of variables between layers and under different forages independently from the absolute variable values and was calculated at each lag distance by dividing the corresponding semivariance at each lag *h* by the square of the mean of all data used to calculate the semivariogram.

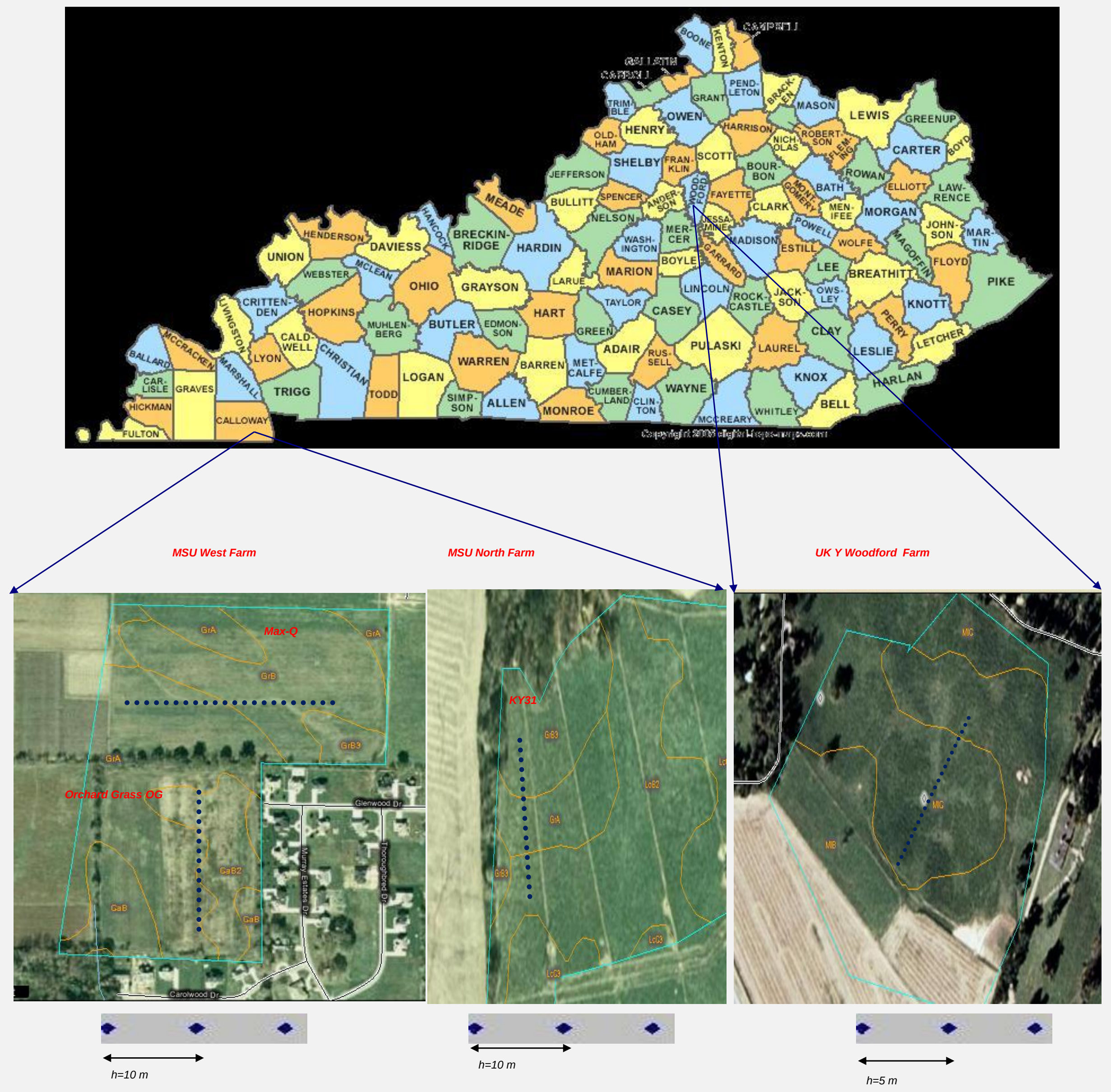

Figure 1. Location map, soil map, transect position and corresponding sampling points under four different forage species in western and central Kentucky.

**** GrA is Grenada Silt loam 0:2 % slope, GrB is is Grenada Silt loam 2:6 % slope, LoB2 is Loring Silt loam 2:6% slope, CaB2 is Callaway Silt loam 2:6 % slope, MIB is Maury silt loam 2:6 % slope and MIC is Maury silt loam 6:12 % slope**

Results

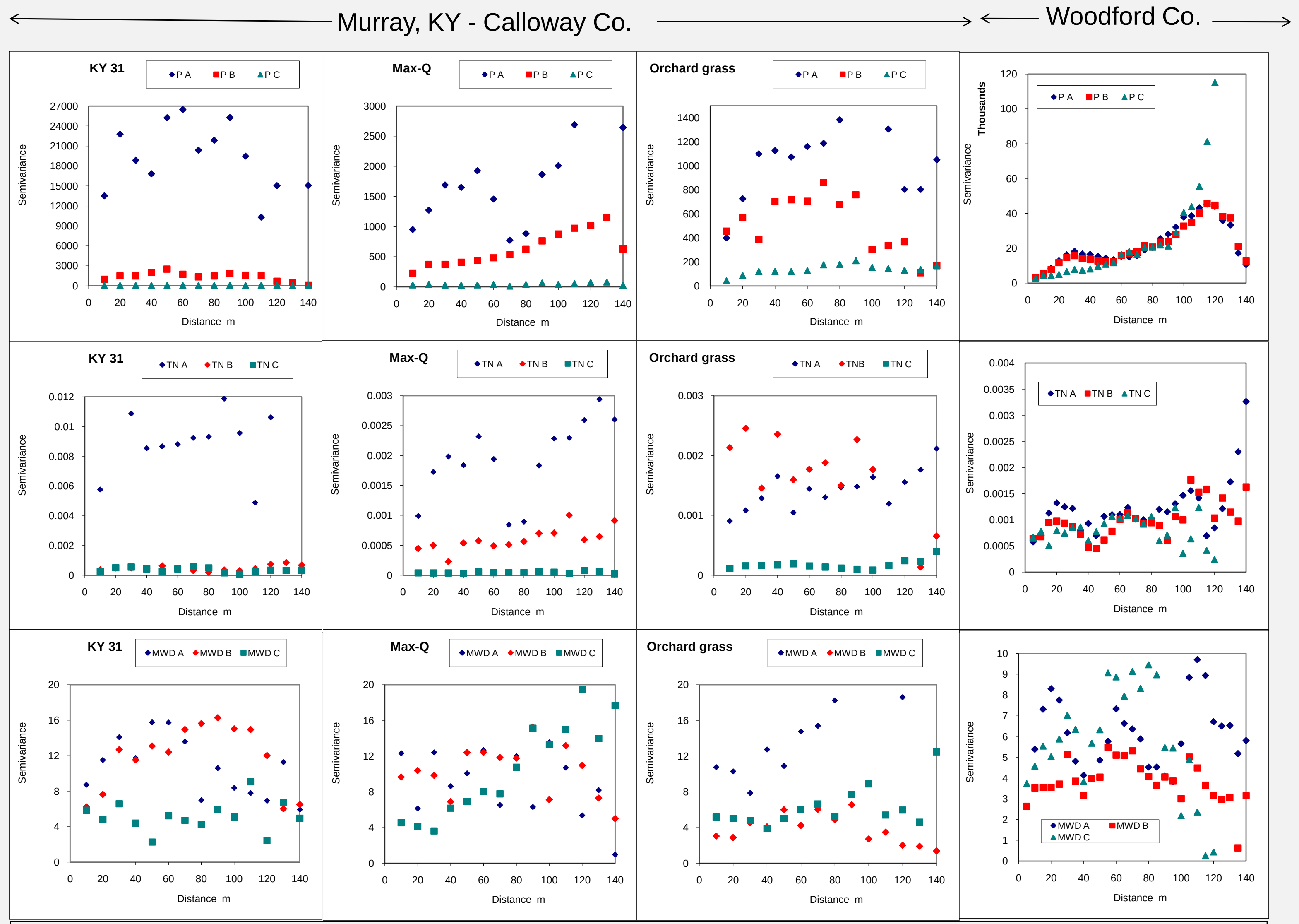

Figure 2. Semivariograms for P, TN, and aggregate MWD under different forage species at Calloway and Woodford counties sites for three soil depths A: 0-10 cm, B: 10-20 cm and C:20-30 cm.

Fig. 2 represents the spatial patterns of total P, total N, and dry soil aggregate MWD under the four forage species. Semivariance analysis and the ratio between nugget to the total semivariance showed a strong spatial structure for P, TN and aggregate MWD over 30 m range in the 0 to 10 cm layer under Woodford county blue grass site comparing to a moderate to weak spatial structure in the 10 to 20 and 20 to 30 cm layers. The three variables showed a second spatial structure appeared between 40 to 80 m then another increase in the semivariance between 100 to 160m. This trend is associated with other soil factors such as the topography of this site, clay ,and SOM distribution. Because of the higher nugget ratio, a moderate to weak spatial structure over 30 to 80 m range was observed for P, TN, and aggregate MWD under the KY 31, Max Q and Orchard grass in western kentucky. Relative semivariance analysis indicated a higher magnitude of the variances in the upper two layers compared with the 20 to 30 cm layer under all forage species

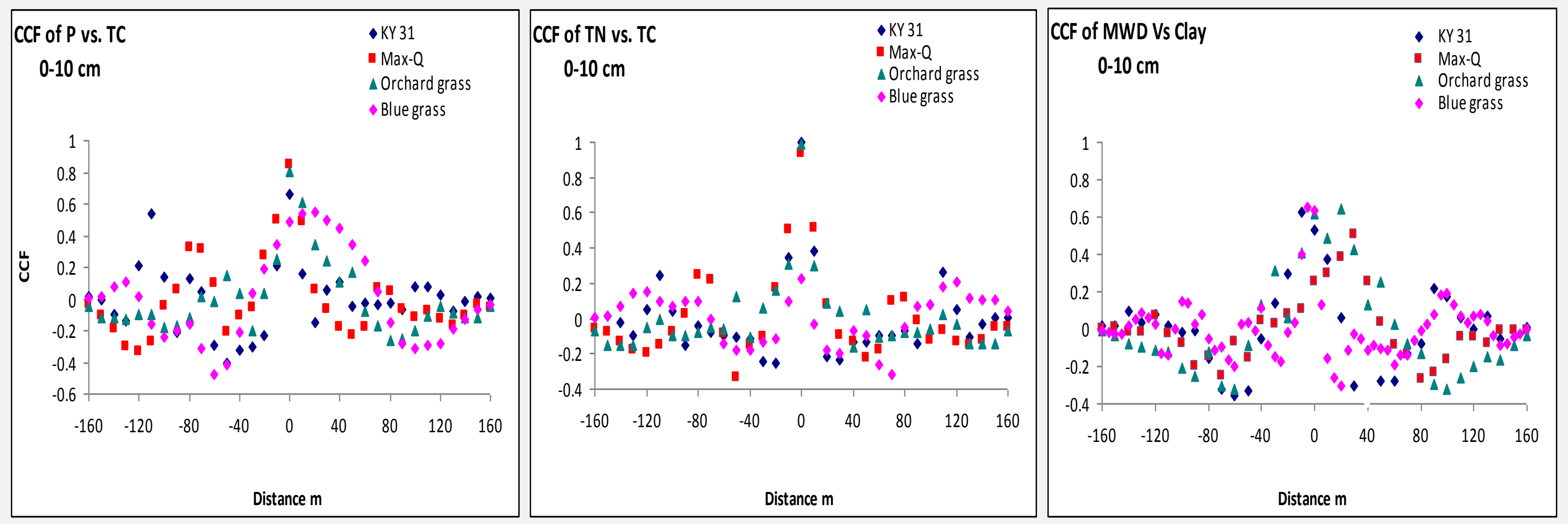

Figure 3. Spatial cross correlation between both total P and total N versus total C and between aggregate MWD and clay content for 0-10 cm under the forage species.

Cross correlation analysis showed a significant and strong spatial cross correlation between total P and soil total C under all grasses, and it followed the order : Max-Q> orchard grass> KY 31> bluegrass for a spatial correlation range between 10 to 30 m. Significant and positive spatial cross correlation between TN and TC for about 20 m correlation range was observed under all grasses except for bluegrass, where non significant spatial cross correlation was observed. The spatial cross correlation between MWD and clay content was significant for a range between 10 to 20 m under KY 31 orchard grass and bluegrass while it was positive but not significant under Max Q.

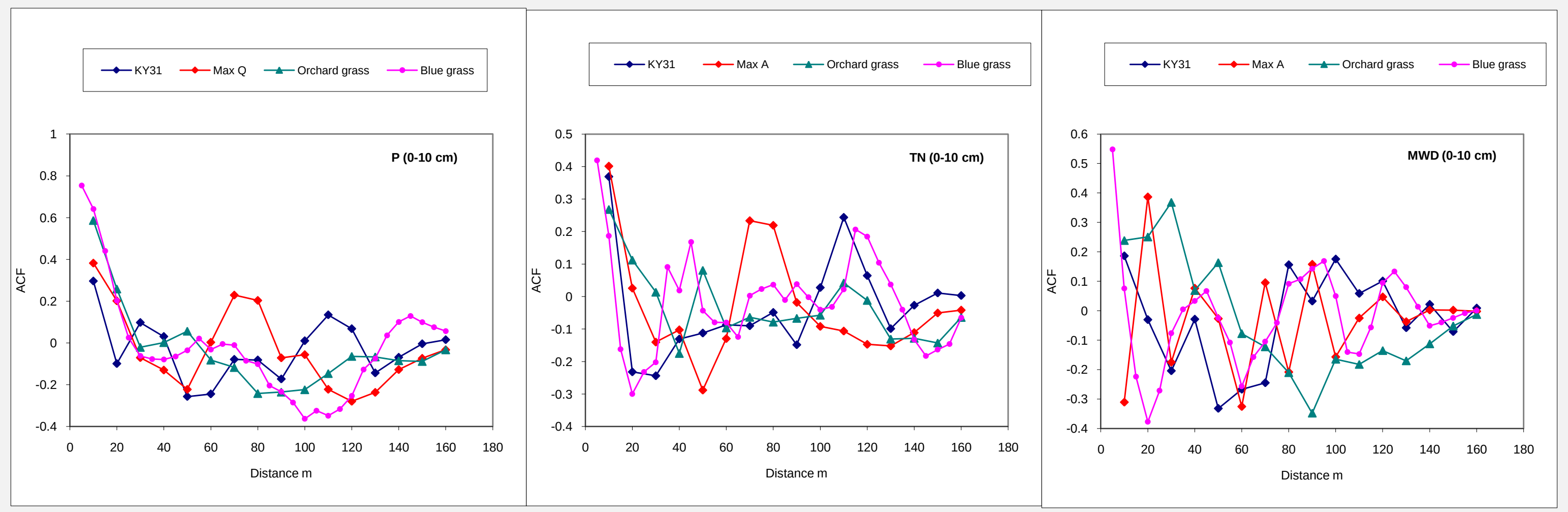

Figure 4. Spatial autocorrelation of total P, total N and dry aggregate MWD for 0-10 cm depth under the forage species.

Total P showed a positive decreasing auto correlation to approximately 30 m followed by a negative auto correlation to 60 to a 100 m approximately under all forage species . P auto correlation was significant for 15 to 20 m auto correlation range under all forage species except for KY31; the positive auto correlation was not significant. TN showed also a positive decreasing autocorrelation to approximately 15 to 30 m distance followed by repeated positive and negative cycles fluctuating around zero between 30 and 140 m distance. TN autocorrelation was significant for the first 5 to 10m range under all forage species except for the orchard grass. Aggregate MWD auto correlation was positive and significant for the first 8 m only under the blue grass compared with positive but not significant over 15 to 60 m range under KY31 and orchard grass and negative autocorrelation under Max-Q species. Autocorrelation analysis also showed a periodic cycle of negative and positive autocorrelation between 40 to 140 m of the transects related to other factors such as the distribution of clay and SOM and other unknown factors.

Conclusion

Forage species and inherited soil properties such as clay content were associated with differences in the spatial characteristics of total P, TN, and aggregate MWD. Soil organic matter content ,as represented here by TC, was highly correlated with the level of P and N in soil and their spatial distribution under all forage species. The amount and spatial distribution patterns of SOM is directly related to the growing forage species in the soil which affects the C to N ratio, N and P mineralization rate, biomass amount, soil microbial activities, and the decomposition rate of plant litter and residues. These processes are also influenced by other factors such as local topography, soil texture and clay content, which control the condition of moisture in the soil. Therefore the combined effect of these processes with the forage transition (*i.e.* forage species) and other factors will be reflected on soil structure and rate of gas, water and solutes movement in the soil and ultimately soil and environmental quality.

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Acknowledgements: This study was funded by the USDA-ARS Forage Animal Production Unit (FAPRU) under Agreement No. 3049022644. Mention of trade names is for information purposes only and does not imply endorsement by the Kentucky Agricultural Experiment Station or the USDA.