Factors Influencing C Sequestration in Northern Great Plains Grasslands

D. Annam[1] and L.J. Cihacek[2], [1]Department of Statistics, [2] School of Natural Resources Management, North Dakota State University, Fargo, ND 58015

Introduction:

Soil organic carbon levels within the soil are related to parent material, organisms, topography, climate and time (Franzmeier et al., 1985).The effects and influence of these factors vary among different regions. Study of the factors responsible for higher soil organic carbon (SOC) improves the estimates and knowledge of carbon in different systems (Liebig et al., 2005). This study seeks to understand the influence of vegetation, slope and landscape on SOC in Conservation Reserve Program (CRP) grasslands, restored grasslands, and undisturbed grasslands across the northern Great Plains of the U.S.

Materials and Methods:

Between 2006 and 2008, 1425 sampling points were sampled to a depth of 30 cm over 8 regions across 5 states in the northern Great Plains of the U.S. Of these sampling points, a total of 1163 points were grassland sites that were selected for this study (Table 1). In formation on plant species composition, estimated slope at the sampling points and the aspect of the sampling points was collected during the sampling process. This study attempts to relate soil organic carbon (SOC) levels in the soil at each sampling point with the other factors using statistical methods. The factors and their classification are shown in Table 2. The classes shown in Table 2 were selected from data analysis with a general linear model (SAS PROC GLM) to determine class groupings. A second round of analyses was conducted using a partial F-test in SAS 9.1.3 (SAS institute, Cary, NC) using PROC REG at two levels for each of the eight regions independently. The results are shown in Table 3 and Table 4.

Statistical analysis:

Level 1: Full models were first tested for the significance of interaction effects against a reduced model with no interaction effect:

y= a* vegetation + b* Slope + c* Aspect + Slope * Aspect

y= a* vegetation + b* Slope + c* Aspect + Slope * Vegetation.

where vegetation includes 3 dummy variables, slope includes one dummy variable and aspect has 4 dummy variables. The model with Vegetation * Aspect was not tested due to insufficient data for few of the classes.

For the regions where the interaction effects were not significant, a full model: y= a* vegetation + b* Slope + c*Aspect was tested for the significance against reduced models with one of the factors excluded.

Level 2: Full models with only two factors at a time were tested for significance in each region independently against a reduced model with only one factor.

Table 1: Sampling sites

Location	# of Fields Sampled	# of Sample Points	# of Sampled Acres
Montana	11	129	1290
Central North Dakota	15	166	1660
Eastern North Dakota	11	103	1030
North-Central South Dakota	15	166	1660
Central South Dakota	19	211	2110
Western Minnesota	20	189	1890
North-Central Iowa and Southern Minnesota	18	199	1990

Table 2: Factors under study and their classes

	Factors+		
Level	Vegetation	Aspect	Slope
1	Cool season grasses(C)	No Aspect	0-3"
2	Cool season grasses and Legumes (CL)	North,Northeast	> 3"
3	Warm Season grass (CW) and Cool + Warm Season grass + Legumes (CWL)	South,Southwest	NA
4	Legumes (L), Warm season grasses (W), Warm season grasses + Legume (WL)	East,Southeast	NA
5	NA	West,Northwest	NA

Table 3: P-Values from Partial F-Test (Level 1: Including all 3 parameters)

Region	Vegetation	Slope	Aspect	Slope*Aspect	Slope*Vegetation
Central South Dakota	0.00***	0.63	0.83	0.67	0.78
North-Central South Dakota	0.00***	0.00***	0.47	0.94	0.89
Montana	0.00***	0.88	0.03*	0.16	0.77
Western Minnesota	0.06	0.17	0.00***	0.25	0.74
Iowa	0.53	0.15	0.21	0.16	0.22
Southern Minnesota	0.26	0.00***	0.04*	0.70	0.60
Central North Dakota	0.02*	0.74	0.12	0.99	0.28
Northeastern North Dakota	NS	NS	NS	NS	NS

*p<0.05, *** p<0.01, NS – Not Significant (full and reduced models are not significant)

Table 4: P-Values from Partial F-Test (Level 2: Including only 2 parameters)

Region	Vegetation	Slope	Aspect
Central South Dakota	0.00***	0.44	--
	0.00***	--	0.76
North-Central South Dakota	0.00***	0.00***	--
Montana	0.00***	--	0.02*
Western Minnesota	0.03*	--	0.00***
Iowa	--	0.06	0.28
	0.32	--	0.04*
	0.70	0.01*	--
Southern Minnesota	--	0.00***	0.02*
Central North Dakota	0.00***	--	0.10
	NS	NS	--
Northeastern North Dakota	NS	NS	--
	NS	--	NS
	--	NS	NS

*p<0.05, *** p<0.01, NS – Not Significant (full and reduced models are not significant)

Table 5: Parameter estimates of factors that are significant

Region	Vegetation			Slope	Aspect			
	Veg2	Veg3	Veg4		Asp2	Asp3	Asp4	Asp5
Central South Dakota	-1.38	-1.47	-1.4	NS	NS	NS	NS	NS
North-Central South Dakota	-1.48	-1.37	0.15	-0.49	NS	NS	NS	NS
Montana	-1.58	-1.1	-2.77	NS	-3.43	-2.49	-2.65	-3.39
Western Minnesota	-1.7	-0.45	-0.49	NS	0.18	-0.67	-0.5	-1.03
Iowa	NS	NS	NS	-1.11	-0.25	-1.77	-1.16	-1.58
Southern Minnesota	NS	NS	NS	-1.46	-3.19	-2.5	-2.78	-2.17
Central North Dakota	-0.78	-0.58	NA	NS	NS	NS	NS	NS
Northeastern North Dakota	NA	NA	NA	NA	NA	NA	NA	NA

NS-Parameters not significant at Level 2 of partial F-test, NA- Not Applicable (full model not significant)

Results and Discussion :

Table 3 shows the P-values and their significance from the Level 1 test using comparisons with 3 parameters. Vegetation effects were noted to be very highly significant for the central South Dakota, north-central South Dakota and northeastern Montana regions. Vegetation also had a significant effect for the central North Dakota site. Slope had a very highly significant effect in north-central South Dakota and southern Minnesota. Aspect was very highly significant for western Minnesota with significant effects in northeastern Montana and southern Minnesota. No effects were significant for the northeastern North Dakota region or for interactions between slope and aspect or slope and vegetation.

Table 4 shows P-values obtained from the Level 2 partial F-test. These data generally reflect the information presented in Table 3.

In general, no interactions were observed between slope and aspect or slope and vegetation. The relationship between vegetation type and SOC was an important relationship in most of the regions. The relationship between slope and SOC or aspect and SOC were important only in a lesser extent.

Table 5 shows parameter estimates for factors that are significant. For these comparisons Level 1 (from Table 1) was used as the reference for the comparisons, a negative number indicates that that factor level was less important than the reference factor level.

Summary and Conclusions:

- **Vegetation:** When cool season grasses were used as a reference, all other levels of vegetation show negative values indicating that <u>cool-season</u> grasses help accumulate more carbon in all the 5 regions where vegetation composition was found to be significant.
- **Slope:** In the three regions where slope is significant factor, the reference <u>0-3" slope</u> has higher SOC levels than slope > 3%.
- **Aspect:** Except for western Minnesota, the reference level of <u>"no aspect"</u> showed higher accumulations of SOC levels than the other aspects.

From this data analyses, we conclude that the greatest SOC accumulations occur under cool-season grasses on slopes of <3% that tend to have no defined aspect.

References:

Liebig, M.A., J.A. Morgan, J.D. Reeder, B.H. Ellert, H.T. Gollany, G.E. Schuman. 2005. Greenhouse gas contributions and mitigation potential of agricultural practices in northwestern USA and western Canada. Soil and Tillage Research. 83:25-52.

Franzmeier, D.P., G.D. Lemme, and R.J. Miles. 1985. Organic carbon in soils of north central United States. Soil Sci. Soc. Am. J. 49:702-708.

Riopel, J. "Evaluating carbon Sequestration in CRP and restored Grasslands in the North Central US" (MS thesis, North Dakota State University, 2009).

Acknowledgments:

The authors gratefully acknowledge the partial support of US-DOE Plains CO_2 Reduction (PCOR) Partnership and Ducks Unlimited, Inc. The assistance of Jason Riopel, Chris Augustin, Gayatri Yellajosula, Gabriel Aher, Dismas Macha, Kevin Brown, Kevin Horsager, Dave Olson, Keith Jacobson, Doug Tjon, Shawn Koltes, Kelly Kritsky, Craig Kritsky, Amar Singh, Josh Elke, Carlee Elke, Sachin Grag, Gabriel Hayes, Jesse Beckers and Deven Styczynski is also gratefully acknowledged.