YIELD LIMITING FACTORS IN THE CONDITIONS OF SOUTHERN ALBERTA

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ABSTRACT

The main goal of our experiment was to determine the main factors determining yield of green biomass of spring barley in the conditions of Southern Alberta. To analyze soil properties in the field, grid sampling was conducted at 1-ha grid. Soil samples were collected from the depths of 0…15 and 15…60 cm and analyzed for over 20 different characteristics including soil organic matter content, pH, cation exchange capacity (CEC), and the concentrations of macro- and micronutrients. Spatial variability of green biomass in the field was estimated using normalize difference vegetation index (NDVI) calculated from a multispectral satellite image (Landsat 5TM) collected at the peak of the growing season. In addition, surface curvature was calculated for the same field using high-resolution elevation data. As a result of analysis, it was determined that soil organic matter content was strongly correlated to the NDVI and field surface curvature, whereas the concentrations of nitrogen and phosphorus had only a weak correlation with the vegetation index. In the conditions of Southern Alberta, field topography determines the level of soil moisture. Therefore, the amount of plant available water in soil was the most important factor determining the uptake of nutrients by plants and crop development in the field. The strategy for nutrient management in Southern Alberta should be oriented to the optimization of soil moisture to create favorable conditions for the uptake of the main nutrients.

Keywords: precision agriculture, soil, soil moisture, NDVI, satellite imagery.

INTRODUCTION

The most important component of precision agriculture is the identification of yield limiting factors with their subsequent adjustment. In most cases, nitrogen is considered as the main factor, primarily because of high cost of nitric fertilizers and high mobility in soil. However, the experiments indicate that it is not always true. There are many other factors influencing yield, such as soil moisture, compaction, salinity, concentrations of other nutrients (phosphorous, potassium, sulfur, microelements) etc. Obviously, correct identification of yield limiting factors helps to select the right strategy for fertility management. The main goal of our experiment was to determine the main factors determining yield of green biomass of spring barley in the conditions of Southern Alberta.

MATERIALS AND METHODS

This experiment was carried out in a farmer's field near Beiseker, AB, Canada. Multispectral imagery (Landsat 5TM) was collected on July 21, 2009. In addition, LiDAR data (Light Detection And Ranging) were collected for the same field on July 25, 2009. LiDAR data were used for the analysis of field topography.

Grid soil sampling was done on November 18-19, 2009. The density of grid was 2.5 acres, or approximately 1 hectare. A total of 91 composite soil samples were collected from two depths (0…15 cm and 15…60 cm). The results of soil analysis were saved in tabulated format and linked to the geo-referenced points, where each sample was taken. This operation allowed mapping every soil characteristic that had been analyzed. After that, an interpolated map was created for each characteristic. Spatial maps were created for the following soil properties: organic matter content, cation exchange capacity (CEC), pH, soluble salts, concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, sodium, zinc, manganese, iron, boron, copper, chlorine, aluminum, percent of base saturation (for potassium, phosphorus, magnesium, calcium and sodium), and potassium/magnesium ratio. The mapping was done separately for two sampling depths: 0…15 and 16…60 cm.

To estimate the effect of various soil characteristics on yield, an estimated yield map was created for the field using the information about the total amount of green biomass harvested from the field, and normalize difference vegetation index (NDVI) to calculate yield for each location in the field.

RESULTS AND DISCUSSION

The results of grid soil sampling are shown in Fig. 1-7. Visual analysis of maps indicated that the spatial variability and distribution of different soil characteristics in the field were not similar. For example, nitrate nitrogen and phosphorus in soil were distributed quite differently. However, in many cases, zones with comparable soil characteristics followed field topography (Fig. 8-9).

To estimate the effect of various soil characteristics on yield, a yield map was created for the field using the information about the total amount of green biomass harvested from the field, and normalize difference vegetation index (NDVI) to estimate yield in each location in the field. Correlation analysis indicated that the highest correlation was determined between the yield and soil organic matter content. Since soil OM is determined mainly by field topography, we concluded that the main factor determining yield in the tested field was soil moisture. The second characteristic that had medium-strong correlation with the yield was the concentration of potassium. All these results corresponded with our previous finding. The correlation between the yield and concentration of nitrogen in the soil was medium-weak, which indicated that this element still played the important role in this particular case, but was not the main factor that limited the yield. The soil characteristics ranged within the following limits: soil organic matter – 1.6…6.6 %, nitrate nitrogen – 9.0…144.0 ppm, available phosphorus – 9.0…73.3 ppm, potassium – 100…625.0 ppm, cation exchange capacity –

11.8…44.2 meq •100 g $soil^{-1}$, soil pH – 5.8…8.4, elevation – 905…920 m above sea level.

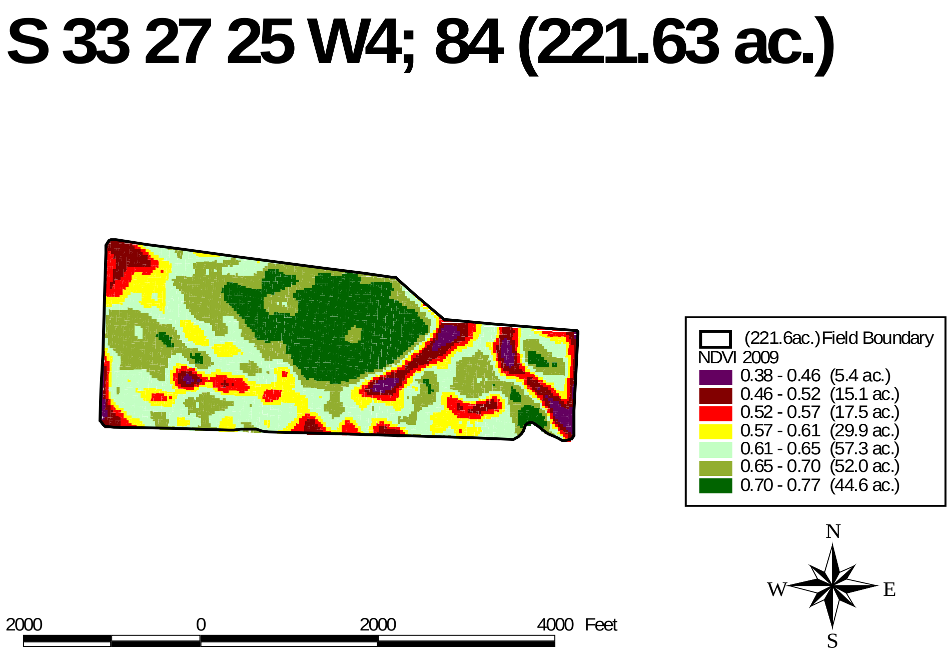

Fig. 1. Normalized difference vegetation index (NDVI), Landsat 5TM, Jul 21, 2009.

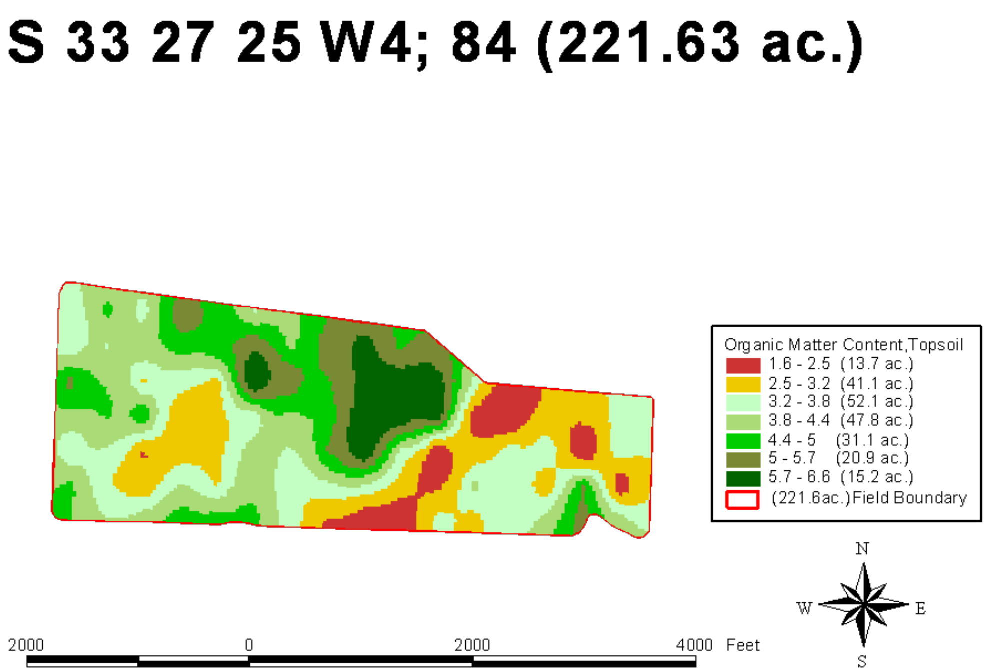

Fig. 2. Soil organic matter, %, topsoil

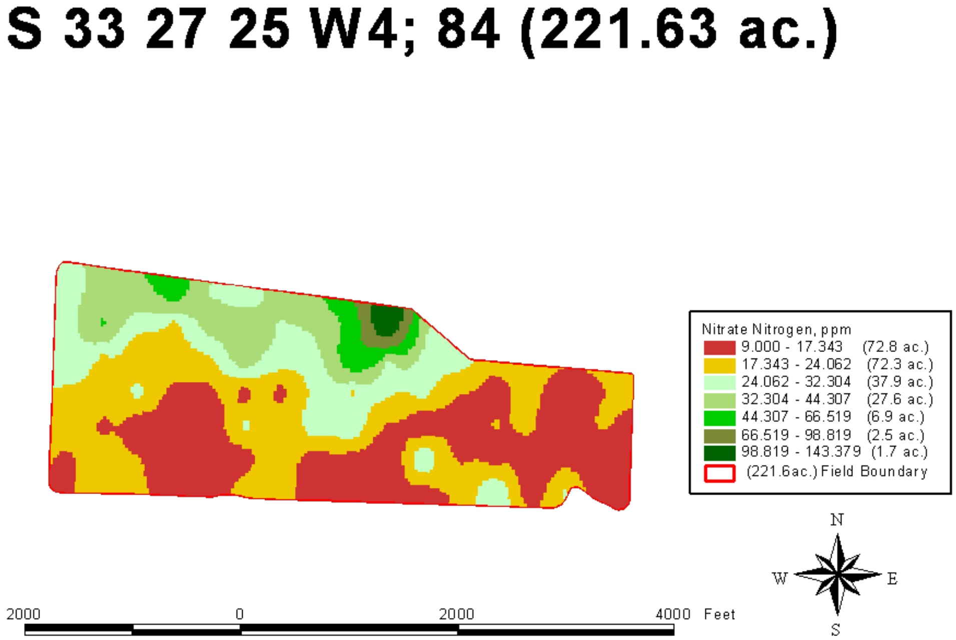

Fig. 3. Nitrate nitrogen, ppm, topsoil.

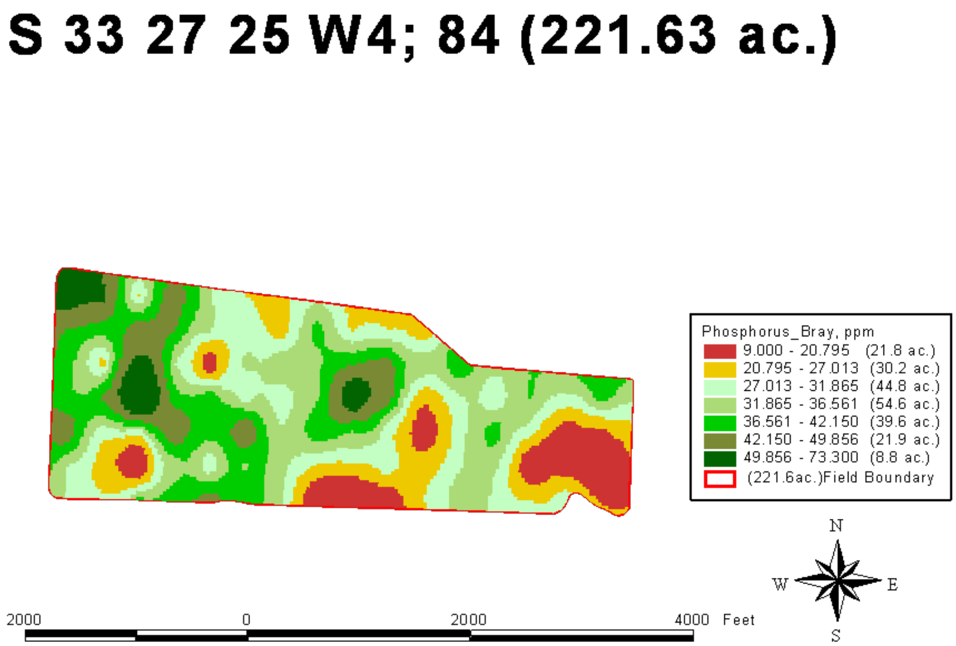

Fig. 4. Available phosphorus, ppm, topsoil.

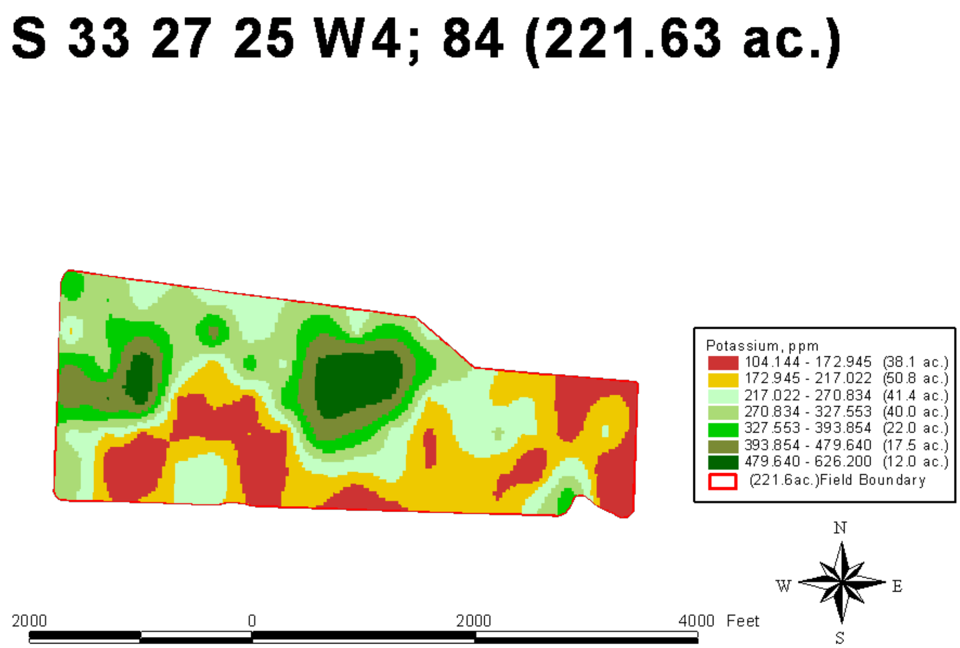

Fig. 5. Potassium, ppm, topsoil.

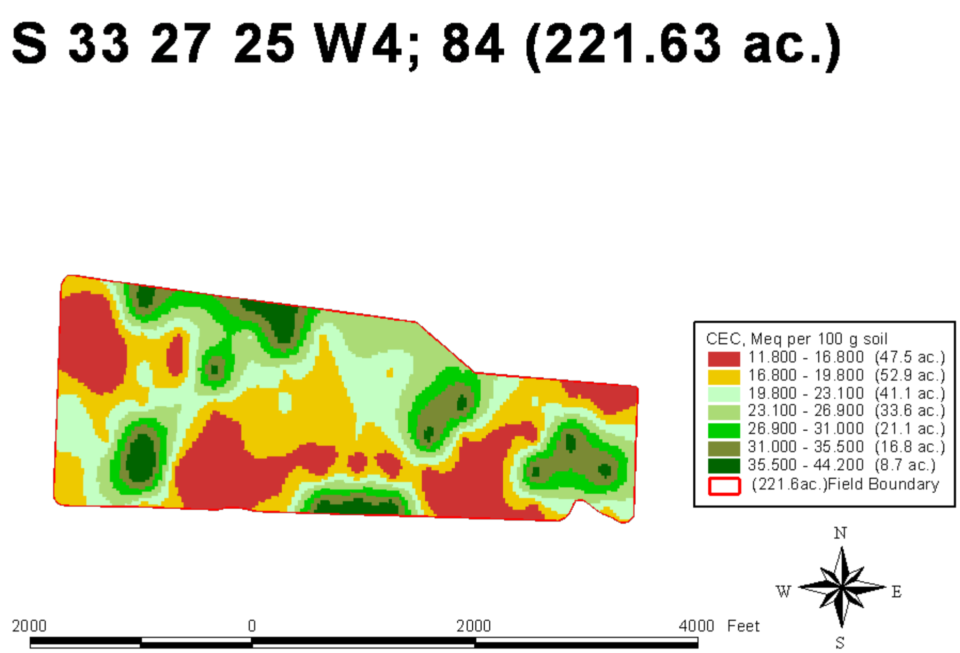

Fig. 6. Cation exchange capacity (CEC), meq/100 g soil, topsoil.

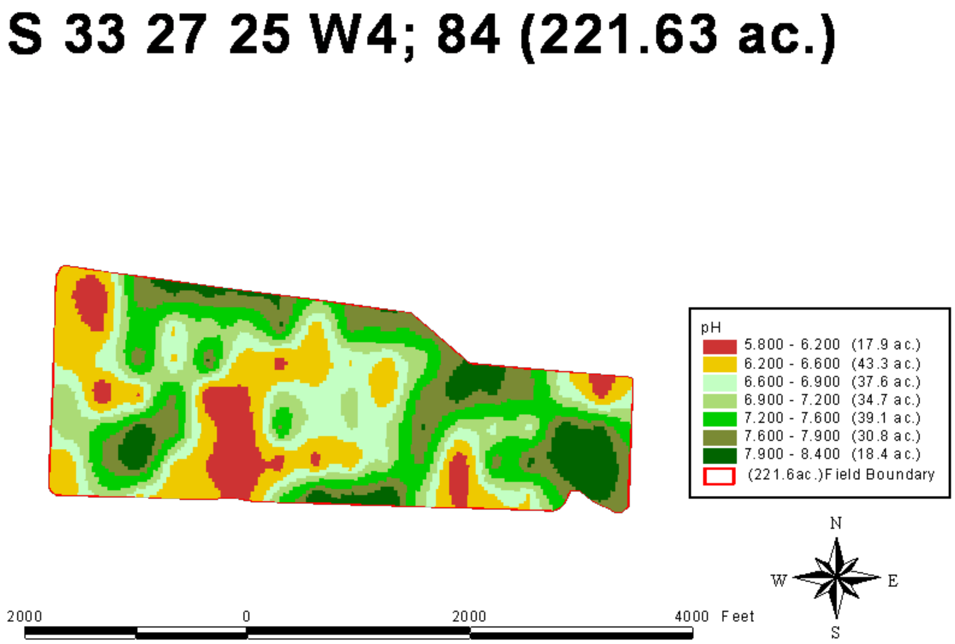

Fig. 7. Soil pH, topsoil.

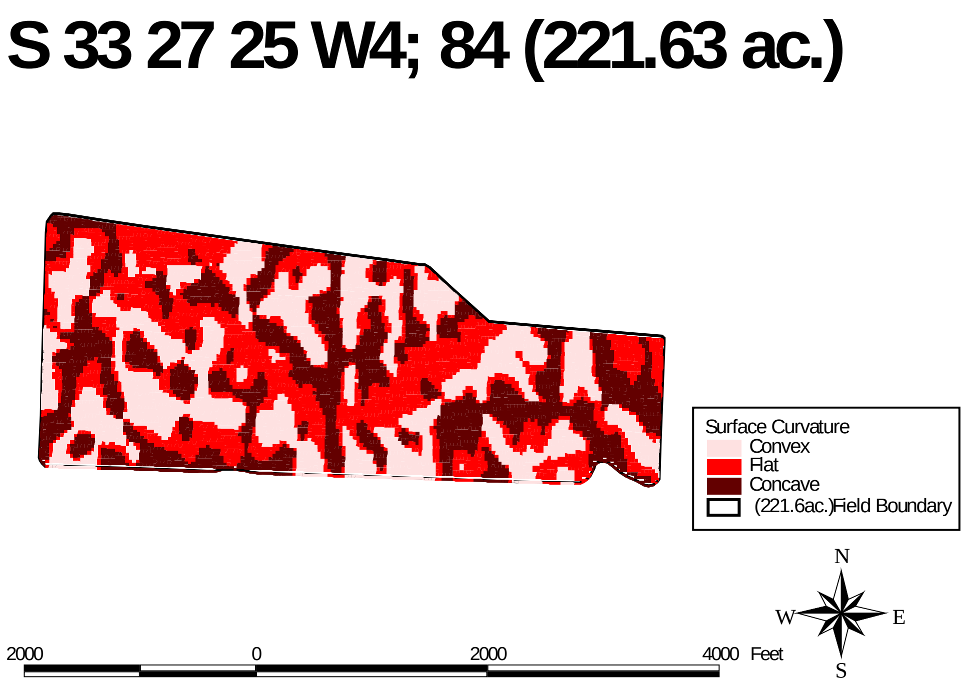

Fig. 8. Field surface curvature.

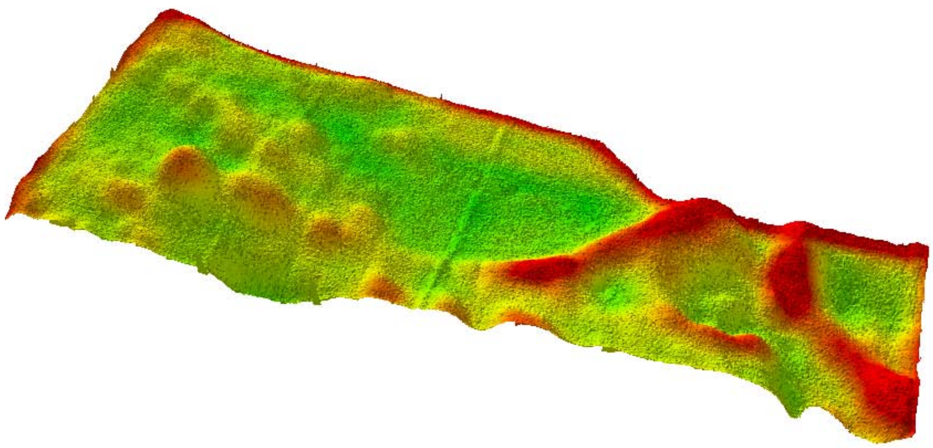

Fig. 9. NDVI image in 3D.

Visual analysis of the maps indicated that the distribution of green biomass in the field was very similar to the contours of soil organic matter and field surface curvature. In the conditions of Alberta, field surface curvature is the principal factor determining soil properties including soil organic matter and moisture. Correlation analysis indicated that soil organic matter content in the topsoil had the highest correlation with NDVI (Table 1). Another characteristic moderately correlated with NDVI was potassium. It is typical for Canadian Prairies, where farmers often did not consider application of potassium fertilizer to be important. As a result, this element became one of the main yield limiting factors in this area. Surprisingly, correlation coefficient between nitrogen and NDVI was considerably lower – 0.37 only. Also, there was no linear relationship found between cation exchange capacity (CEC) and NDVI (r= -0.03). It showed that ability of soil to hold cation nutrients were less important than the ability to hold the moisture. As expected, phosphorus was not determined to be among the factors highly correlated with the green biomass.

Table 1. Correlation between Normalized Difference Vegetation Index (NDVI) and soil characteristics, 2009.

	NDVI	*OM*	*CEC*	*PH*	*SALT*	*P1*	*K*	*CA*	*MG*	*S*	*NO3N*
NDVI	1.00										
OM	0.64	1.00									
CEC	-0.03	-0.09	1.00								
PH	-0.15	-0.28	0.77	1.00							
SALT	0.38	0.54	0.46	0.33	1.00						
P1	0.14	0.34	-0.53	-0.55	-0.11	1.00					

K	0.51	0.69	-0.17	-0.23	0.34	0.56	1.00				
CA	-0.12	-0.21	0.98	0.85	0.42	-0.58	-0.25	1.00			
MG	0.32	0.39	0.61	0.42	0.52	-0.26	0.19	0.50	1.00		
S	0.34	0.47	0.38	0.23	0.76	-0.14	0.22	0.33	0.52	1.00	
NO3N	0.37	0.57	0.08	0.04	0.81	0.17	0.46	0.05	0.24	0.37	1.00

It is also interesting to note that the correlation between the concentration of soluble salts in the soil and vegetation index was moderate to weak (r = 0.38). Together with no linear relationship between CEC and green biomass, it bears an assumption that using electrical conductivity (EC) mapping for delineation of management zones will not be a good tool to delineate accurate management zones.

CONCLUSION

Soil moisture appears to be the main factor limiting yield in the conditions of Southern Alberta. This characteristic is strongly influenced by field surface curvature and closely related to the soil organic matter. Lack of potassium in soil is also important because of the local farming practices. Nitrogen remains the most important nutrient, however, the ability of plants to uptake it is limited by the moisture.