Analyzing Color Infrared Aerial Photographs for the Delineation of Management Units in Site-Specific Agricultural Management

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Abstract

This poster addresses the potential of a color infrared aerial photograph to provide spatially distributed information for site specific management. In this process digitized color infrared aerial photographs were used to extract vegetation index information. Crop and soil information were obtained through field sampling. Most important factors for affecting crop productivity were determined using principal component analysis. Point information were interpolated using kriging to create grid surface of the study area. Centroid of each grid cell was used to collect crop and soil information, and vegetation index at a regular interval throughout the study area. Fuzzy k-means with extra-grades algorithms were used to delineate potential within-field management units based on soil and crop information and vegetation index separately. Within-zone grain yield variation were calculated and used to evaluate management zones. The methodology is fast, can be easily automated in commercially available GIS software and has considerable advantages when comparing to other methods for delineating within-field management zones.

Introduction

Site-Specific agricultural management involve collection and control of agronomic information to supply actual needs to parts of fields rather than average needs to whole fields. Past research has revealed the importance of considering additional site characteristics that exert a major influence on crop yield. The additional information needed for better management can come from extensive soil sampling using a dense grid sampling procedure which are costly and time consuming.

Agricultural remote sensing involving crops and soils is extremely complex because of the dynamic nature and inherent complexity of biological materials and soils, yet remote sensing technology offers numerous advantages over traditional methods of extracting soils and crops related information by the virtue of it's cost effectiveness and easy and timely data collection and analysis over a large area. Because of the continuous nature of soils data, classification systems that allow any one observation to belong to exactly one class are often inappropriate. Fuzzy or continuous classification procedures were developed to use in situations where class boundaries are not, nor can they be, sharply defined.

For site-specific management, careful consideration of the likely management operation or agrichemical input(s) to be employed is needed in order to determine the procedure of how to divide a field into different management zones. Once the management units are determined, each zone should represent a unique combination of potential yield-limiting factors for which we can improve the site-specific management prescription. Relative to management dependent on soil/landscape variation, the question considered here is “how should different management zones be determined?”

Objectives

The primary objective of this research was to evaluate if data obtained from scanned aerial-infrared color photographs can be used to predict and map variation of wheat grain yield within a managed field.

The second objective was to compare management units delineated using information extracted from photograph and information gathered through intensive-sampling. An important aspect of this work was to ensure that observed spatial patterns in crop productivity were consistent.

Materials and Methods:

Description of Study Area

The study site is near highway 13, 11 Km. NE of Shaunavon (NE10-09-18w3). A color infrared aerial photograph (Figure 1) of this area was taken in 21st August 2000.

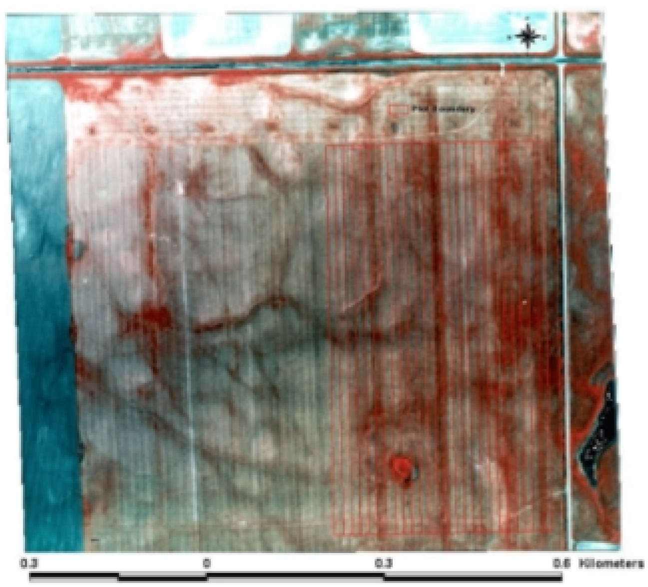

Figure1: Color Infrared Photograph of the study area.

The field was planted with spring wheat under uniform fertilization. Each plot inside the study area (bounded by red polygon) received different amount of fertilizer in previous year (i.e. from 1997 to 1999). Darker red pigmentation on the photograph is the indication of more green vegetation. Topographically the area is more undulated as shown in Figure 2 below. 3D image of both study area is based on the elevation information obtained from the ground control points using geographic positioning systems(GPS).

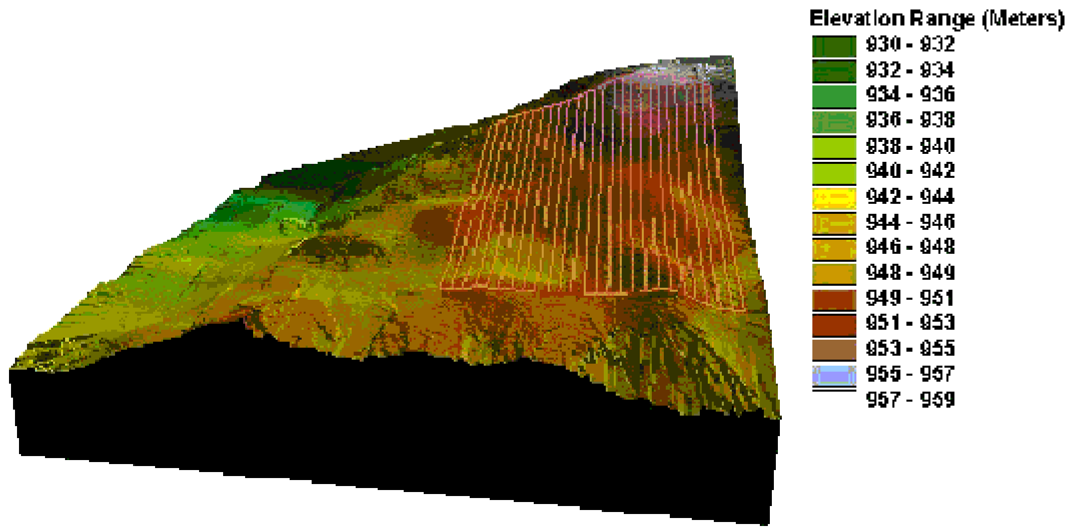

Figure 2. Topography of the study area.

Topographic, crop and soil information were collected using following sources:

-Color infrared aerial photographs local Infrared Air Photo Services.
-Elevation information field survey using global positioning system.
-Crop and Soil information Field survey.

Once the data were collected, they are further processed using following:

-Scanned aerial photographs at 600 dpi using flat bed scanner.
-Georeferenced digital image data.
-Extracted vegetation index using red and green band (Figure 3).
(We have used a distance-based vegetation index "Modified Soil Adjusted Vegetation Index 2" suggested by Qi et al. (1994) which uses an inductive soil adjustment factor (Eastman 1999).)
-Soil and topographical data interpolated to cover the study area using Kriging.
-Extracted soil, crop, topographical and vegetation index information for evenly spaced (1m) sample points over the study area.
-Delineated area behaving differently using first vegetation index information using "Fuzzy K-means with Extra-grades".
-Identified important soil, crop and topographical attributes using principal component analysis.
-Delineate area behaving differently using important attributes identified by Principal Component analysis with the help of "Fuzzy K-means with Extra-grades".
-Calculated average grain yield within each zone.
-Determined the optimum number of zones based on yield analysis using yield variance reduction criteria.

Results and Discussion

The vegetation index shows both within and between plots variation. The soil and crop information collected in the study site were first analyzed using "principal component analysis" to identify most important variables describing the total variation in a data set. Hence, rather than substituting the principal components for the original variables, we selected a set of variables that have high correlation with the major principal components. These point information were used to create grid surface for the study area using kriging interpolation (Figure 4 to Figure 8). Landscape position were delineated using ARC/INFO 7.2.1 which calculates slope position from valley floor to ridge.

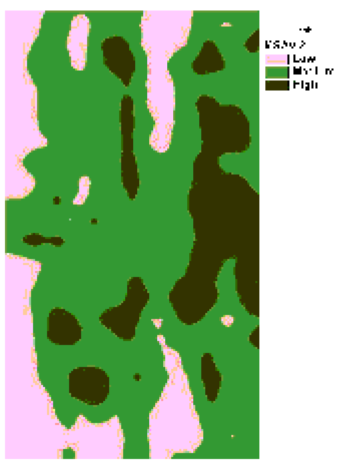

Figure 3. MSAVI2

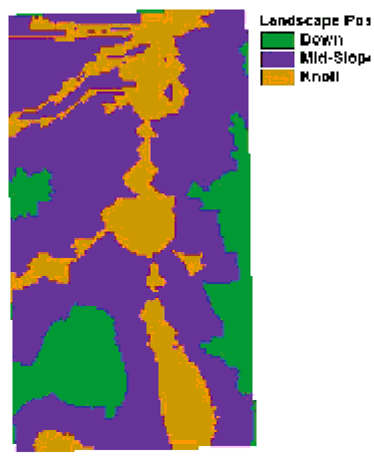

Figure 4. Landscape Position

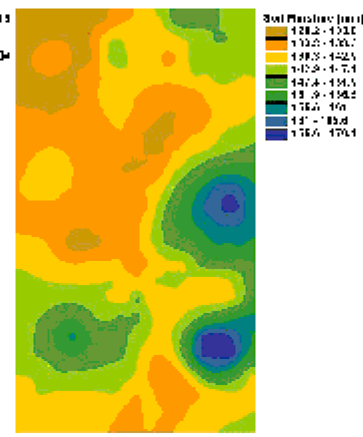

Figure 5. Soil Moisture

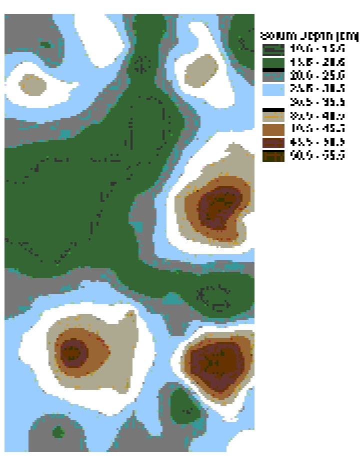

Figure 6. Solum Depth

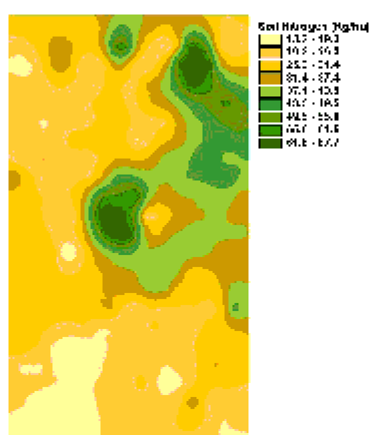

Figure 7. Soil Nitrogen

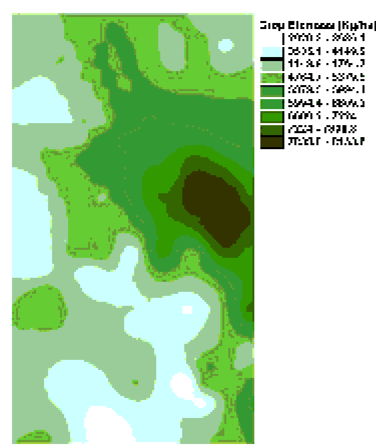

Figure 8. Crop Biomass

Grain yield measurements were obtained using a combine and hand sampling. Mid position of combined area (may be several within each plot based on the landscape position) and mid point of hand sampled area (1 sq m) were noted. A grid surface was generated using kriging from these point sample information for field 2. Grid surface of the field 2 reveals the yield pattern of the crop (Figure 9), which shows variation within and between experimental plots. Once the yield information is collected correlation between vegetation index and yield were calculated (Table 1).

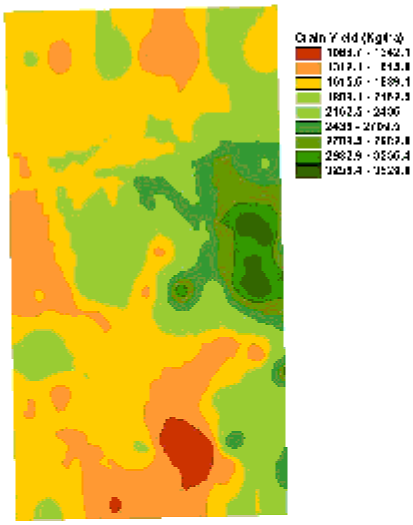

Figure 9. Crop Yield

Table 1. Pearson Correlation Matrix (Year 2000)

	MSAVI2	Land_pos	Solum Depth	Biomass	Soil H2O	Soil N
MSAVI2	1	-0.304	0.338	0.456	0.45	0.352
Land Position	-0.304	1	-0.347	-0.081	-0.39	0.079
Solum Depth	0.338	-0.347	1	0.223	0.771	0.078
Biomass	0.456	-0.081	0.223	1	0.373	0.416
Soil H2O	0.45	-0.39	0.771	0.373	1	0.101
Soil Nitrogen	0.352	0.079	0.078	0.416	0.101	1
Yield	0.521	-0.212	0.336	0.862	0.495	0.432

Clustering

The unsupervised classification procedure was used to delineate management zones in field 2 beginning with two zones and further dividing the field into maximum of twelve zones. As the number of zones increases, less pronounced and possibly less interpretable features were included. Figure 10 and 11 show the location of each management zone when the area was divided into six zone using vegetation index and crop and soil information respectively. Based on the reduction in the yield variance, optimal number of management zones were selected.

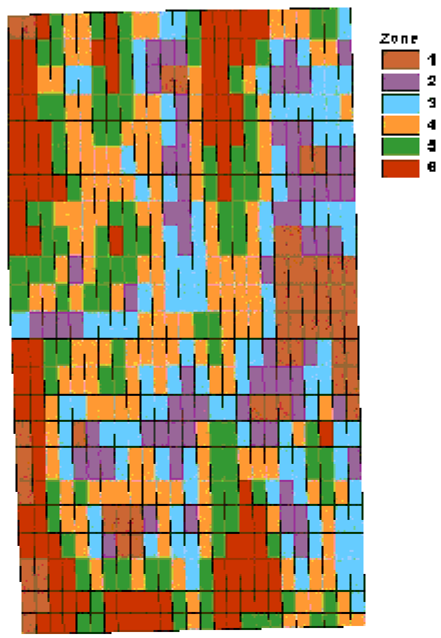

Figure 10. Zone using VI

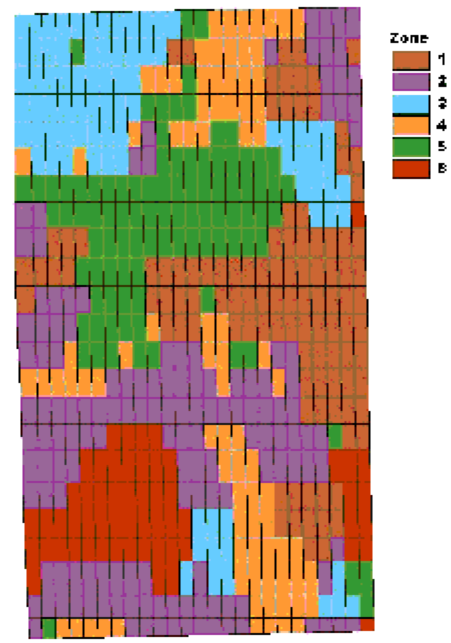

Figure 11. Zone using Soil & Crop Info.

There was 28.8% of total variance reduction when the area was divided into six zone using vegetation index (Figure 12) and the variance reduction was 35% when the area was divided into six zones using crop and soil information from intensive sampling which shows the usefulness of information obtained from CIR aerial photographs.

Once the optimal management zones are identified agriculture inputs prescription for each management zone will be calculated based on the past agriculture input treatment trials. Appropriate level of input prescription should based on the productivity of the zone, cost of the input and benefit of applying the recommended amount. Such decision are more of a management problem.

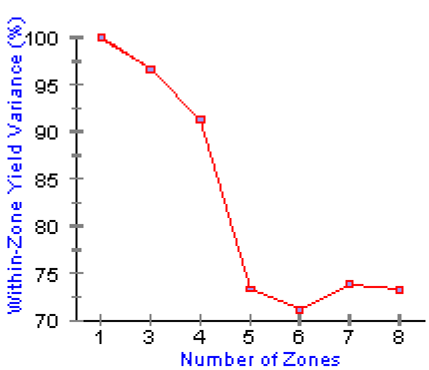

Figure 12. Optimal management Zone verification

References

Eastman, R.J. 1999. Guide to GIS & Image Processing Vol2. Clarke Labs, Clarke University, Worcester, MA, USA.

Acknowledgments

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