Zoning of an Agricultural Field Accounting for the Significances of Parameters Affecting Productivity

H. Allen Torbert¹, D. A. Kurtener², E. D. Krueger³

¹USDA-ARS National Soil Dynamics Laboratory, Auburn, AL, USA
²European Agrophysical Institute, Amriswil, Switzerland
³Insight Global, Greenwood Village, CO, USA

Correspondence: H. Allen Torbert, USDA-ARS National Soil Dynamics Laboratory, 411 S. Donahue Dr., Auburn, AL 36832, phone: (334) 844-3979, fax: (334) 887-8597, e-mail: allen.torbert@ars.usda.gov

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Abstract

Precision farming technology depends on accurate zoning of agricultural fields so that proper management applications can be imposed. Many existing methods for zoning of agricultural fields are based on the use of complex parameters, which includes both topographic yield data and soil characteristics. Utilization of these methods is dependent on relating the assessment of the significance of each of these parameters to the productivity of specific zones found in the field. In this paper, a new method for assessing the significance of the parameters affecting productivity is elaborated in combination with existing method for zoning of agricultural fields.

Keywords: zoning of agricultural field, fuzzy indicator, multi-attributive decision-making

1. Introduction

Zoning of agricultural fields is an important task for utilization of precision farming methods in production (Tou & Gonzalez, 1974; Fraisse et al., 1999; Fridgen, 2000; Pilesjo et al., 2000; Stafford et al., 1999; Mitchell 1999). Modern technologies allow data to be obtained for yield and other parameters affecting plant productivity, which is geographically referenced. This provides a basis for zoning of agricultural field which are to be management with precision forming methods.

A Review of the literature shows that the development of methods for the identification of areas with quasi homogeneous productivity of crops is carried out mainly in two ways. One method is to use methods of data processing of crop yield monitoring and mapping alone (Yakushev et al., 2007). In second method, complex parameters, which include both topographically referenced yield data and soil characteristics, are used for zoning of agricultural fields (Fridgena, 2004; Kurtener et al., 2011, 2013; Kurtener, & Yakushev, 2014).

Utilization of the second method requires the assessment of the significance of each of these parameters. A review of the literature shows that this question has been insufficiently studied.

In this paper, a method for assessing the significance of various parameters affecting crop productivity is elaborated in combination with the existing methods of agricultural field zoning (Kurtener et al., 2011, 2013). The theoretical considerations are illustrated using data collected from a precision agriculture study in central Texas, USA (Torbert et al., 2000).

2. Material and Method

In recent years, methods for zoning of agricultural fields using a fuzzy indicator model have been developed (Kurtener et al., 2011, 2013). In the framework of this method, the significance of various parameters affecting productivity is evaluated by an expert panel. Defining the significance of various parameters affecting crop productivity is a very difficult task and it is possible that an agreement between members of expert panel on the the significance aof any given paratmeter is disputed. For the resolution of this problem, it is suggested that the combining of the existed method with a tool for multi-attributive decision-making would be beneficial. In this case, the expert opinions are formulated as several alternatives, and an optimal alternative is defined using the tool for multi-attributive decision-making. A chart illustrating how the combination of the developed method (Kurtener et al., 2011, 2013) with a tool for multi-attributive decision-making could work is shown in figure 1.

Generally, different existed tools for comparison of alternatives can be use. In this work, we applied a tool for fuzzy multi attributive comparison of alternatives (Kurtener et al., 2010). The tool creates: a) normalized decision matrix, b) relative weights of attributives, c) target functions, and d) ranking alternatives. An absolute value deviation/distance of each alternative from the ideal alternative is used as a measure for choosing the optimal alternative. In this method, experts can define their own opinions about the significance of parameters determining productivity in numerical forms, or
as linguistic propositions. It should be noted that with this developed method (Kurtener et al., 2011, 2013) it is postulated that at within an agricultural field all zones with the different levels of productivity exist, but with different grades. The value of the grade is estimated with fuzzy indicators, which range from zero to one.

3. Results and Discussion

Following the procedures outlined by Kurtener et al. (2011, 2013), we used data from an experiment carried out on an agricultural field located in North Bell County, TX on the Elm Creek watershed (Torbert et al., 2000). Preliminary analysis of the experimental data showed that the experimental field was relatively homogeneous. Nevertheless, it two zones can distinguish with the medium productivity (Z 1) and good productivity (Z 2). For defining these zones, we selected 4 parameters: grain yield (Y), total carbon (C), total nitrogen (N), and available phosphorus (P) (Table 1).

![Chart](image.png)

Fig. 1. Chart, illustrating how the combination of the existed method with a tool for multi-attributive decision-making potentially works.

<table>
<thead>
<tr>
<th>Zones</th>
<th>Parameters affecting to the productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone with the medium</td>
<td>Total C, %</td>
</tr>
<tr>
<td>productivity (Z 1)</td>
<td>1.5 – 2.4</td>
</tr>
<tr>
<td>Zone with the good</td>
<td>2.41 – 3.5</td>
</tr>
<tr>
<td>productivity (Z 2)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Zoning of agricultural field.
In this case, we applied the developed method for defining zones with different levels of productivity (Kurtener et al., 2011, 2013) in the field where there was a dispute regarding the importance of the parameters that determine the productivity. Also, we assumed that a discussion by a four member expert panel resulted in four different alternatives being formulated. The first alternative (index as alternative 1) reflected the case when there was agreement between the experts. The other alternatives (index as alternatives 1, 2 and 3) reflected cases, when there was disagreement between the experts.

Table 2. Brief description of alternatives.

<table>
<thead>
<tr>
<th>Index of alternative</th>
<th>Assessment of experts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Application of the tool for fuzzy multi attributive comparison of alternatives (Kurtener et al., 2010) gave the relative weights of attributives, the target functions, and the rank of alternatives (Table 3). Results presented in Table 3 indicate that alternative 3 was the best. The second best alternative was alternative 2. Alternative 1 (the case where there was agreement between experts) was the worst.
Table 3. Outputs of multi-attribute analysis.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>The relative weights of attributives</th>
<th>The target functions</th>
<th>Rank of alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.084005</td>
<td>0.067513</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>0.164650</td>
<td>0.020174</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0.597371</td>
<td>0.003177</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0.153973</td>
<td>0.04305</td>
<td>3</td>
</tr>
</tbody>
</table>

The zones with the medium and good productivity for the special case described by alternative 3 are defined using the method developed by Kurtener et al. (2011, 2013) and are shown in figures 2 and 3. The zones with medium and good productivity for the special case described by alternative 1 are shown in figures 4 and 5. The calculations were carried out utilizing MATLAB (http://www.mathworks.com/).

Comparing figure 2 with 4 and figure 3 with 5, it can be easily observed that the expert assessment of the significance of parameters affecting productivity can significantly affect the zone boundaries.

4. Conclusion

Many existing methods for zoning of agricultural fields are based on the use of complex parameters, which include both topographic yield data and soil characteristics. Utilization of these methods requires relating the assessment of the significance of each of these parameters to productivity. In this paper, the assessment of these parameters was carried out using an expert panel, but with several alternatives of the expert opinions formulated. An optimal alternative was defined using the tool for fuzzy multi-attributive comparison of alternatives as defined by Kurtener et al., (2010). In this study, we also combined this tool with the existing method defined by Kurtener et al., (2011, 2013). This approach was illustrated using data collected from a precision agriculture study in central Texas, USA (Torbert et al., 2000). The results of the calculations showed that the expert assessment of the significance of the parameters affecting productivity can significantly affect the boundaries of zones found in an agriculture field to be used for precision agriculture practices.
Fig. 2. Combined fuzzy indicator (CFI) describing within agricultural field area with a medium level of productivity (case, described by alternative 3).

Fig. 3. Combined fuzzy indicator (CFI) describing within agricultural field area with a high level of productivity.
Fig. 4. Combined fuzzy indicator (CFI) describing within agricultural field area with a medium level of productivity (case, described by alternative 3).

Fig. 5. Combined fuzzy indicator (CFI) describing within agricultural field area with a high level of productivity (case, described by alternative 3).
References


