Using GIS to map soil organic matter and nitrogen content to prevent cultivation effects on soil quality

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Abstract

Human activates such as tillage and cultivation practices along with low organic matter have been led to soil degradation, compaction and increasing its erosion. Sustainable and precise soil management is one of approaches to prevent these problems. This study was aimed to investigate the relationship among different soil characters alike soil organic matter and nitrogen content with fertilizer demand. These information could be useful to reduce cultivation practices. Our results indicated that because of non-uniformity in measured soil characters, fertilizer demand also is completely different. Therefore GIS as an approach could be useful for precise management of soil fertility and consequently soil cultivation practices.To do this, reclassified maps of organic matter and nitrogen content were provided by using Digital Elevation Model and the gap of aforementioned characters with recommended values were calculated. These gaps were used pixel by pixel to provide fertilizer demand maps. These maps are fruitful guidelines to sustain soil as the main component of agroecosystems. In this study, spatial analyst tools, procedures and function were used to interpolate and reclassify the raster maps. Organic matter changed from <1 to 5% and nitrogen content was less than 0.14 ppm. Our results indicated that for precise management of soil cultivation, the practices intensity should be adjusted based on soil physiochemical characters to maintain high-quality zones and improve low-quality ones.

Keywords: Organic matter, Soil structure, Nitrogen content, GIS maps.

Introduction

High and sustainable crop production is linked to improved soil physical, chemical and biological properties, which in turn are a primary function of soil organic matter. Conversion of natural ecosystems to agriculture as well as increasing intensity of tillage are known to decrease soil organic matter (SOM) levels and contribute significantly to the increase in atmospheric CO_2 concentration (Lal et al., 1998). Human activates such as tillage and cultivation practices along with low organic matter have been led to soil degradation, compaction and increasing its erosion. Sustainable and precise soil management is one of approaches to prevent these problems. Management practices that simultaneously improve soil properties and yield are crucial to sustain high crop production and minimize detrimental impact on the environment. Management options such as no-tillage (NT) (Saffigna et al., 1989; Halvorson et al., 2002), choice of crops in a rotation and rotation length (Havlin et al., 1990; Janzen et al., 1992; Soon and Arshad, 1996), and adequate fertilization (Nyborg et al., 1995b) can be used to enhance level of organic matter in soil, which might offset the potentially negative impact of residue removal. Because of the increased awareness of environmental impacts of soil C and N loss, there is a need for reliable monitoring instruments.

Technological development in positioning, sensing and control system has opened a new era, in which traditional agricultural practices are left behind. Precision farming is a term used to describe the management of variability within a field, applying agronomic inputs in the right place, at the right time and in the right quantity to improve the economic efficiency and diminish the adverse environmental impact of crop production (Earl et al., 2000). Study and understanding of the soil spatial variability is very important as soil variability causes crops yield to be distributed unevenly in a field (Liu et al., 1999). The first step in addressing the problems caused by soil variability is to develop a Site Specific Crop Management program (SSCM) to help improve soil quality through practical and economically efficient treatments. Some of suitable tools that can provide the necessary facilities in the basis of soil fertility management are nutrients classification maps that provided with using from statistical techniques in environment Geographic Information System

(GIS). Fertility maps are useful for identifying soil sources. These maps is based on fertilizer recommendations, monitoring changes soil nutrition, and one important tools that predicted deficiency or toxicity of nutrients in the soil. According to role effective of soil fertility in modern agriculture, providing soil fertility maps for better planning for the use of chemical fertilizers is more necessary. This study was carried out to determine organic matter and nitrogen content in a raster layer to assess precise deficiency values, and so provide fertilizer demand maps.

Material and methods

This study was carried out in Research field of Gorgon University of Agricultural Science and Natural Resources, Iran which is situated at $36^{\circ}82$ N latitude, $54^{\circ}32$ E longitude, at an altitude of 13 m above mean sea level and with 85102 m^2 area. For this purpose the field border was determined using global positioning system (GPS), and 51 points were identified in that by 25m × 100m distance grid cells throughout the felid. To determine nitrogen and organic matter content sampling was done from 30 cm soil depth. Reclassified maps of organic matter and nitrogen content were provided by using Digital Elevation Model (DEM) and the gap of aforementioned characters with recommended values were calculated. These gaps were used pixel by pixel to provide fertilizer demand maps. spatial analyst tools, procedures and function were used to interpolate and reclassify the raster maps, Spline (Sp) and Inverse Distance Weight (IDW) method was used to interpolate nutrient contents. Nitrogen content were measured by Kejeldal method and organic matter measured by Weakly Black method. Field border and sampling points are presented in Fig.1.

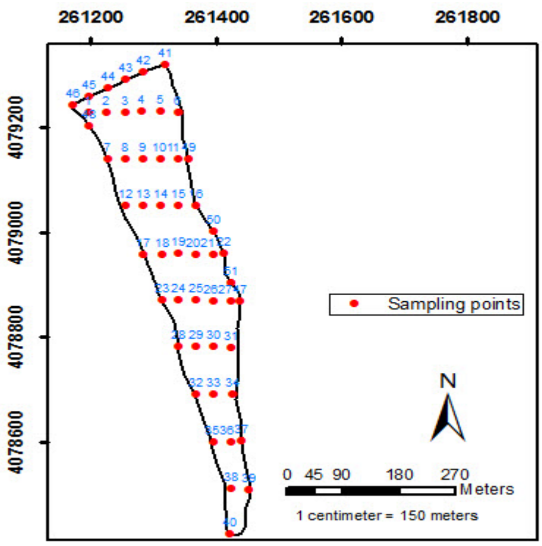

Fig.1. Field border and sampling points position.

Results

In this research, Spline (Sp) and Inverse Distance Weighted (IDW) as two interpolation methods were used to evaluate nitrogen (N) and organic matter (OM). Our results showed that both of them are suitable methods, this was obtained by comparing actual data whit interpolation values, but Observed against predicted values revealed that IDW interpolation method was superior than Sp method (RMSE=0.016), however Sp method also has reasonable outputs. Field nitrogen variability was interpolated between 0.071-0.14 and 0.001-0.13 ppm base on Sp and IDW methods, respectively (Fig. 2).

Reclassifying of nitrogen maps is not impossible in general, due to different response thresholds of different crops.

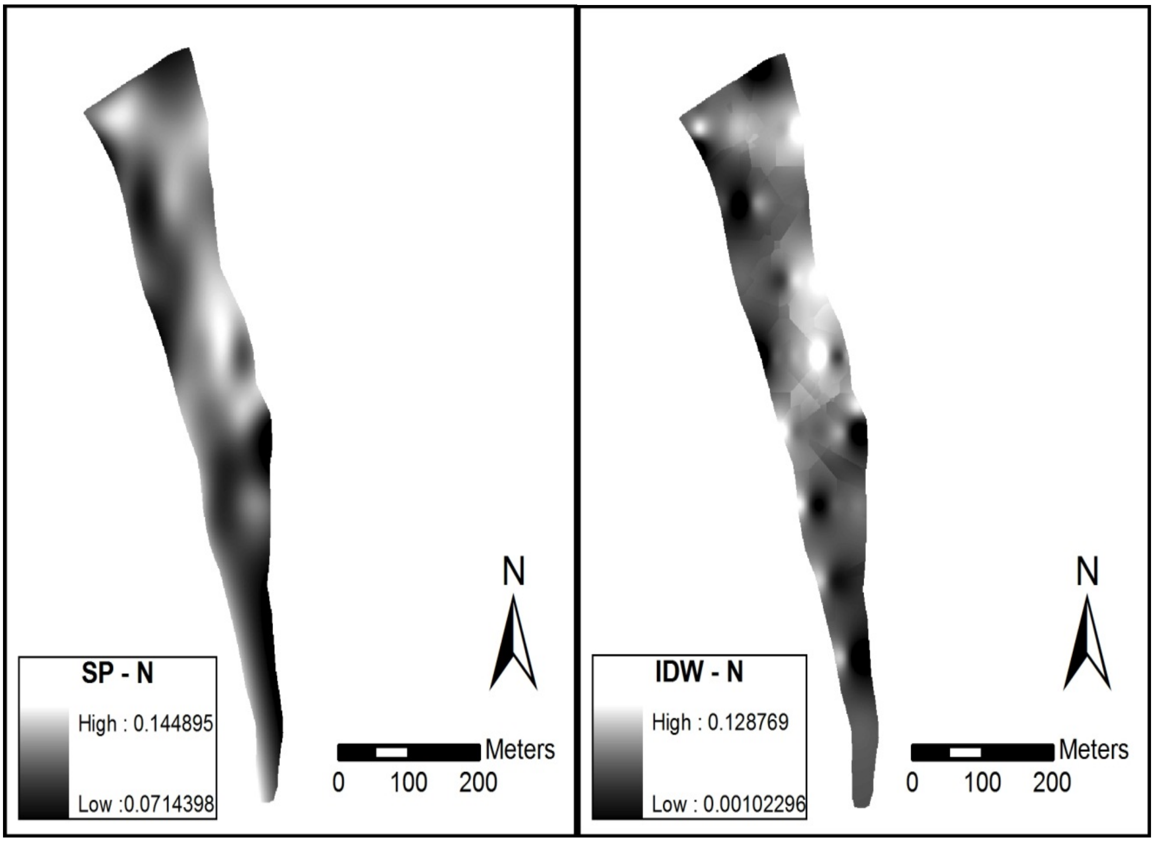

Fig. 2. Nitrogen variability in studied field base on Sp and IDW interpolation methods.

Interpolated Field organic matter varied between 0.17-5.18% and 0.47–5.17% base on Sp and IDW methods, respectively (Fig. 3). To reclassify organic matter maps and determine favorable and unfavorable areas, plant response threshold to organic matter range for plants, classified as Sp ranged from o.17-2 and 2-5.19, and as IDW ranged from 0.47-2 and 2-5.17. The results showed that are presented in Fig. 4. Generally organic matter changed from <1 to 5% and nitrogen content was less than 0.14 ppm.

Our result indicated that favorable and unfavorable zones areas were as 84461 and 652 m^2, respectively. This expressed that major part of field is suitable for plants cultivation, approximately. According to this results for precise management of soil cultivation, the practices intensity should be adjusted based on soil physiochemical characters to maintain high-quality zones and improve low-quality ones.

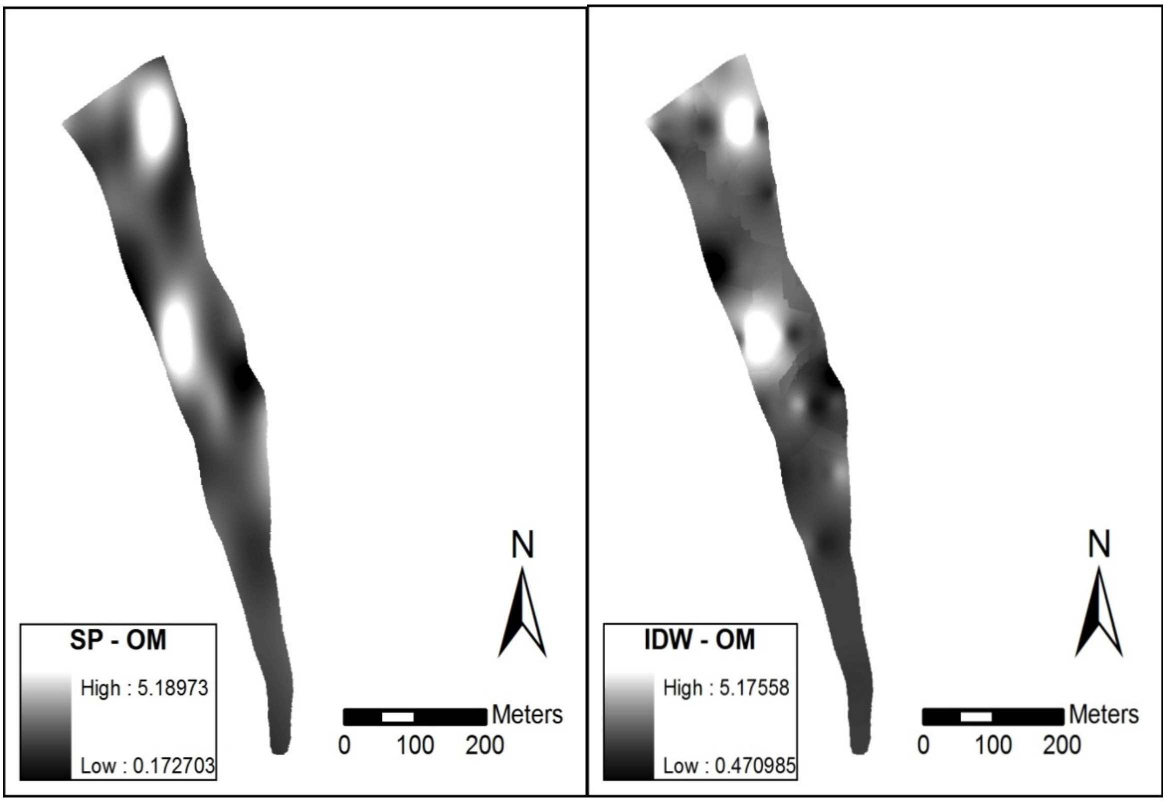

Fig. 3. Organic matter variability in studied field base on Sp and IDW interpolation methods.

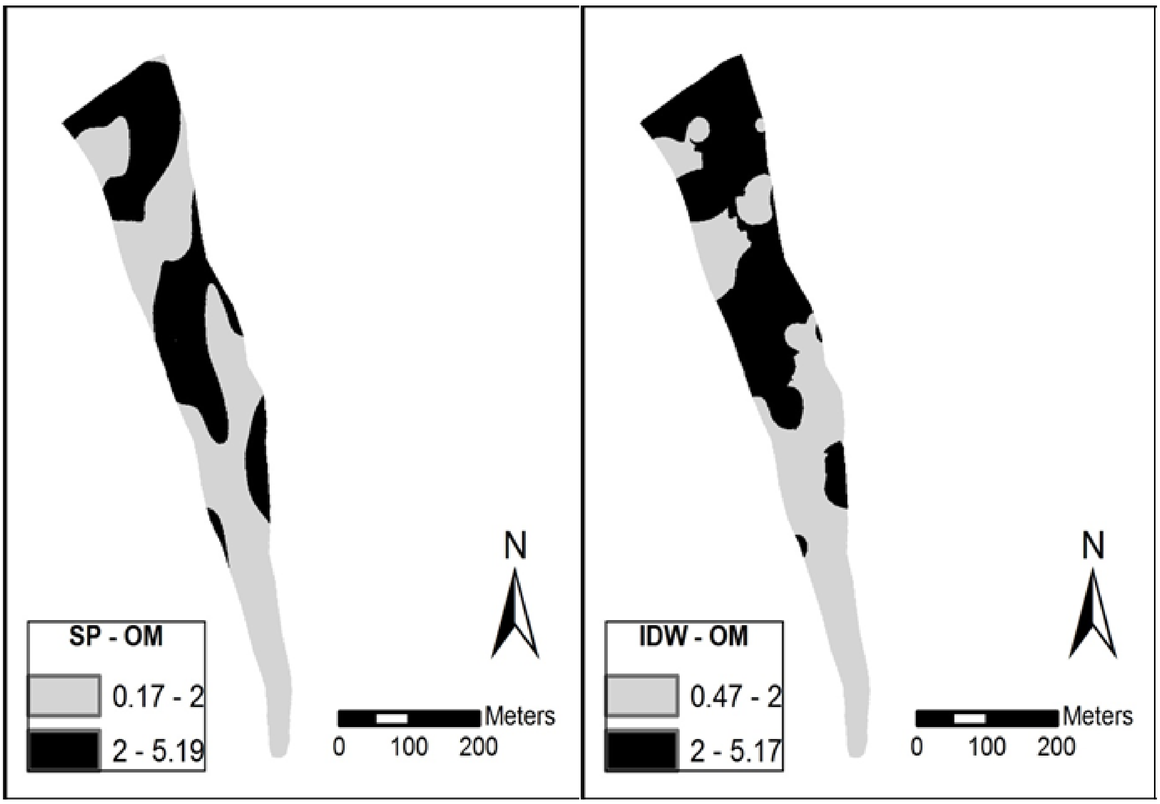

Fig. 4. Favorable and unfavorable area in respect to soil organic matter content base on Sp and IDW interpolation methods in studied ares, unfavorable (Top rang) and Favorable (Bottom rang).

Map deficiency values organic matter was prepared according to Sp and IDW methods, too. Our results showed that 18 points were less than 2% organic matter, which organic matter deficiency variability was interpolated between 1.2-1.7% and 0.11-1.5 % base on Sp and IDW methods, respectively. Fig. 5.

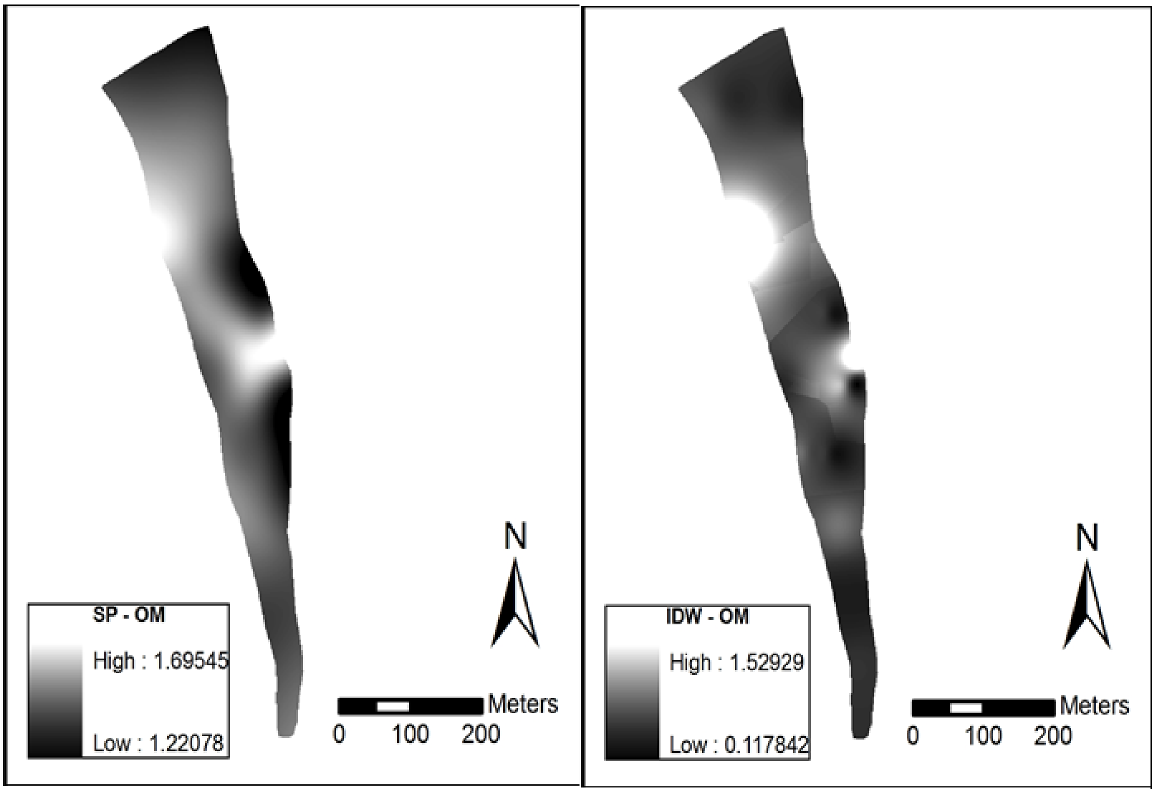

Fig. 5. Organic matter deficiency values variability in studied field base on Sp and IDW methods.

Discussion

The cause of nutrient depletion is due to the imbalance between the input and output of a soil system. Maintenance of proper nutrient status in soil is a key factor for high yield production. The inputs include nutrients in the soil profile, fertilizer application; nutrients derived from rainfall or from water apply to the crop, sediments accumulated on the soil and bio fixation. Nutrient removal from soil is due to uptake by crops, soil erosion, leaching, and volatization. The ability of soil to provide nutrients for crop production of fertility of a soil system is enhanced by systematic returns of nutrients. In order to properly manage nutrient balance of a soil system in a sustainable way it is necessary first to know availability, depletion and balance of nutrient in a soil system.

A geographic information system (GIS) is useful to produce the interpolated maps for visualization, and for raster GIS maps algebraic functions can calculate and visualize the spatial differences between the maps. These maps are fruitful guidelines to sustain soil as the main component of agroecosystems. Our results showed that because of non-uniformity in measured soil characters, fertilizer demand also is completely different. Therefore GIS as an approach could be useful for precise management of soil fertility and consequently soil cultivation practices.

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