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APPLICATION OF REMOTE SENSING TO DETERMINE SPATIAL CHANGES IN SOIL PROPERTIES AND WHEAT PRODUCTIVITY UNDER SALINITY STRESS

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Abstract

This research paper aims to investigate the geographic dissimilarity in soil salinity in a selected site in major wheat growing region (about 151 hectare). The experimental field is located in Dawar El Gabla village Sinnuris district, Fayoum governorate, Egypt, this area is subject to the effects of various soil amendments i.e. gypsum, compost and organic manure which have a significant impact on soil salinity and productivity. To reach the objective of this work top soil was sampled on 25 X 25 meter grid over an area of about 3 hectares over 3 years (2014-2016). Soil pH and EC were measured and the weight of 1000 wheat seed was also monitored. Landsat-8 imagery attained for wheat growing season (across 3 years) was used for estimating the Normalized Difference Vegetation Index (NDVI) to detect the crop status. The Spatial analysis technique was used for mapping the spatial (geographic) differences in soil pH and EC. Results indicated geographic deviations in soils and wheat response during the 3 years of study period. The weight of 1000 seed wheat increased over the years due to the decrement in soil pH and EC responded to soil amendments. The estimated NDVI values correlated with 1000 seed weight, therefore, supports that the former is noteworthy index for crop productivity.

***Keywords*:** Saline soils, Salinity Index, Spatial analyses, Wheat yield, El Fayoum governorate, Egypt.

Introduction

Salinity is a dynamic process with severe adverse influences on the soil productivity in turn, economic returns for a given agricultural production system. It is a thoughtful problem in Egypt with up to 33% of cultivated land impacted by high salinity (> 4 dSm-1) due to low precipitation (< 25 mm) and irrigation with brackish water (El-Hendawy *et al*., 2005).

Salinity is the key restrictive issue impacting plant growing and yields worldwide (Munns, 2002). The negative effects of salinity on plant growing could be associated to an increase in the osmotic potential of soil solution that shrinks available water, or increase in concentrations of certain ions that inhibit plant metabolism (Onani, 2005 and Saleh *et al*., 2015). Therefore, for implementation of efficient soil reclamation program and preventing any further salinization to sustain agricultural lands and agro-ecosystems, data on the geographic range, type and distribution of soil salinity is turning actual critical. Thus, appropriate discovery of salinity, checking and evaluation of its levels are very important for management of saline soils at large and small scales.

Wheat is the most vital cereal crop in Egypt; though, national wheat production provisions only 40% of the total request. The increment of wheat yield is a priority to uphold food security. Therefore, developing crop management alternatives is vital issue to overcome the salinity stress and hence increase total wheat production.

Mapping of soil properties is vital to maintain sustainable management of soils. Using spatial analysis permits producing thematic layers of soil properties, representing a great source of data for the land use planners. The geographic variation of soils could display the connection among soil characteristics and landforms and could be used in understanding the differences in crop yield (Ali *et al*., 2007; Darwish and Abd El-Kader, 2008). Information on spatial changes in topsoil nutrient properties becomes essential for estimating fertilizing needs on site specific basis. One method for mapping topsoil properties is to sample the investigated area by grid sampling and analyzing soil properties. Then, mapping of management zone could be created through the interpolation of measured property values of each sample by either "inverse distance weighting-IDW" or "kriging" statistical techniques (Weisz *et al*., 1995). These models assess values at non-sampled sites considering the quantities from the nearby locations with definite weights given to each of the quantities. The IDW method is calmer to perform, while "kriging" is extra time-exhaustion and cumbersome. Some studies found that "kriging" provides an additional precise explanation of the data spatial construction, and produces respected statistics about approximation of errors distributions (Leenaers *et al*., 1990 and Mueller *et al*., 2004). Satellite images are significant part in the field of monitoring the vegetation cover. Vegetation differs across land area because of difference in soil parameters which impact crop response. Crop vegetation tends to strongly absorb sunlight in red wavelength but reflects in the near-infrared wavelength. Chlorophyll ingests light in red band (0.58-0.68 microns) and recoil spectra in near infrared band (0.72-1.10 microns). Therefore, greater photosynthetic actions will consequence in lower reflectance in the red band and more recoil in the near infrared band. This signature is unique to green plants. The Normalized Difference Vegetation Index (NDVI) provides a statistics of the vegetation on the land surface. Dense vegetation shows up very strongly in the imagery which shows sharp contrast to the areas poor vegetation. Spatial and time-based differences in vegetation indices are originate to be connected to main climate, ecosystem, terrain, and soil properties. Sumfleth and Duttmann (2008) and Hansen *et al*. (2009) indicated that NDVI is one of the most main indicators of plant growth characteristics then it could be linked with the changes in soil site specific characteristics and soil productivity. The aim of this research work is to determine spatial changes in soil properties and wheat productivity under salinity stress using remote sensing.

Materials and Methods

The Study Area

Al Fayoum is a depression located west of Nile bank at 90 km from Cairo, between latitudes 29°02′ and 29°35′N and longitudes 30°23′ and 31° 05′E. the depression is coupled with the Nile by the Hawara canal, through which Bahr Yousef canal is transporting the Nile water. The main public activity in the province is agriculture. Inadequate management of the existing land resources is the reason of unsustainable development in the area. The climatic data of the investigated area (Table 1) show that the mean yearly rainfall in this region is 7.2 mm. The average minimum and maximum yearly temperatures are 14.5°C and 31.0°C, respectively (CLAC, 2014).

Most of cultivated soils in El Fayoum are deep, loam to clayey alluvial, originated mostly from the Nile flood alluvium. In addition, calcareous clayey and sandy soils are found as patches towards the depression edges (Abo El Enean, 1985; Ghabbour, 1988; Shendi, 1990). The Fayoum governorate is located in a depression of about 179,500 ha south of Cairo and 25 km west Nile River. It is a basin with sloping and rolling topography with heavy to medium-textured soils initiated basically from Nile alluvium.

Table 1 : Mean Climatic conditions in El Fayoum station during 2004 – 2014

Month	Mean temp (C°)	Max temp (C°)	Mini temp (C°)	H (%)	WS (Node)	SS (Hour)	SR (Mega Joule/m^2)	Rain (mm)	E (mm)
Jan	12.6	20.3	5.9	62	3.1	6.9	12.5	1	1.9
Feb	14.4	22.2	7.3	52	3.5	7.6	15.5	1.4	2.7
Mar	17.6	25.4	9.8	49	4.3	8.7	19.7	1.2	3.9
Apr	21.3	29.9	13.2	43	4.4	9.9	23.6	0.6	5.3
May	25	33.8	17.1	39	4.7	10.7	25.7	1	6.5
Jun	21.3	36.1	19.8	40	4.7	11.1	26.6	0	7.2
Jul	28.6	36.8	21.2	46	4.3	13.2	29.5	0	7.3
Aug	28.6	36.5	21.4	51	4.2	12.4	27.3	0	6.7
Sep	27	33.9	19.6	52	4.5	11.4	23.7	0	5.8
Oct	23.9	31.6	17.1	54	3.9	9.6	18.2	0.7	4.2
Nov	18.9	26.4	13	62	3.8	7.7	13.3	0.9	2.8
Dec	14	21.8	8.4	64	3.4	6.6	10.9	0.4	1.9

Note: H= humidity, WS wind speed, SS= sunshine, SR= sun radiation, E= evaporation

The Experimental Field

The study site occupies an area of about 151 hectares affected by salinity and cultivated with wheat (Cultivar Sakha 93). It is located in Dawar el Gabla village, Sinnuris district, Fayoum governorate (Fig. 1). The area is cultivated by small farmers traditional operating as owners, tenants, and sharecroppers, or those operating as grouping of these three roles. This area is irrigated six times per season by water combination of agricultural drainage water and Nile water.

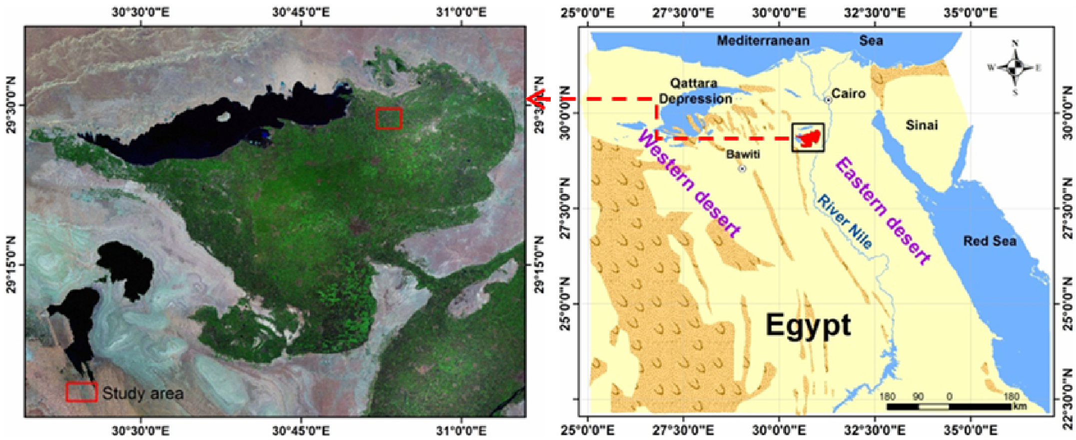

Fig. 1 : Location of the study area

Field Work and Laboratory Analyses

Surface soil samples were collected, in 3 years (2014-2016), after harvesting wheat from the selected field in 25m X 25m grid. Field experiment was conducted with soil amendments applications (e.g. gypsum, compost and organic manure) aimed to reduce salinity hazard on wheat production. Soil characteristics measured included (Klute, 1986; Cottenie *et al*., 1982): i) Soil pH in suspension of soil: water at 1:2.5; (ii) electrical conductivity (EC) of soil extract of soil: water at 1:5 ratio. Wheat response was evaluated by 1000 seed weight.

Spatial Analysis

Spatial fulfillment is usually used for creating continuous information when statistics are gathered at separate locations (e.g. grid sampling). Normal "kriging" model is an interpolation system, which weighs the nearby known values to originate estimates for an unmeasured location. The weights are depending not only on the space between the known site and the unmeasured one but also on the complete geo-statistical relations among the known points. Arc-GIS 9.2 ordinary kriging software was used to interpolate the soil properties (EC, pH) and weight of 1000 wheat seeds over the study area. The model has been used to develop the semi-variance diagram separately for each characteristics consequently, values of the soil pH, EC and wheat yield were assimilated at unknown points considering the structure of the diagrams.

Remote Sensing

Landsat-8 satellite images (path 177 / row 40) acquired during the wheat growing season in (February 2014, 2015 and 2016) were used to estimate the Normalized Difference Vegetation Index (NDVI). The NDVI present forms of vegetative growth by demonstrating the amount of photosynthesizing biomass on a land (Burgan et al., 1996). The NDVI can be estimated as follows: NDVI = (NIR - RED) / (NIR + RED) where: NIR=near infrared band and RED= red band. The equation produces records differ from –1 to 1. Negative values indicate non vegetated areas or non-reflective surfaces, while positive values denote vegetation or reflective surfaces. Values between 0.3 and 0.7 reflect the cultivated areas where the large values indicate healthy plants (Burgan and Hartford, 1993).

Results and Discussion

The soil pH and EC in the selected fields were detected and mapped during the 2014, 2015 and 2016 seasons. The corresponding wheat yield represented by 1000 seed weight for the same fields for the same period were mapped by using the spatial analysis. Figure 2 shows the changes in soil pH and EC during 2014, 2015 and 2016 seasons. The data indicate considerable differences in soil pH over the study area.

From 2014 to 2016, minimum values of soil pH decreased from 7.6 to 7.2, while maximum soil pH decreased from 8.3 to 8.0. Essential changes in soil pH were seen in 2016 especially in the southern part of the study site. In 2014, the changes in soil EC over the study site were 2.2 – 9.0 dS/m, whereas in 2016 the range was 1.4 – 4 dS/m. Most of these changes occurred in the north of the field.

The maximum values of soil EC in 2015 decreased from 9.0 to 4.0 dS/m indicating a significant impact of the applied treatments. Wheat 1000 seed weight increased with the decrease in soil pH and EC due to application of amendments (Fig. 3). Wheat yield increased from the range of 11 – 25 g /1000 seeds to the range of 46 – 74 g /1000 seeds.

Wheat yield in the salt affected area north to the field increased from 11 – 15 g /1000 seeds in 2014 to 46

– 55 g /1000 seeds in 2016. The Normalized Difference Vegetation Index (NDVI) was estimated for wheat across all three seasons (Figure 3). The data indicate that the NDVI gradually increased from 2014 to 2016 seasons which resembles to the wheat yield increase.

The NDVI in general reflect the crop health and vigor with high NDVI representing plants with high vigor. The large NDVI value was changed from 0.54 (weak plants) in 2014 season to 0.71 (good plants) in 2015 and 2016. The minimum NDVI value remained around 0.40 across all three years, but the area under low NDVI decreased from 2014 to 2016.

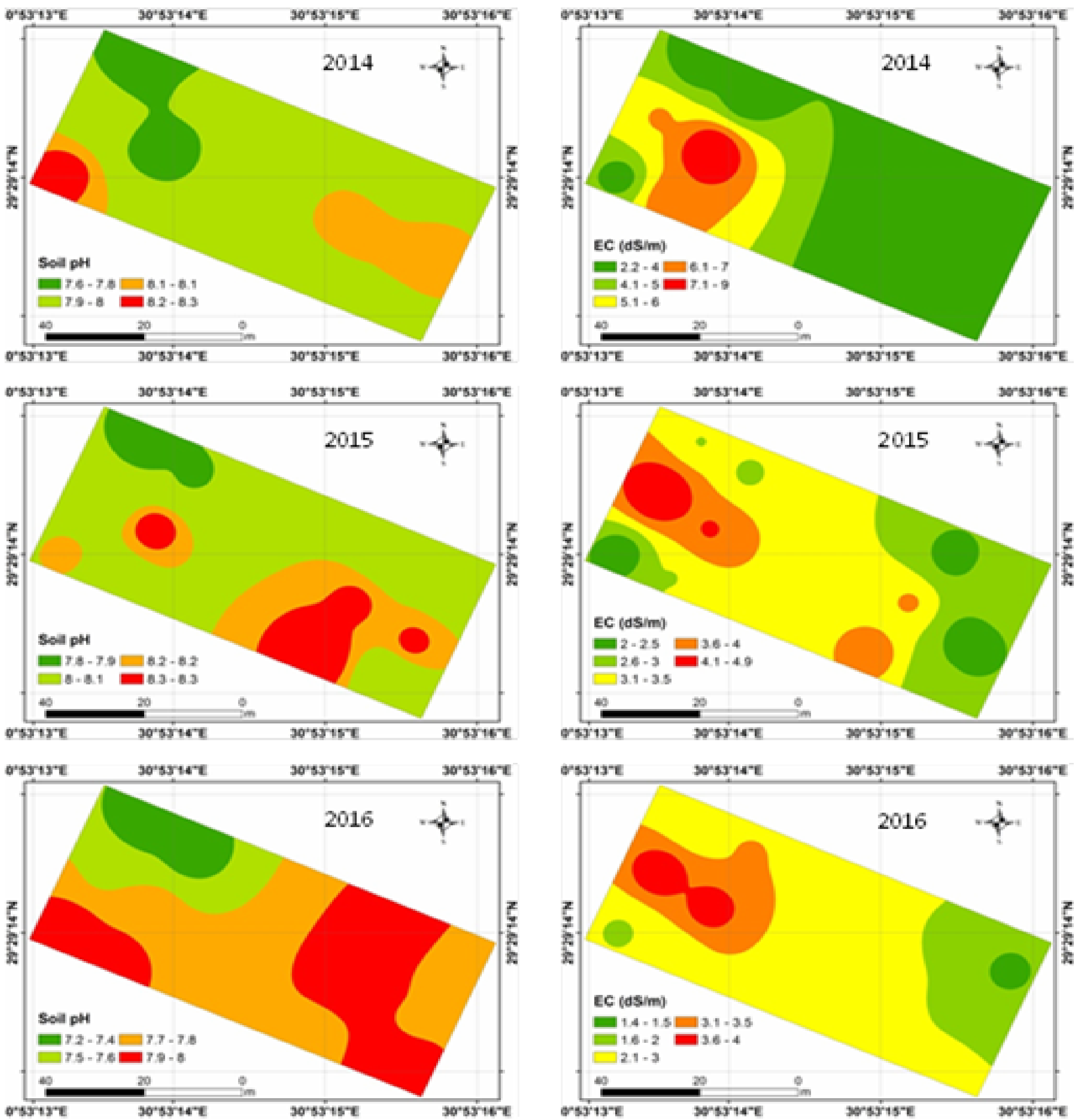

Fig. 2: Changes in soil pH and EC of the study area during 2014, 2015 and 2016 seasons

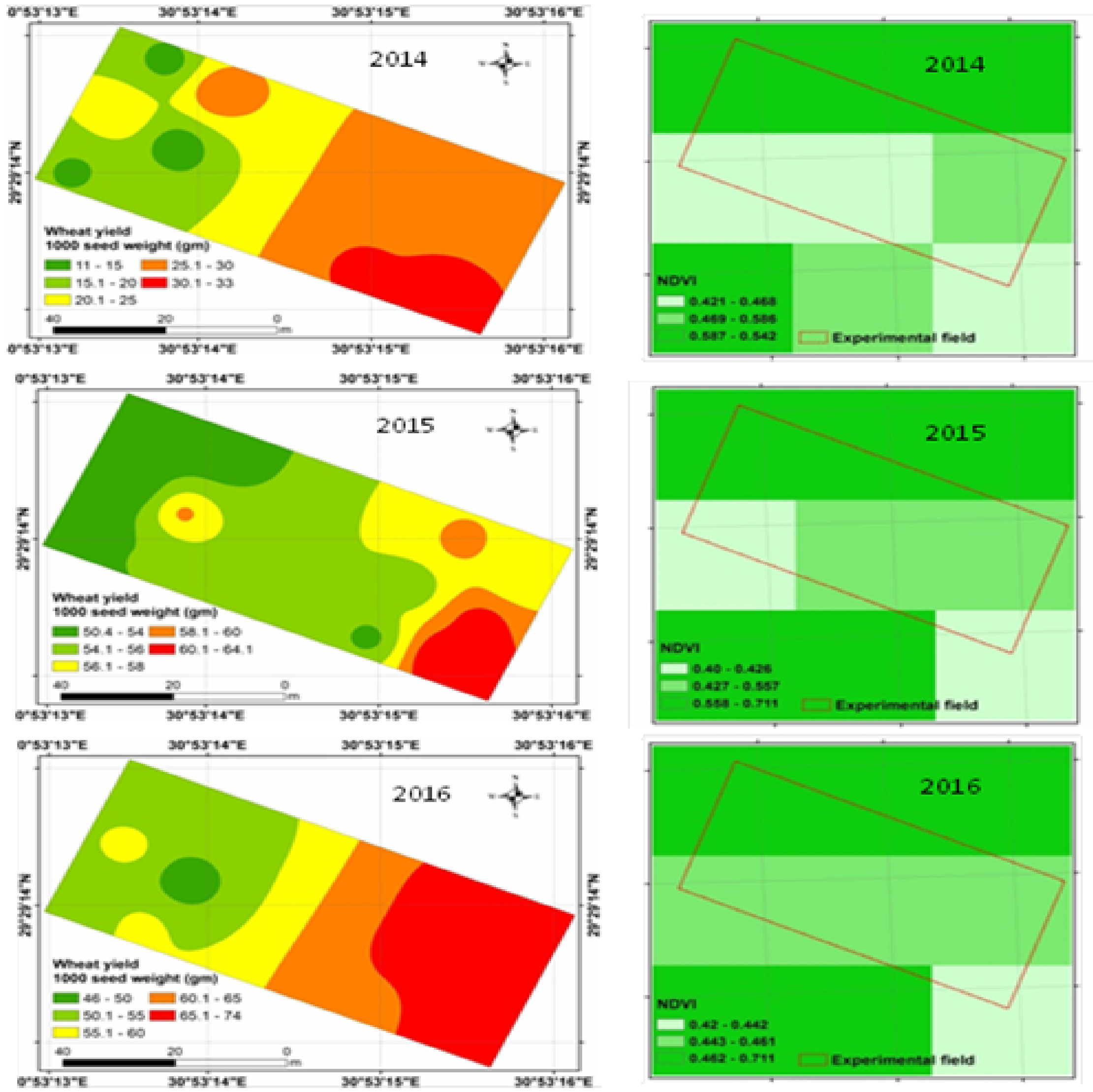

Fig. 3: Wheat 1000 seed weight and the NDVI during 2014, 2015 and 2016 seasons

Conclusion

An evaluation of geographic changes of soils (i.e. pH and EC) and 1000 grain weight facilitates monitoring changes in wheat yield, and correlate crop yield with variations in pH and EC. The cultivation method and soil amendments such as gypsum, compost and gypsum/compost mix influenced soil pH and EC and in turn crop yield. The findings show that 1000 grain weight increased by 150% one year after the application of amendments. The difference in the weight of 1000 seeds was significantly associated with NDVI; therefore, this is an appropriate index to represent the soil productivity. The use of remote sensing followed by site observations is a robust means in representing the soil variation and tracking changes in soil characteristics in response to soil amendments in salinity impacted agricultural areas.

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