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Geomatics-Based Mapping of Hydraulic Soil Properties for Agricultural Management

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Abstract

Soil water is one of the most important information as input to land surface, ecological and hydrological models. Reliable soil water information with current coverage in the area is needed for proper cultivation management. A number of 460 soil profiles data were evaluated for the performance of estimates inverse distance weighting to map some of the soil quality properties. Maps with the investigated coverage were produced with the soil information available about soil texture and organic matter. It was observed from the results that increasing the number of soil profiles to cover the area in detail helped to overcome its unknown reliability. The results also demonstrated that hydraulic properties of field soils can improve predictions for such models using remote sensing data. A reliable soil water map can serve multiple purposes, including scientific research and application of models on different geographical scales. It is also essential for the development and spatial implementation of a comprehensive soil quality (SQ) indicator planned by the investigated study.

Keywords: Geostatistics, Geographic Information System, Hydraulic Soil Properties, Soil Quality.

Introduction

Many environmental modelling studies requires collecting of information on soil hydraulic properties (Van Looy et al., 2017). Most regularly, measured information on soil water retention or hydraulic conductivity is not obtainable for environmental modeling either at the territorial or tarry scale. In the 1980s was the start of the extensively analyses on the prediction of soil hydraulic properties (Ahuja et al., 1985; Pachepsky et al., 1982; Rawls and Brakensiek, 1982; Saxton et al., 1986; Vereecken et al., 1989). The availability and continuously updated of data and develpoed of newly statistical methods helps in increasing the performance of predictions (pedotransfer functions – PTFs). Latest works include among others McNeill et al. (2018), Román Dobarco et al. (2019), and Zhang and Schaap (2017). Geostatistics have been found to be efficient tools in general for prediction purposes (AbdelRahman et al., 2008; AbdelRahman et al., 2018; Caruana et al., 2008; Caruana and Niculescu-Mizil, 2006; Olson et al., 2017). These methods are used to derive values, providing predictions of several individual locations with built-in randomization. Geostatistics provide mean values of groups that can be geographically presented. Due to developing of these Approaches of providing estimations, these methods do not derive any extraordinary values; therefore, predictions will always be reasonable. It has been proven that often, but not always, the greater the number of forms combined to predict the more accurate the results. (Baker and Ellison, 2008; Cichota et al., 2013; Nussbaum et al., 2018; Wu et al., 2018). Hengl et al. (2017) stated that accuracy, interpretability and computation power required to be used in the prediction geostatic method. The model should be successful in harmonizing different soil texture classification systems (Cisty et al.,

2015) and prediction of soil bulk density (Chen et al., 2018; Dharumarajan et al., 2017; Ramcharan et al., 2017; Sequeira et al., 2014; Souza et al., 2016) but have not been intensively applied yet to derive input parameters for hydrological modelling (Koestel and Jorda, 2014; Tóth et al., 2014). Adhikari et al. (2014) found that kriging was a good method for mapping soil organic carbon concentration. The same was observed by Matos-Moreira et al. (2017) was appropriate for this purpose for mapping the phosphorus concentration. Behrens et al. (2018) found that a lot of state-of-the-art studies digital soil mapping using methods including geostatistical techniques (i.e. ordinary kriging, regression kriging and geographically weighted regression). Hengl et al. (2018) found that universal kriging is a powerful method for soil mapping.

Mapping Soil hydraulic is produced in two ways; (1) an indirect method by applying pedotransfer functions (PTFs) and (2) a direct method of spatial inference of observation point data (Bouma, 1989). PTFs are used to measure and/or predict Point data. Several studies have analyzed the efficiency of geostatistical methods for mapping saturated hydraulic conductivity (Motaghian and Mohammadi, 2011; Xu et al., 2017) and water retention at specific matric potential (Farkas et al., 2008). Both methods (1) and (2) were used to map at 1 km resolution the hydraulic conductivity characteristics of the soil for the Spanish region of the Iberian Peninsula by Ferrer Julià et al. (2004). Geostatistical methods were implemented on 1483 ha to map both of wilting point and water content at field capacity by Farkas et al. (2008) where the needed sampling density was optimized to derive 10m resolution maps of soil hydraulic.

In cases where geostatistical methods are not applied due to the lack of available raster data; therefore, in several studies, soil hydraulic maps have been generated using PTF applied to readily available spatial soil data (Chaney et al., 2016; Dai et al., 2013; Marthews et al., 2014; Montzka et al., 2017; Tóth et al., 2017; Wu et al., 2018). A better description of extreme conditions was provided by Montzka et al. (2017) with prediction the uncertainty for modelling tasks where PTFs are usually having root mean square error(RMSE) values between 0.02 and 0.07 cm^3.Based on the foregoing, the aim of the study is to Geomatics-based map of hydraulic soil properties to help in better agriculture management

Material and methods 3.1. Study Area

The study area is located in New Salhya, Ismailia governorate eastern Nile delta. The area is bounded by longitudes 31°59'17.55"E and Latitudes 30°27'29.81"N. The climate is arid

Mediterranean type with an average temperature 28.9 c^o. The original land of El-Salhiya area featured by dark yellowish brown (moist) and light yellowish (dry), sandy, single grains, nonsticky, non-plastic and friable or loose characteristics had been changed to dark brown (moist) and dark yellowish brown (dry), sandy loam, moderate medium sub-angular blocky structure, sticky, plastic and firm hard dry after 30 years of cultivation according to **Gobran and ElBarbary** (1998).

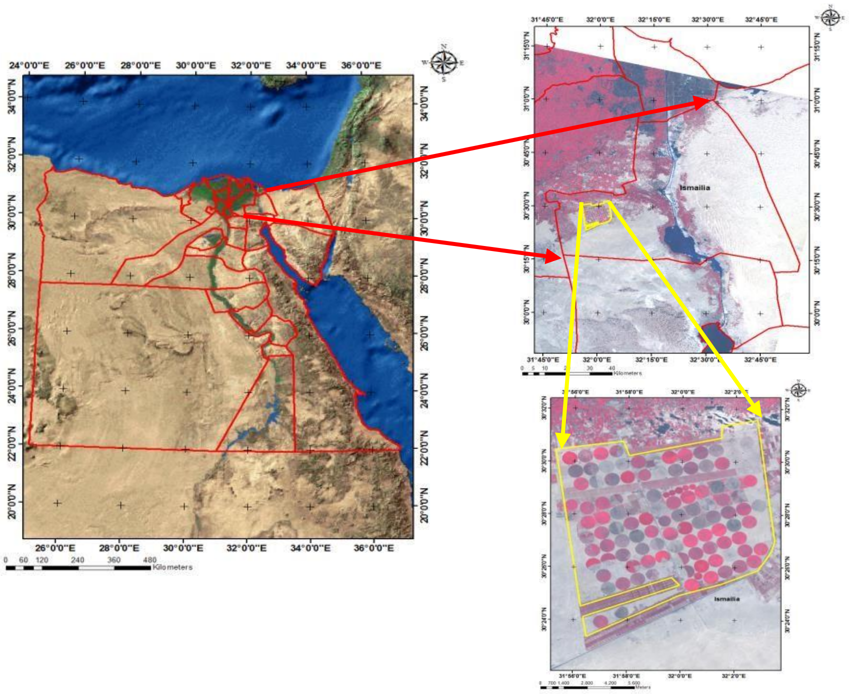
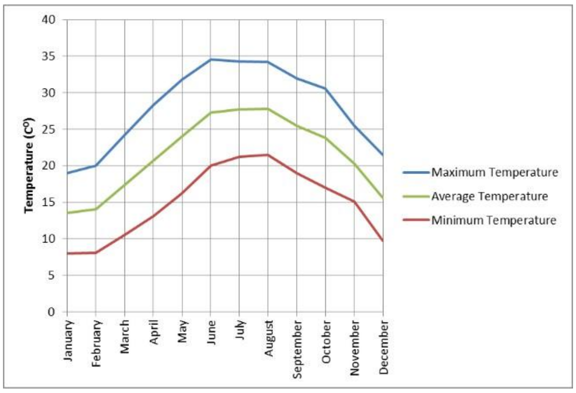


Figure1 Location of study area, Satellite image in false color composition

Meteorological data required to calculate the reference evapotranspiration (ET_0) that were collected are maximum air temperature, minimum air temperature, relative humidity, wind speed, average sunshine hours and average solar radiation, within the period from January to December 2014 as shown in Figures 2, 3, 4, 5 and 6. The area has a hot temperate climate with Average high temperature 28.2° C, Daily mean 22.8° C, Average minimum temperature 14.7° C, the lowest temperature is −2° C. so 22.8° C mean annual temperature and 37mm mean annual precipitation; lower temperature in winter and rainfall only in winter as well according to data of Climate (2013). Elevation is between 8 and 65m on the northern part and 65 and 141 m in other areas of the catchment.



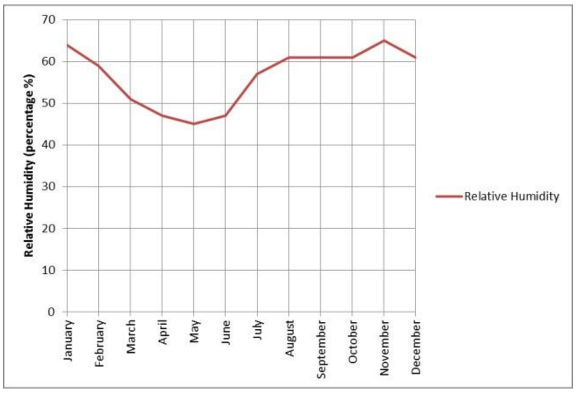


Figure 2. Maximum, minimum and average temprature data for 2014 Figure 3. Relative humidity data for 2014

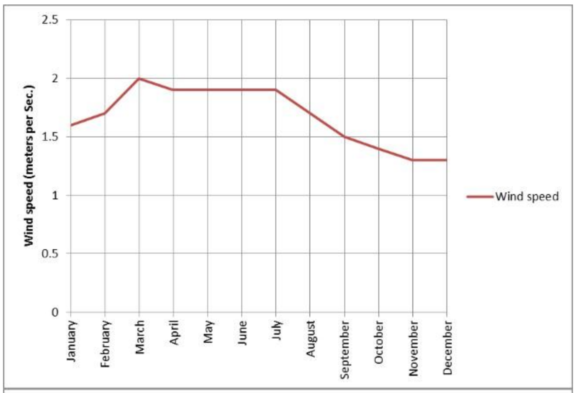


Figure 4 Wind speed data for 2014

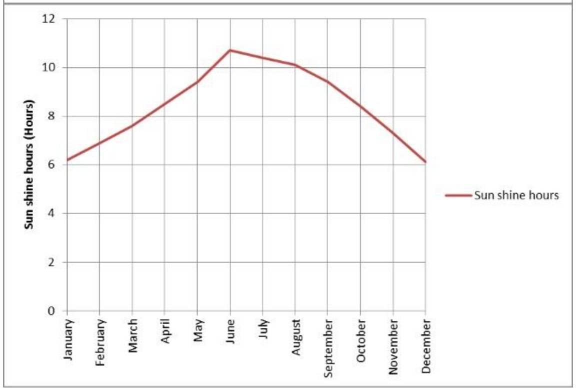


Figure 5 Sun shine hours data for 2014

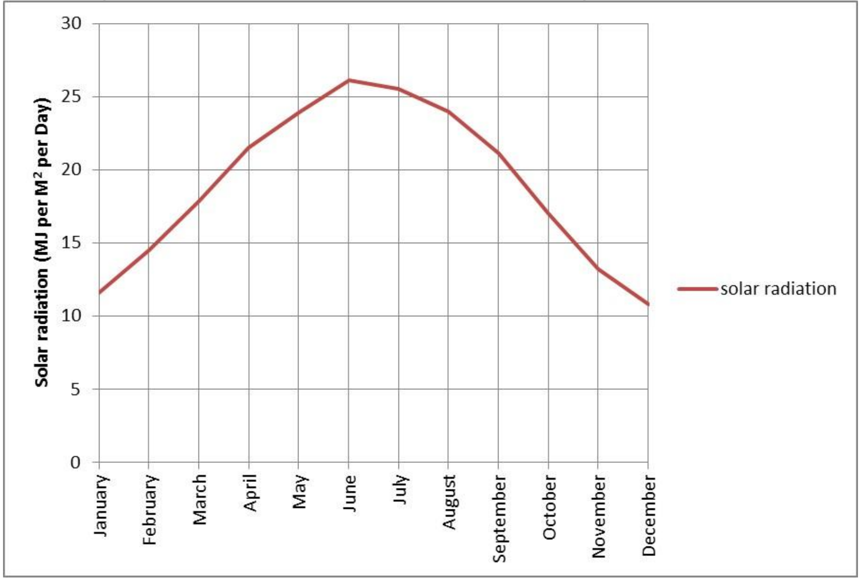


Figure 6 Solar Radiation for 2014

Experiment design

Distances among neighboring points were designed in this experiment to be ranged from minimum 300 m to maximum 2 km. the design of this slope distances is probably distributed uniformly which met the Geostatistical interpolation methods requirement. The soil samples depth was based on the difference of layers a long with the profile depths. The interpolations were performed for the surface layers of all profiles, while the interpretation of soils was described based on the weighted average of all profile's layers

Interpolation methods

The following equation is used for IDW and kriging interpolation methods are well discussed by Yao et al., (2013)

$$Z^*(X_0) = \sum\nolimits^n_{i=1} w_i Z(x_i) \quad (1)$$

Where The Z (x_i) data value of locations which used to generate the variable Z value of at x_0 the unsampled location, Z (x_i) value is assigned by the weight w_i , n is the number of the used closest neighboring data points for estimation.

$$= \frac{1 \quad _i}{\sum_{i=1}^{n} \quad 1} \qquad /d2 \quad w_i \quad /di2 \qquad (2)$$

di is the distance between the estimated point and the observed point.

$$\gamma(\mathrm{h}) = \frac{1}{2n} \sum_{i=1}^{n} [Z(x_i) - Z(x_i) + h)]^2$$

(3)

x_i and x_i+h are sampling locations separated by a distance h, and $Z(x_i)$ and $Z(x_i+h)$ are the observed values of variable Z at the corresponding locations.

The least squares method which was used to estimate the linear regression is the following equation

$$y = B_0 + (x + a)^n = \sum{}^{n}{}_{i=1} B_i X_i$$

(4)

Result and discussion

The spatial information on soil type, clay, silt and sand content, organic matter content, calcium carbonate content and pH in water (pH) at 10 m resolution were provided by the collected soil sample in the entire field. Information on topography, meteorology, geology and vegetation was used for interpretation the output mapping of soil hydraulic properties topographical, meteorological, geological information and remotely sensed vegetation properties and soil horizons' data belonging to 460 soil profiles. The samples in it have measured information on basic soil properties – e.g. soil depth, organic matter content, clay, silt and sand content, calcium carbonate content and pH – and also on soil hydraulic properties such as soil values.

Soil texture and organic matter were used to produce soil information maps. The results were used to develop a comprehensive spatial index of soil quality (SQ) based on the characteristics of the hydraulic soils in the examined study.

Wilt Point (WP) shown in Figure 7, explore the minimum amount of water in the investigated soil that a plant needs in order not to wilt. The results showed that the effect of soil texture at this level is clear depending on the nature of the soil. In soils where the proportion of clay and silt is increased, the wilting point occurs at higher levels than in sandy soils, due to the tensile strength of the clay grains of water. Soil water content can be measured on a mass or volume basis. Finetextured soils retain higher amounts of water (~26%–32% v/v) than the coarse textured soils (10%–15% v/v) at the permanent wilting point.

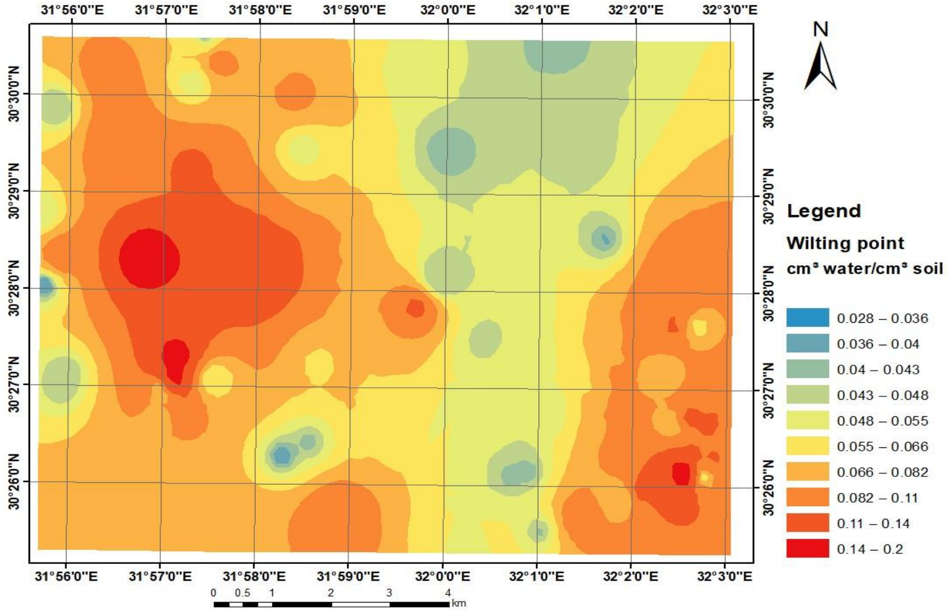


Fig. 7. Wilting point

Available water (Figure 8) was found to be highly correlated with the physical properties; soil texture, bulk density and porosity and was found to have negative correlation with chemical properties i.e. EC and OM

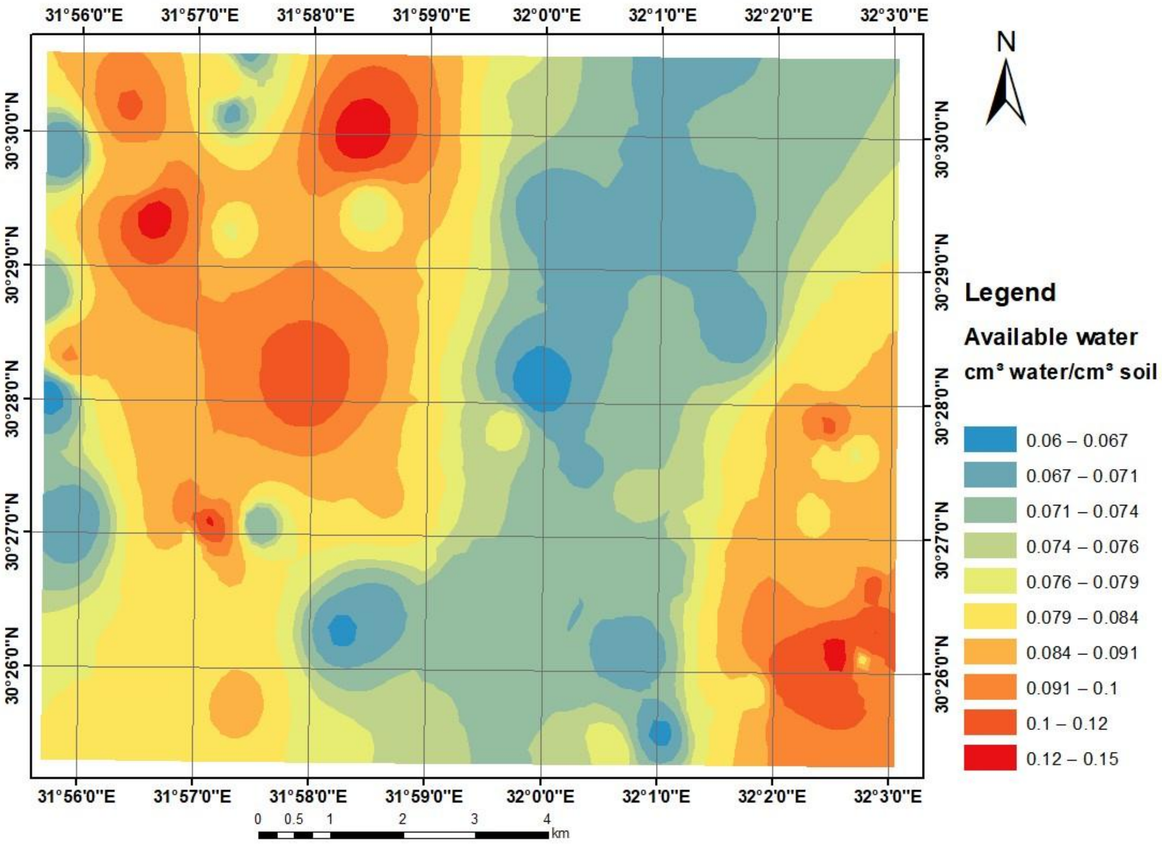


Fig. 8. Available water

The field capacity (Fig. 9) was found to decrease with the increase in the depth of the sector in the case of sandy lands in the region, in contrast to the areas where the percentage of silt and clay increases in the lower layers of the land sector. The study shows that the field capacity in the study area is affected by many factors that, specifically, are not constant (for a particular soil).

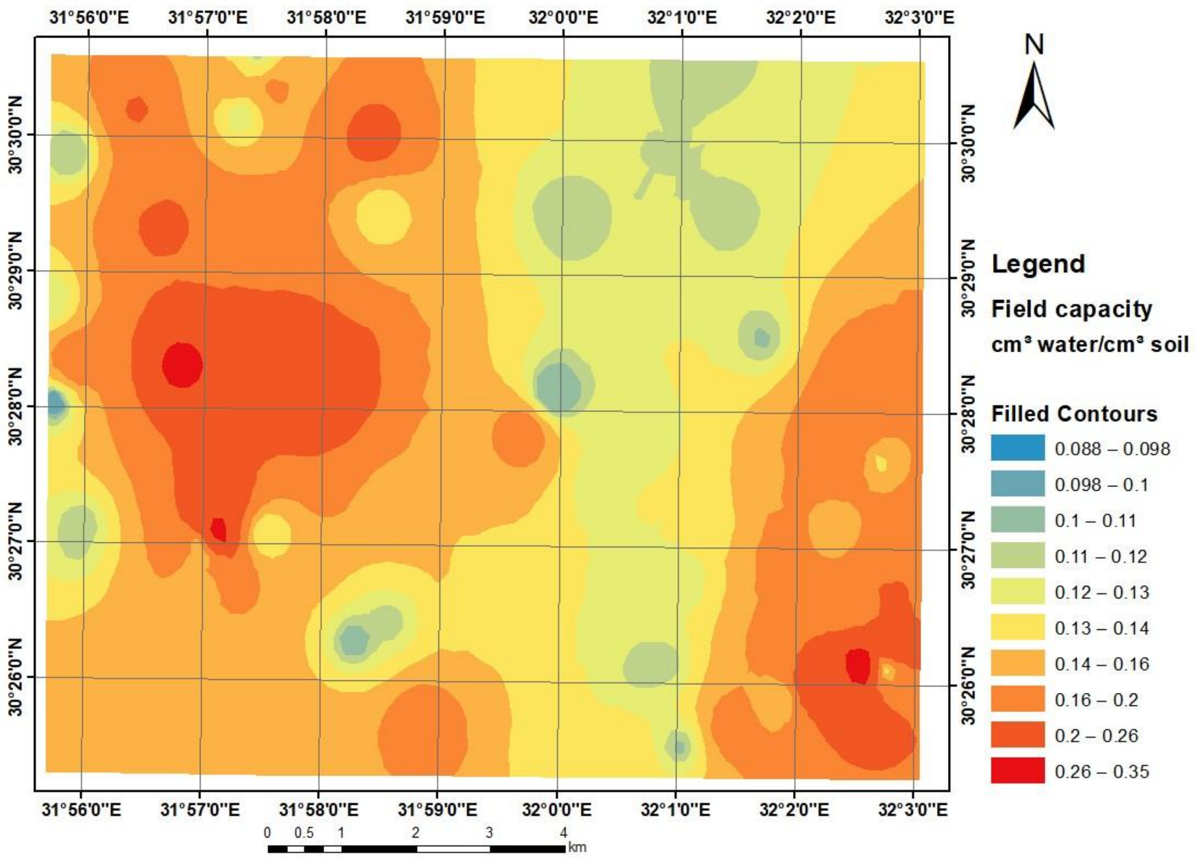


Fig. 9. Field capacity

The importance of soil drainage (Fig. 10) is due to determining the suitability of the different types of crops. The study area is characterized by good drainage that helps in improving or sustaining production and thus determines the management of water irrigation. Where saturation (Fig. 11) was found to be affected by soil physical properties

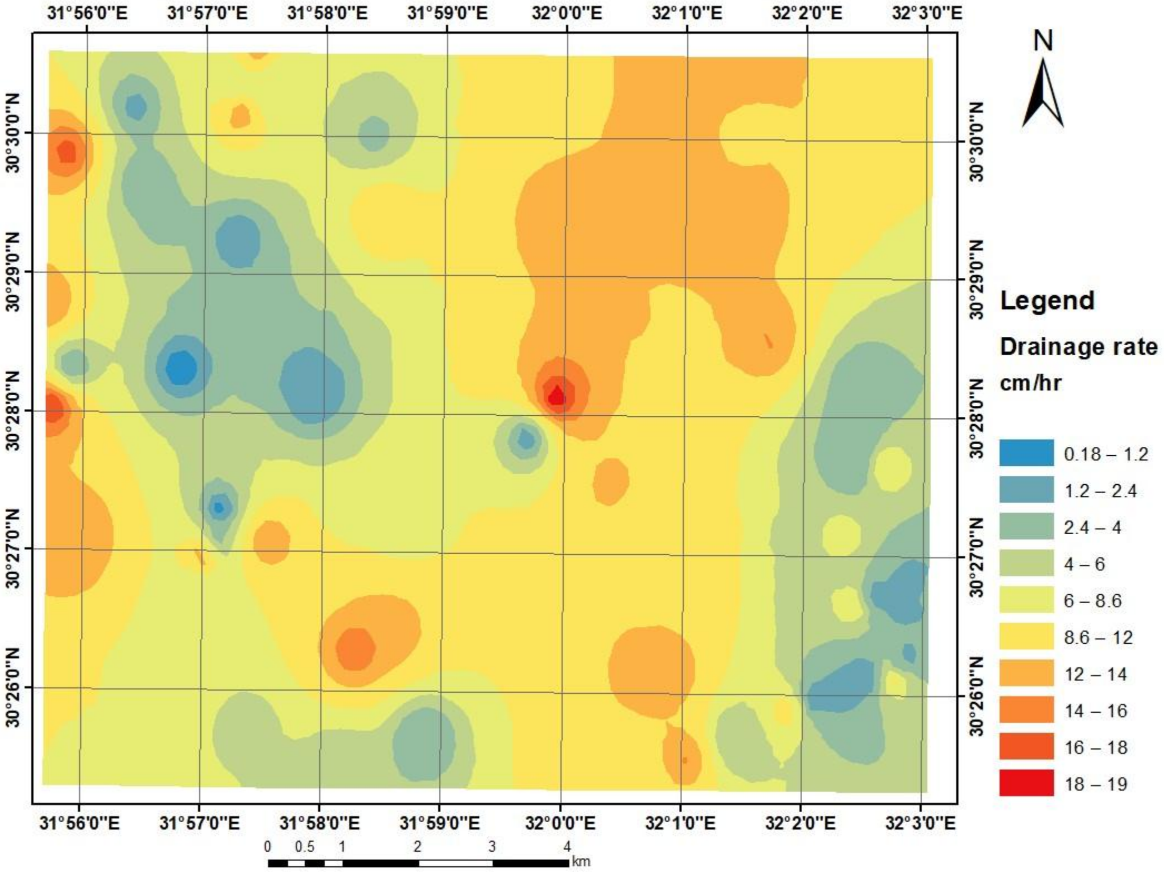


Fig. 10. Drainage rate

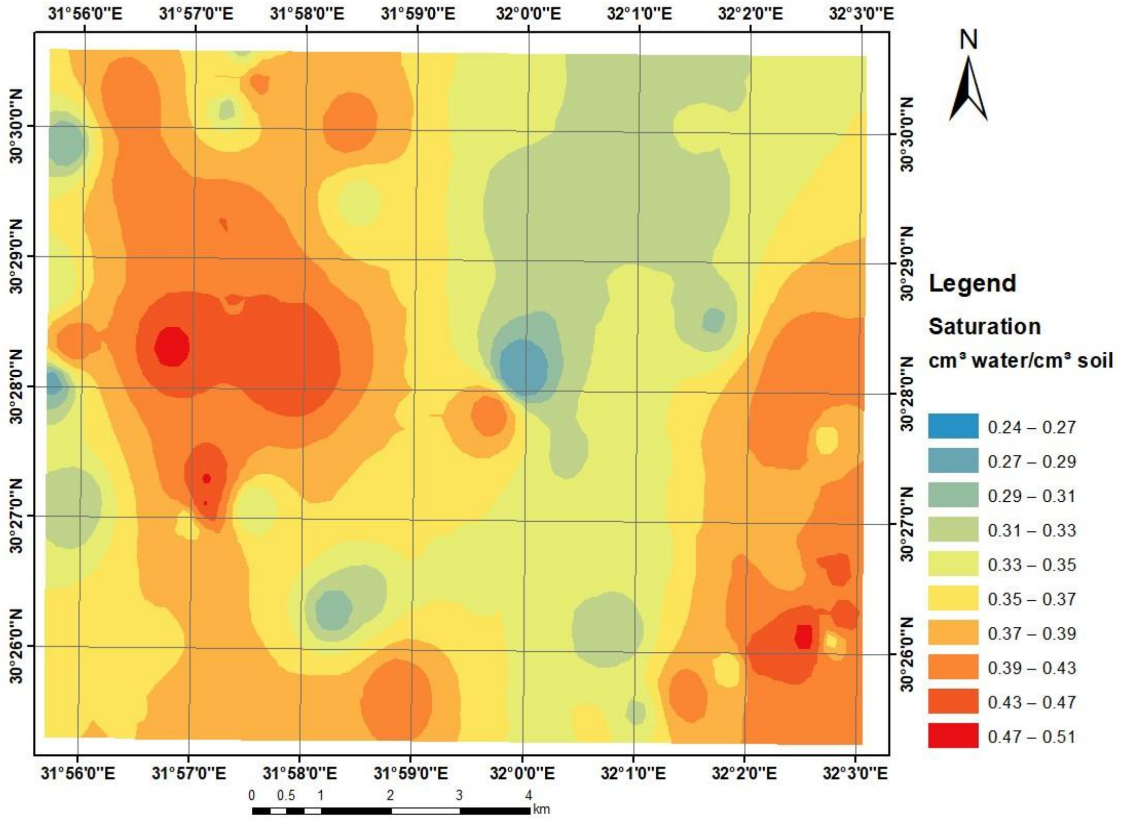


Fig. 11. Saturation

The amount of water available in the soil depends on several variables and these variables include the effective root depth and density of the crop, the efficiency of the root system in soil exploration, as well as the ability of the soil to store the available water and basic soil properties used to estimate the potential amount of available water stock, including field capacity, wilting point, and available water.

Conclusions

Soil hydraulic maps are closely related. The benefit of computed maps of wilting point, available water, field capacity, drainage rate and saturation is that locally determined values can be distinguished better than any of the produced maps. This is due to the association with the same determinants of soil properties that affect the amount of water in the soil .The results showed that the positive improvement in some of the physical properties of the studied soil leads to an improvement in the water properties of the soil. The study showed the importance of modern methods of agriculture, especially modern irrigation methods, which help to reach the water directly to the root system. Also they become greatly facilitated for plants, and to avoid water loss caused by wind or evaporation from the surface of the soil during or after the operation process.

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رسم الخرائط القائمة على الجيوماتكس لخصائص التربة الهيدروليكية للإدارة الزراعية

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تعتبر مياه التربة من أهم العوامل اللازمة لتطوير نماذج سطح الأرض والنماذج البيئية والهيدرولوجية للأراضي الزراعية. لتحقيق الإدارة الزراعية المناسبة لابد من توافر معلومات دقيقة عن كمية المياه وتوزيعها داخل قطاع التربة وخاصة في منطقة أنتشار الجذور. تم تقييم عدد 460 من بيانات خصائص التربة بأستخدام التقديرات العكسية لوزن المسافة (IDW) لرسم خريطة لبعض خصائص جودة التربة. تم إنتاج خرائط التربة و تشمل بعض خصائص الهيدروليكية للتربة والمواد العضوية .وقد لوحظ من النتائج أن زيادة عدد عينات التربة لتغطية المنطقة بالتفصيل ساعد في التغلب على صعوبة تفسير بعض الظواهر في منطقة الدراسة بحدود ثقة معنوية و مرتفعة. أظهرت النتائج أيضًا أن الخصائص الهيدروليكية للتربة يمكن أن تحسن التنبؤات لمثل هذه النماذج باستخدام بيانات الاستشعار عن بعد.كما أظهرت النتائج انه يمكن أن تخدم خريطة مياه التربة أغراضًا متعددة ، بما في ذلك البحث العلمي وتطبيق النماذج على نطاقات جغرافية مختلفة. كما أنه ضروري لتطوير وتنفيذ التخريط المكاني لمؤشر شامل لجودة التربة (SQ) المخطط له في الدراسة .