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Spatial Analysis of Yield and Soil Components in an Onion Field

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Abstract

The main objective of this study is to determine spatial variability in a dry onion field in EL-Saff agricultural farming village, Giza Governorate, Egypt, and to produce a management strategy, which is based on spatial variability of yield and soil components. The onion field properties were determined and given in maps. Soil samples were taken to determine properties of soil such as salt (EC), pH, available N-P-K and onion yield. Longitudinal slope was also measured. Results were used to produce maps. Most percentage of the field soils was determined as sand to sandy loam textured soils and loamy sand in lower depth. Their surface is covered with many fine and medium gravel.

The final goal of the current study is to produce the application maps through delineation of the management zones. It is found that there is no much variability of salinity before harvest, except in the western part of the field. However, in the northern parts of the field, there is a big variability of salinity and reaching higher levels. Yield of dry onion increased by decreasing of total soluble salts. The range of research field pH fits well with the spatial variability range provided in most study area to meet satisfactory yield. Nitrogen variable showed a pronounced tendency for local clustering of similar values, with gradual changes from areas of low to high values from south to north direction of the sampled area. Visually, there is an obvious association of available K with the salinity-related characteristics, especially after yield harvest. Contradictory, a manor relation between P and field salinity conditions is existed. Yield distribution showed a pronounced tendency for local clustering. Available Nitrogen, Phosphorus, and Potassium in the field reflecting the good nutrient power supply of the studied soil as well as onion dry bulbs according to the related maps. It is evidence that fertilization with N, P and K should be applied with required technical solutions protected accumulation and leaching of nitrogen and phosphorous. The models can provide partial information to help improve soil fertility to increase the yield production. The work reports on how soil variables and crop growth (statistical and spatial models) can be used to asses the relationships between the crop yield production and soil variables and to delineate different management zones in the test area. Generally, precision farming applications require high technology but there are some opportunities such as creating yield map for crop production may apply in Egypt.

Key words: Precision Farming, Spatial Variability, Yield Map, Dry Onion.

INTRODUCTION

Growing of dry onion by sets considers in 3 steps; seed growing, onion set growing and dry onion growing [1]. The parameter for planting of sets were of a grid interval 25 X 25 m row spacing, 20-40 cm planting depth of sets and 25-45 pieces/m2 by hand into row opened by cultivator or harrow in February and March for dry onion growing. The sets are covered by harrow in the conventional method. Plants are hoed 2-3 times by hand in May and June. Onions are dug by hand in August and dried approximately 7-10 days in the field.

The first is production of dry onion by onion sets and the second by seeds, which is only used for irrigated area. There are some problems such as planting of onion seeds for the production of onion sets. The planting of seed is realized by man labor; because row spaces between seeds are very narrow (3 cm). There are two methods for dry onion production. One of them is production of dry onion from seeds; other method is production of dry onion from onion sets, which is most widely used method in Giza governorate, Egypt [1].

Yield maps are important tools for producers or scientists practicing site-specific management in precision agriculture programs. Detailed yield maps can be linked by global positioning systems (GPS) coordinates to other maps that show soil chemical and physical properties, soil depth and topography, Remote sensing data, weeds, diseases, nematodes, insects; and cultural practices [2].

There are a number of ways to measure crop yields. Most of methods developed over the years have involved weighting the crop after it has been separated, and cleaned. Three major yield measurement approaches are listed below. Yield monitoring has been most widely applied to grain harvesting, but is certainly not limited grains. Yield monitors are being, or have been developed for several non-grain crops as potatoes, tomatoes, sugar beet, peanuts, cotton and forage crops [3].

Yield mapping and soil sampling tend to be the first stage in implementing PF curve. Yields are reduced by processing data from an adapted combine that has a vehicle positioning system integrated with a yield recording system. The combine has a fitted to it that can be identified by the GPS receiver on the roof of the cab and the differential aerial above the engine. The output from the combine is a data file that recorded every 1.2 seconds the position of the combine in Longitude and Latitude with the yield at that point. This data set can then be processed by various geostatistical techniques (usually involving Kriging) into a yield map [4].

A land suitability method using MicroLEIS program in integration with SALTMOD was applied before to predict the effect of water table and salinity on the productivity of wheat in sugar beet area, west Nubaria, Egypt [5]. They found that the productivity of wheat will be decrease due to increasing salinity and water table depth, as a result of mismanagement practices.

Main objective of this paper is to determine spatial variability in a dry onion field and to produce a management strategy, which is based on spatial variability of yield and soil components to improve yield for dry onion production in El-Saff area. In this research, there was a GPS apparatus for measurement soil properties and positioning of the data. All data were measured by using transportable weighbridge and evaluated by known software.

MATERIALS AND METHODS

Description of the study area

El-Saff area is one of the Giza Governorate districts, Egypt. It lies on the eastern bank of the River Nile, while all other parts of the Governorate are on the western bank. The study area is a part of El-Saff district; more preciously exist in Arab Al-Hissar area. It exists between latitude 29° 39' 01" and 29° 38' 58" N, and longitude 31° 19' 26" and 31° 19' 29" E; occupying an area of about 2835 m^2 (Fig.1).

Figure 1. Location of sample points in study area.

Regarding the climatic conditions of the area, it is characterized by its hot rainless summer, mild winter with low rainfall. Climatic data of EL-Saff district; mean annual temperature is 21.1 ºC, average rainfall total is 3.4 mm, average evaporation per day is 6.6 mm and average relative humidity is 58.2 % [6].

Materials were onion field and dry onion. The onion field properties were determined and given in maps. Dry onion variety is Yarim Imrali.

Thirty-eight soil samples were taken to determine properties of soil such as pH, salt, total N, P, K and longitudinally slope [7]. Longitudinal slope was measured with GPS and plotted on Map. Accuracy of the GPS NAVDLX-10 was ± 0.2 % [8].

Field divided grids that its dimensions were 25m x 25m. Field markers were used to determine grids position in the field. Each grid was harvested by hand and dry onions put in sacks and were weighed with weighbridge.

Based on the morphological characteristics of the examined profile, laboratory analysis of the collected soil samples and according to classification of the soils, there are Typic Torripsamments and Typic Gypsiorthids soil subgroup in this area [9]; [10] and [6].

There are soil texture types such as sandy (S), coarse and fine loam (CL), loamy sand (LS) and clayey (C). The majority of the soils (90%) in the region are low or very low organic matter, 45% of soils were rich in calcium carbonate [6].

Measured results were used to produce maps (soil EC & pH component maps, yield maps, plant nutrition elements maps etc.) to show relationship between yield variability and soil properties. The maps are produced by using a methodology that developed and published by Denmark Royal Veterinary and Agricultural University, Centre for Precision Farming [11]; [12]; [13] and [14].

Positioning of data points on the maps were determined due to field size. Coordinates of the onion field is illustrated clearly in maps. Data will also be used to determine next year fertilizing strategy for different agricultural applications such as chemical applications, seeding rate, etc. Produced maps will be used to investigate reasons of the yield variability in the field. In addition, effect of soil properties and field slope on the yield will be evaluated.

Map analysis

The interpolated values of the variables were imported into ARC/INFO [15] to create maps. Correlation and regression analyses were conducted to measure the relationships between the mapped values of available N-P-K and those of soil variables. These relationships among mapped variables may be compared with those among the data for the original 38 sites from which the maps were derived.

RESULTS AND DISCUSSIONS

Statistical Characterization of Data

The statistical results of the EC, pH and available N-P-K measurements for study area are listed in Table 1. The statistical analysis can just explain the sample difference in volume and in homogeneity, but it cannot describe the spatial variability. The mean of EC values before and after harvest in the 38 samples was 0.84 and 0.84 dSm^{-1} that exploring a large range of about 1.08 and 2.97 dSm^{-1} between the minimum and maximum values.

The EC values of Feb. and May are the only attributes with a bit large skewness and kurtosis, showing that the distributions of these characteristics were fare from normal.

The quite large positive skewness for EC values especially after harvest in May reflects asymmetry in the distribution caused largely by a number of relatively high values (Table 1).

Table 1. Statistical summary of data.

Items	Mean	Median	Standard Deviation	Sample variance	Min.	Max.	Sekwness	Kurtosis
EC dSm^{-1} Feb.	0.841	0.78	0.242	0.059	0.63	1.71	1.85	3.29
EC dSm^{-1} May	0.946	0.8	0.504	0.254	0.3	3.0	2.35	6.86
pH	6.796	6.85	0.250	0.062	6.29	7.24	-0.32	-0.79
N Kg/Fed.*	581.974	517.5	194.702	37908.837	325.0	980.0	0.57	-0.90
P Kg/Fed.*	84.947	80.5	22.544	508.216	48.40	128.00	0.35	-0.96
K Kg/Fed.*	404.474	392	132.612	17586.040	94.00	630.0	-0.35	-0.30
Yield ton/Fed.*	10.142	11.0	2.697	7.271	4.00	15.50	-0.29	-0.64

* Fed ≈ Fadden = 4200m^2

A natural logarithmic (Ln) transformation was applied to the data for EC values both in Feb. and May; soil pH data, available N and P variables. Another benefit of transformation is that distortion of the semivariance and other computed statistics by extreme values is reduced [16] and [17]. After transformation, the skewness and kurtosis of EC values were greatly reduced, providing a more normally distributed data. Data of available (K) and yield were distributed in an approximately normal fashion.

Soil pH ranged from the slightly acid 6.29 to the neutral pH of 7.24, with a mean of 6.79. Soil pH varied only about 0.95-fold between their respective minimum and maximum concentrations. The statistical distribution of available K and yield data was reasonably normal as shown by the values close to zero for skewness and kurtosis [18]. Available Potassium was less variable. The distributions of soil pH, P, K and yield values were only slightly skewed (skewness <1), and their medians were quite close to their means, while it is slight far in case of Nitrogen data. As mentioned before, when investigated content of salt in the soil samples, it varied according to its spatial position. Figures 2 and 3 show the frequency distribution of EC dSm^{-1} values in study area in respect to the yield harvest, before harvest in February and after in May respectively. Both data exhibit abnormal distribution that deemed *Ln* transformation prior to kriging.

Semivariogram Analysis

Semivariograms were prepared for the selected seven variables**.** They were calculated from 19 pairs of samples. The semivariograms were limited to an average separation distance of 12.9 m to avoid distortions in semivariance caused by the arbitrary restriction of site-pairs by the boundaries of the area sampled. Omni-directional semivariograms were prepared, but it should be noted that, because of the rectangular shape of the site, these variograms are dominated by trends in the north-south direction. All of the variograms show a high degree of spatial dependency. Thus, for most variables, it were able to fit at least a portion of the experimental semivariogram with the spherical model, then exponential, Gaussian and Linear model using the parameters listed in Table 2.

In this research, none of the variograms for the selected seven variables were bounded by a constant sill, when the entire range of data was considered. After *Ln* transformation and removal of the trend, the residual (detrended) values were used to recalculate the semivariances. This process significantly improved the semivariogram for EC, pH and P, but the improvement for nitrogen N was only slight.

The variogram of EC dSm^{-1} Feb. increased almost linearly with lag distance, suggesting a linear trend that was modeled shows a very small nugget variance and sill with a range of about 50m (Fig.4).

The detrended variograms for EC dSm^{-1} May and available N were fitted by the exponential model using range distances

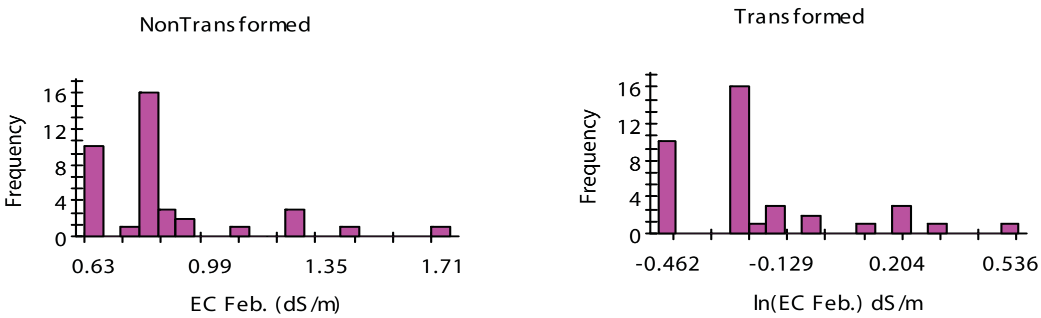


Figure 2. Frequency distribution of EC dSm^{-1} values in February before harvest.

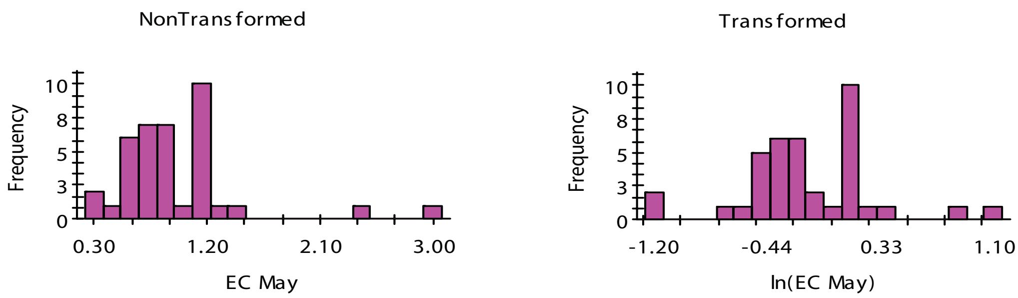


Figure 3. Frequency distribution of EC dSm^{-1} values in May after harvest.

of 0.3 and 6.0 m, respectively, and the nugget and structural variances given in Table 2.

Figure 4 shows the semivariogram of pH, which was fairly well described throughout the range of the data by the Gaussian model. The fitted curve for relative semivariance has a small nugget variance, a large structural variance, and a range of 6.7 m (Table 2). In case of phosphorus, potassium and yield attributes, No corrections for periodicity were used in modeling the semivariogram for them, because the simple spherical model provided a reasonable fit, especially at short-range lag distances which dominated the interpolation process based on the 19 closest points (Fig. 4).

In general, the obvious positive small nugget, the proportion of sample variance C/(Co+C) and relatively the small RSS values indicate better fitting of variogram models and significant structural of spatial variability.

Map Preparation and Comparison

Produced maps are given below. Variability of the soil, yield, pH, available N-P-K and others can be seen on these maps. These maps can be used to determine spatial variability and to apply variable rate application in that field.

The distributions of soil characteristics, available N-P-K and crop yield in the field are most easily seen when portrayed in maps. Using the fitted parameters of nugget, sill, and range

Table 2. Parameters of the models used to describe isotropic semivariograms for the studied variables.

Parameters	Variogram model	Nugget	Sill	Range	Variogram Model Fitting		
		C_0	$(C_0 + C)$	A	RSS	r^2	C/(Co+C)
EC dSm^{-1} Feb.	Linear	0.072	0.072	51.02	0.01	0.00	0.000
EC dSm^{-1} May	Exponential	0.004	0.180	0.30	0.02	0.00	0.978
pH	Gaussian	1.750	1.390	6.93	1.40	0.27	0.874
N Kg/Fed.*	Exponential	0.011	0.107	6.00	9.25	0.04	0.893
P Kg/Fed.*	Spherical	0.033	0.073	14.50	1.7	0.34	0.544
K Kg/Fed.*	Spherical	10.00	15070.0	2.80	9.17	0.00	0.999
Yield ton/fed*	Spherical	0.35	7.440	9.10	5.12	0.30	0.998

* Fed ≈ Fadden = $4200m^2$

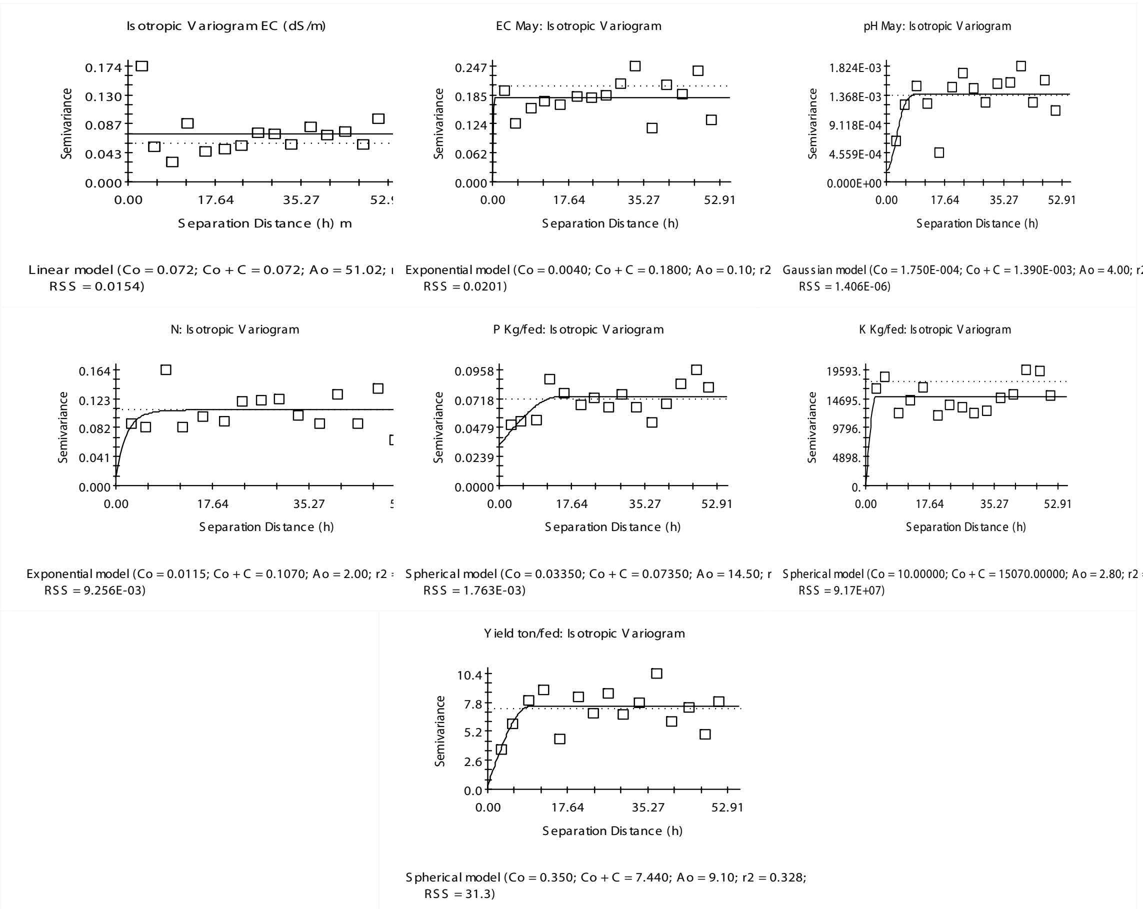


Figure 4 . Semivariograms of EC (Feb. & May), soil pH, available N-P-K and crop yield characteristics.

(C_0, C, and A) the out come of semivariogram analysis, then performed block kriging with a block size of 2 by 2 m^2 to obtain interpolated values for all selected variables across the sampled area of 2835 m2 (i.e., 105 by 27 m^2). For soil EC, pH, N, P, K and yield; the kriging interpolation method was performed on the detrended data, after which the trend surfaces were added to their kriged values to yield the final interpolated values. The produced maps based on the final interpolated values were prepared with ARC/INFO [15].

After calculating the semi-variogram parameters and choosing the best variogram model with its building parameters that fit with linear isotropic model, the ordinary block kriging algorithms was applied to interpolate the EC data using GeoStat program. The resulting block-kriged map of EC values before and after harvest for the study area is illustrated in Figures 4 and 5.

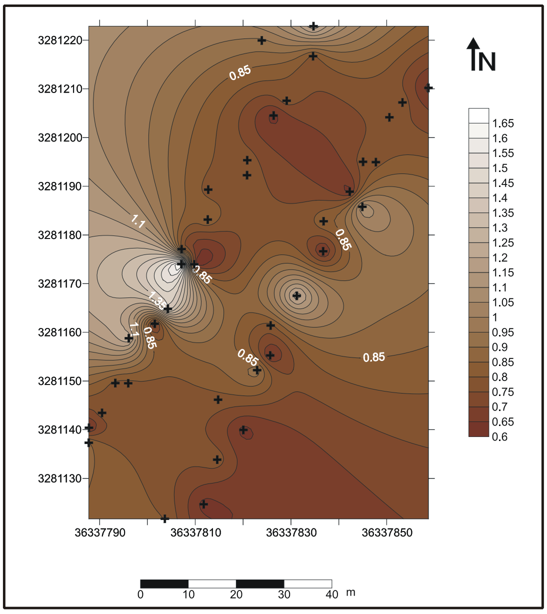
Normally, the smoothness of spatial distribution map illustrated the degree of spatial variability in soil salinity data characteristics.

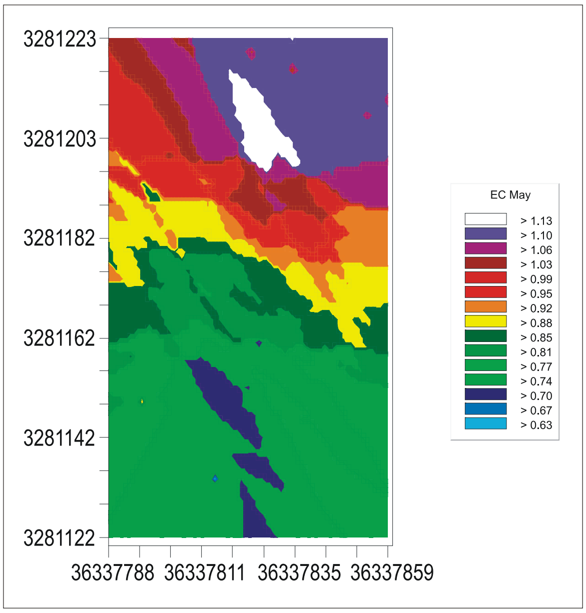
When evaluated the EC maps, it can be seen that there is no much variability of salinity before harvest, except in the western part of the field with higher levels rationally. In May after harvest, the salinity is changed between 0.3 and 3.0 dSm^{-1}. The salinity is generally low between 3281122 and 3281180 northing coordinates. In the northern parts of the field, there is big variability for salinity and reaching higher levels.

The regression coefficient for salinity map = 0.6. The standard error of the regression coefficient (SE = 0.59). The r^2 value is the pro portion of variation explained by the best-fit line = 31%; and the y-intercept of the best-fit line is also provided. The SE Prediction term is defined as SD x (1 - r^2)0.5, where SD = standard deviation of the actual data (SE = 51).

On the other hand, the map for soil pH does not resemble that for any other characteristic. The pH of the research field varied between 6.29 and 7.24 (Figure 6). Although onions are grown best on a slightly acid-neutral soils [19], which fit well with the spatial variability range provided (pH 6.68 to 6.91) in most area. Expected satisfactory yield can be obtained in most cases.

Amount of available nitrogen taken from soil by determined amount of dry onion. Nitrogen value varied between 325.0 and 980.0 Kg/fed. Figure 7 shows clearly that the spatial characteristics of nitrogen were not distributed in a random manner across the field. Nitrogen variable showed a pronounced tendency for local clustering of similar values, with gradual changes from areas of low to high values from south to north direction of the sampled area. Samples collected from the soil at the southern part were generally low in available N, while samples from the north were typically higher.





Figures 4 - 5. Maps of EC (dSm-1) measurements before (left) and after (right) yield harvest.

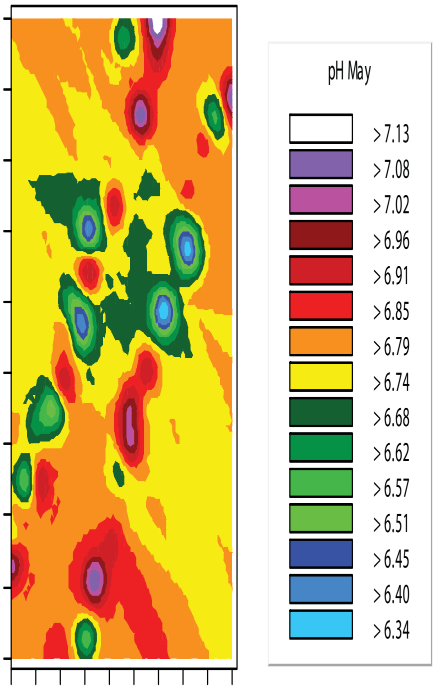


Figure 6. Soil pH map.

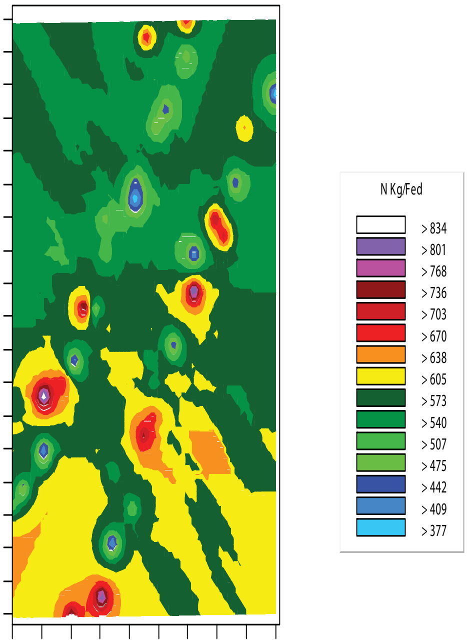


Figure 7. Map of available Nitrogen.

The distributions of available P and K are reasonably, but they are unlike distributions to each other and for other characteristics, except the obvious similarity between K and EC after harvest maps (Fig. 8 and 9). Maps for available K and EC dSm^{-1} of May were similar; showing visually the association of K with the salinity-related characteristics, especially after yield harvest. The distribution of P is gradually increasing in the NE to SW direction, but the correspondence is clearly less close in relation to salinity. Available phosphorus deficiency causes slow growth, delayed maturity, light green foliage, and high proportion of thick necks [19].

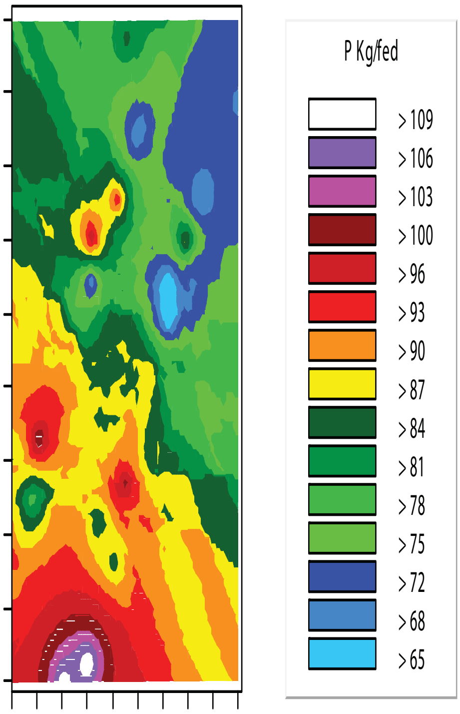


Figure 8. Map of available Phosphorus.

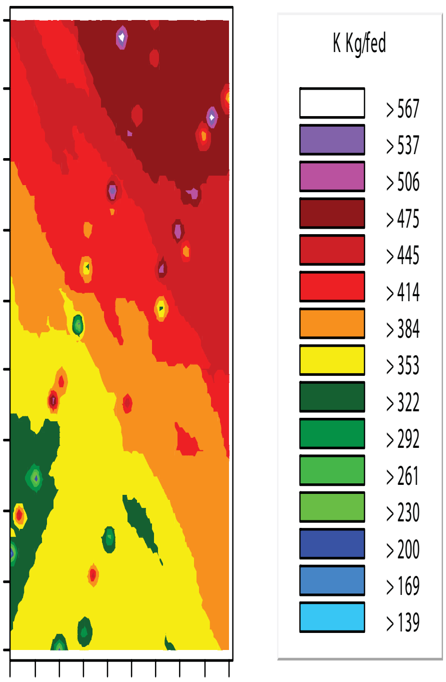


Figure 9. Map of available Potassium.

When evaluated the yield map, it can be seen that there is variability for yield in the field (Fig. 10). The yield is changed between 4.0 and 15.5 ton/fed. The yield is generally moderate 9.6 to 10.2 and up to 10.9 ton/fed in most parts of the study area. In the other parts of the field, there is big variability for the yield. Yield distribution showed a pronounced tendency for local clustering of similar values, with gradual changes from areas of low to high values.

There is not big changing for yield in correspondence to the longitudinal slope in the research field. In the most part of the field, slope varied between 2 and 3 %. As a result of this no variation of the slope, there was not effect on the yield.

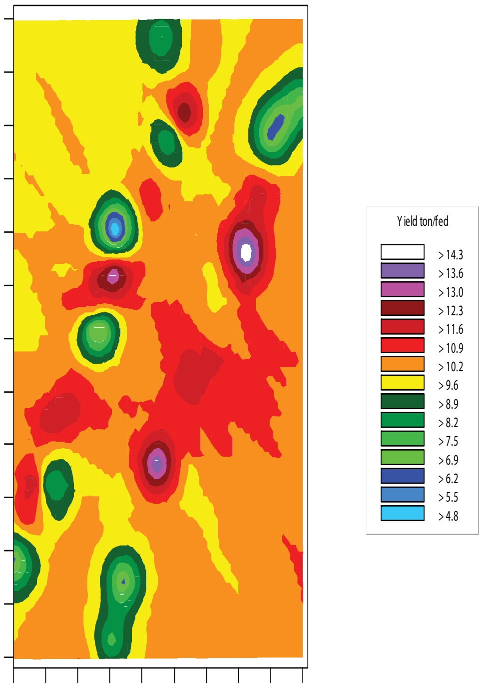


Figure 10. Map of dry onion yield ton/fed.

Most percentage of the field soils was determined as sand to sandy loam textured soils. Small part of the field was loamy sand in lower depths. There is not big difference in the research field for soil texture. There is no effect of the soil texture on the yield. The determined soil textures were suitable for the onion production in this research.

When investigate pH and yield map; it was determined that there was a less relationship between yield and pH in this research field. Yield of dry onion decreased by increasing of soluble salts in the field according to the related maps. The results were measured after harvesting of dry onions.

Fertilizers with N, P and K should be applied with required technical solutions protected accumulation and leaching of nitrogen and phosphorous. Accumulation and leaching of nitrogen and phosphorous in the soil may prevent by using right and stable fertilizer applications. If fertilization applies according to the soil-plant analyses, excessive fertilizer can be preventing. It is getting important application of fertilizers at desired amount for the right using of source, profitability, environmental pollution and health.

CONCLUSION

Egypt has big potential for the application of precision agriculture but it requires time to solve the problems such as education of farmers, implementation of pilot precision farming projects. If it is realized chemical use in the agriculture will be reduced and yield of agricultural products will be increased.

In this study, the results show the effect of soil variables on the yield production. These results suggest that the delineation of the management zones will help to develop the yield production in the study area through the addition of certain soil variables based on crop requirements and soil conditions and also through soil reclamation procedures. Furthermore, the maps produced by the model can be used as a optimize fertilizers input for onion crop management. Truly, there is a big possibility still to use high-resolution remote sensing imagery is a useful tool in monitoring crop yield for further research in the future.

In fact, some processes of products such as economic crops, vegetables and fruit harvesting etc. have been doing by hand in Egypt. In that fields precision farming applications can be used. Farmer's should be educated for sustainable agriculture and they can learn the actual meaning of precision farming and start creating their specific precision farming solutions.

REFERENCES

[1] Ulger P., Akdemir B., Arin S., 1993. Mechanized planting and harvesting of onion. Agricultural mechanization in Asia. Africa and Latin America (AMA), Vol. 24, 4: 23-26.

[2] Schubert A.M., Trostle C., Porter D., 2002. Precision Agriculture Yield Mapping System For Peanuts On The Texas South Plains. Texas A&M University Agricultural Research &Extension Center Lubbock-Halfway-Pecos.

[3] Morgan M. and Ess D., 1997. The precision farming guide for agriculturists. ISBN 0-86691-245-2, Deere and Company, IL: 29, 31, 42.

[4] Blackmore S., (b), 1999. Yield Mapping (Article on University Homepage). Centre for Precision Farming, Cranfield University, England.

[5] Bahnassy M., Ramadan H., Abdel-Kader F. and Yehia H. M., 2001. Utilizing GIS/RS/GPS for land resources assessment of Wadi El-Natroun, west delta fringe, Egypt. Alex. J. of Agric. Res. 46: 155.

[6] Moussa M. A. R., 1991. Land suitability evaluation of El Saff area, Eastern desert, Egypt for agricultural unitization. Ph.D. Thesis, Fac. of Agric., Zagazig Univ., Benha Branch.

[7] ISSS-ISRIC-FAO, 1998. World Reference Base for Soil Resources. FAO, World Soil Re-sources Report, 84. Rome.

[8] Kemmler G. and Hobt H., 1984. Fertilisers (K+S), FRG, Kassel, Germany, 54-55.

[9] Kacar B., 1995. Chemical Analyses of Soil and Plant. III, Ankara University Agricultural Faculty Education, Research and Development Fund, Publication No. 3, Ankara.

[10] U.S. SOIL CONSERVATION SERVICE, 2003. Keys to Soil Taxonomy by Soil Survey Staff. Eighth Edition, (USDA Agriculture Handbook, 436). Washington, D.C.

[11] Blackmore S., Marshall B.C.J., 1996. Yield mapping; Errors and algorithms. The Centre for Precision Farming, School of Agriculture Food and Environment, Cranfield University, Silsoe, Bedford, MK45 4DT, England.

[12] Blackmore S., (a), 1999. Yield Map Primer. Silsoe College, Cranfield University, Silsoe Bedford, MK45 DT, England.

[13] Akdemir B. and Blackmore S., 2004. A methodology for production of yield mapping. Journal of Agricultural Sciences, ISBN, 1300-7580, 10 (1): 38-44.

[14] Akdemir B., Belliturk K., Sisman C. B. and Blackmore S., 2005. Spatial Distribution in a Dry Onion Field (A Precision Farming Application in Turkey). Journal of Central European Agriculture, Vol 6, No 3 (211-222).

[15] ESRI Inc. 1994-2004. ARC/INFO Grid manual. ESRI Inc. Redlands, CA.

[16] Journel A.G. and Huijbregts Ch., 1978. Mining geostatistics. Academic Press, London.

[17] Goovaerts P., 1997. Geostatistics for natural resources evaluation. Oxford University Press, New York.

[18] SAS Institute Inc., 1988. SAS/STAT user's guide. Release 6.03 ed. SAS Institute, Inc., Cary, NC.

[19] Allen D.M. and Timbrell D., 1987. Onions. Ministry of Agriculture and Food. Ontario, Canada: 27.