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Spatial and Temporal Variability of Soil Fertility for Crop Management under Calcareous Soil Conditions

H. M. Ramadan and M. E. El-Fayoumy
Soil, Water and Environment Research Institute (SWERI),
Agricultural Research Center (ARC), Cairo, Egypt.

THE UNIFORMITY trial was conducted during winter wheat season at El-Bangar area (El-Tanmeya Village) to study the effect of several combinations and rates on NPS fertilizer applications to calcareous soils on field spatial and temporal variability of nutrients level and yield.

Descriptive statistical analysis showed that the variance values of available and uptake of phosphorus and iron in tillering and heading stages and grain yield represent the highest variance among different variables under study.

Semi-variogram and the best fitting were exponential and spherical models for soil pH and soil salinity (ED, dS/m) values fitted Gaussian and exponential models in tillering and heading stages. Data showed that the nugget variance values of pH and EC were 4.62, 7.62 and 3.60, 4.42 m, respectively, which reflects medium to strong spatial dependence and inherited variability.

Semi-variogram were Gaussian and exponential models for the available phosphorus (P) and iron (Fe) values fitted Gaussian and spherical models in tillering and heading stages. Data reveal that the nugget variance values of available P were 39.60 and 25.87 m which reflects strong spatial dependence, while available Fe values were 0.64 and 0.18 m. Its values indicated their weak spatial dependence and low inherited variability. P uptake and Fe uptake fitted to exponential model in heading stage. Data showed that nugget variance values of P uptake and Fe uptake were 45.4 m and 3.6 m, which indicated its strong to medium spatial dependence and high inherited variability.

Gaussian model for the measured wheat grain and straw yield. Data showed that the nugget variance value of grain yield was 3.93 m, which reflects medium to strong spatial dependence and inherited variability. Moreover, its value of straw yield was 0.16 m, indicating its weak spatial dependence.

The kriging maps were drawn to indicate the inherited spatial micro-variability distribution of pH, EC, available and uptake of phosphorus and iron, grain and straw yield.

Data were tested for spatial correlation using autocorrelation function. The data showed the autocorrelation values of grain yield gradually decreased from 0.76 to -0.09 with increasing the distance (log). While, the cross autocorrelation values of grain and straw yield increased with distance indicating that spatial correlation in experimental exists between plots even at large separation distance.

Traditionally, researchers attempting to study field variability have collected samples randomly and designed field trials that involve blocking, randomization, and replication (Montgomery, 1913; Robinson & Lloyd, 1915 and Pendelton, 1919). Classical statistical techniques such as analysis of variance, analysis of covariance, and regression analysis are often used to interpret results and evaluate treatment effects.

The classical approach is sufficient if measured soil and crop properties exhibit random variability with little or no spatial correlation. In the presence of significant spatially correlated trends, the classical assumption of independence between plots is violated. In such a situation, a field researcher may be faced with experimental results that show wide variation in crop yields between plots, but classical statistical analysis shows no significant treatment differences. For example, Trangmar *et al.* (1987) conducted a yield trial in which measured yields ranged from 1.00 to 2.08 Mg/ha. Due to large spatial variability, the coefficient of variation in yield was 37%, and a Waller Duncan LSD of 1.08 Mg/ha caused classical statistical analysis to indicate no significant differences between treatment means. In such situations, no single treatment or group of treatments can be recommended.

Soil variability is an important source of external variation that affects crop yields in field experiments. Many careful experiments have been conducted to develop improved methods for measuring true treatment effects when soil variability affects plot yields (Cochran & Cox, 1957; Mader, 1963; Becket & Webster, 1971 and Eghball & Varvel, 1997).

Spatial variability of soils has been studied by soil scientists for many years (Petersen & Calvin, 1986). When correlation between samples exists, geostatistical procedures are useful for modeling spatial patterns (Vieira *et al.*, 1983; Russo, 1984; Trangmar *et al.*, 1985 and Miller *et al.*, 1988).

Geostatistical methods have rarely been applied to analysis of yield trials where randomization and replication occurs (Mulla *et al.*, 1990). Yet, the semi-variogram is potentially a useful tool for quantifying spatial correlation between treated plots and indicating when classical statistical methods of analysis may fail (Perrier & Wilding, 1986; Trangmar *et al.*, 1987 and Miller *et al.*, 1988).

Studying crop growth under field conditions requires a basic knowledge of magnitudes and scales of spatial and temporal variability. Farmers and researchers have known in relative sense that crop yields are not uniform across fields. Some locations will consistently produce higher or lower yields than the field average, while other locations produce higher or lower yields in some years but not in others. With recent evolution of yield monitors (Borgelt, 1991). Quantitative measurement of within-field yield variations is now simple and inexpensive, and will soon become routine, allowing for a more systematic study of yield-both the spatial and temporal components. Currently, we know little about the spatial structure neither of these yield patterns, nor of the consistency of these patterns from month to month and year to year (Dobeman *et al.*, 1995).

The agronomic benefits of using site-specific crop management practices are presumably related to the spatial patterns of soil properties and soil nutrient levels. Variography has been used to compare the spatial variation of soil properties with scale and times (Chan *et al.*, 1994).

In recent years, with the integration of computer and sensor technology, it has become possible to monitor crop yield for different sites within a field. Yield maps can illustrate the location of problem sites within a field, which can be used to guide or identify management practices for the next growing season. Data collected from yield maps can be analyzed for grain yield variability across space or time.

Precision Farming is a way to manage the heterogeneity within a field. Traditional agriculture considers a field as a homogeneous unit. Fields used to be smaller and more uniform, field boundaries were probably adapted to get uniform fields. As a result of mechanization, farmers are able to work bigger areas and fields became bigger and more variable. Because of the large areas of farms and fields, fanners (and agronomists) lost their "feeling" with the fields and are looking for tools to manage the local differences in fields. Nowadays, technology makes it possible to handle these differences and treat the fields in a local way (www.precisionag. com).

Precision farming is a tool to handle the spatial and temporal variability and creates a framework to understand and control the (local) processes in the field. An ensemble of collected information (yield maps, soil maps, multi-spectral satellite images, ...), management decisions and outputs (fertilizing, drainage, spraying, ...) can be used for different goals. The developed management strategy can result in a reducing of inputs, higher profitability, environmental protection and/or higher yields (www.precisionag. com).

The objective of this research was to study the precision fasrming as a tool to handle the soil spatial and temporal variability of site-specific crop management.

Material and Methods

Experimental design and application of fertilizers

The experimental design was split-split-plot with three replications. The main plots were for nitrogen rates, sub-plots were for phosphorus, and sub-sub-plots were for elemental sulphur. Organic manure was well mixed before planting in the soil surface for all plots. Four rates of mineral nitrogen and phosphorus were tested; 0 (N_0), 40 (N_1), 80 (N_2) and 120 (N_3) kg N fed^{-1} and 0 (P_0), 10 (P_1), 20 (P_2) and 30 (P_3) kg P_2O_5 fed^{-1}, respectively. Five elemental sulphur rates; 0 (S_0), 200 (S_1), 400 (S_2), 600 (S_3) and 800 (S_4) kg fed^{-1} were tested. The total number of experimental plots were (4x4x5x3=240 plots) (Fig. 1-a). Seeds of wheat *(Triticum vulgaris* L.) variety Sakha 69 were planted at the rate of 65 kg fed^{-1}. Nitrogen fertilizer was split into three equal doses as NH_4NO_3 within planting, tillering and heading stages. Phosphorus fertilizer was normal superphosphate, and potassium in the form of K_2SO_4 at the rate of 48 kg K_2O fed^{-1} were added during the field preparation.

Soil and plant sampling

Two hundred and forty soil samples were collected from surface soil (0-30 cm) in tillering and heading of wheat growth stages. Wheat grain and straw yields were estimated according to grid system design (2.5x2.0 m) (Fig. 1-a,b).

Soil and plant analysis

Soil samples were air-dried, ground, sieved through a 2mm sieve. Phosphorus (P) extractable in 0.5M $NaHCO_3$ was determined by the ascorbic acid molybdenum blue method (Olsen & Sommers, 1982).

Soil samples were analyzed for pH and electrical conductivity (EC, dS/m) in soil water suspension (1:2.5). Available P and Fe nutrients at tillering and heading stages were determined.

Fresh plant material was washed and dried at 65° for 48 hr, wet ashed by concentrated sulphuric acid and H_2O_2 at tillering and heading stages (FAO, 1975). Phosphorus was determined by the vanadomolybdate yellow method (Jackson, 1958). Iron was determined using atomic absorption spectrophotometer.

Data recorded

The following data were recorded:

1) pH, EC and available P and Fe.
2) Grain (Ardab/fed) (one Ardab = 150 kg) and straw (ton/fed) yields.
3) Plant P and Fe uptake.

Quantification of spatial interdependence

Spatial variations with interdependence are commonly described with a correlogram variogram. In either case, asset of values [$Z(x_1)$, $Z(x_2)$, ..., $Z(x_n)$] was considered. It is not required that the value be for an exact point, but rather that each value is for a defined support volume which is centered at x.

Descriptive statistics (minimum, maximum, mean, medium, standard deviation, variance, Kurtosis and Skewness) were calculated using SPSS software (2002).

N_1	N_0	N_2	N_3	N_2	N_1	N_3	N_0	N_1	N_0	N_2	N_3
P_0S_1	P_2S_3	P_3S_2	P_0S_4	P_2S_3	P_3S_4	P_1S_2	P_2S_1	P_2S_3	P_2S_1	P_0S_0	P_3S_2
P_0S_0	P_2S_4	P_3S_3	P_0S_2	P_2S_4	P_3S_2	P_1S_3	P_2S_0	P_2S_4	P_2S_2	P_0S_4	P_3S_3
P_0S_2	P_2S_0	P_3S_1	P_0S_3	P_2S_0	P_3S_3	P_1S_1	P_3S_2	P_2S_0	P_2S_3	P_0S_3	P_3S_1
P_0S_3	P_2S_1	P_3S_0	P_0S_1	P_2S_1	P_3S_1	P_1S_0	P_2S_3	P_2S_1	P_2S_4	P_0S_1	P_3S_0
P_0S_4	P_2S_2	P_3S_4	P_0S_0	P_2S_2	P_3S_0	P_1S_4	P_2S_4	P_2S_2	P_2S_0	P_0S_2	P_3S_4
P_1S_2	P_3S_0	P_1S_3	P_2S_3	P_3S_2	P_1S_3	P_2S_0	P_3S_3	P1S_1	P_0S_3	P_2S_2	P_3S_3
P_1S_3	P_3S_4	P_1S_1	P_2S_4	P_3S_3	P_1S_4	P_2S_1	P_3S_1	P1S_0	P_0S_4	P_2S_4	P_2S_1
P_1S_1	P_3S_3	P_1S_4	P_2S_2	P_3S_4	P_1S_2	P_2S_4	P_3S_4	P1S_4	P_0S_0	P_2S_3	P_2S_4
P_1S_0	P_3S_2	P_1S_0	P_2S_1	P_3S_0	P_1S_1	P_2S_3	P_3S_0	P1S_3	P_0S_2	P_2S_1	P_2S_0
P_1S_4	P_3S_1	P_1S_2	P_2S_0	P_3S_1	P_1S_0	P_2S_2	P_3S_2	P1S_2	P_0S_1	P_2S_0	P_2S_2
P_2S_0	P_0S_3	P_2S_1	P_3S_3	P_1S_3	P_0S_3	P_3S_3	P_0S_2	P_0S_2	P_3S_3	P_3S_1	P_0S_1
P_2S_1	P_0S_4	P_2S_0	P_3S_2	P_1S_4	P_0S_2	P_3S_2	P_0S_3	P_0S_3	P_3S_1	P_3S_3	P_0S_0
P_2S_4	P_0S_0	P_2S_3	P_3S_0	P_1S_0	P_0S_0	P_3S_4	P_0S_4	P_0S_4	P_3S_4	P_3S_4	P_0S_3
P_2S_3	P_0S_2	P_2S_2	P_3S_1	P_1S_2	P_0S_1	P_3S_0	P_0S_1	P_0S_1	P_3S_2	P_3S_2	P_0S_2
P_2S_2	P_0S_1	P_2S_4	P_3S_4	P_1S_1	P_0S_4	P_3S_2	P_0S_0	P_0S_0	P_3S_0	P_1S_0	P_0S_4
P_3S_2	P_1S_3	P_0S_0	P_1S_3	P_0S_3	P_2S_1	P_0S_0	P_1S_3	P_3S_3	P_1S_2	P_1S_3	P_1S_3
P_3S_3	P_1S_1	P_0S_2	P_1S_4	P_0S_1	P_2S_3	P_0S_2	P_1S_2	P_3S_2	P_1S_1	P_1S_1	P_1S_1
P_3S_4	P_1S_4	P_0S_4	P_1S_1	P_0S_4	P_2S_4	P_0S_4	P_1S_1	P_3S_1	P_1S_3	P_1S_0	P_1S_4
P_3S_0	P_1S_0	P_0S_3	P_1S_0	P_0S_0	P_2S_2	P_0S_1	P_1S_4	P_3S_4	P_1S_4	P_1S_4	P_1S_0
P_3S_1	P_1S_2	P_0S_1	P_1S_2	P_0S_2	P_2S_0	P_0S_3	P_1S_0	P_3S_0	P_1S_0	P_1S_2	P_1S_1

Fig. 1-a. Experimental design and application of fertilizers (N, P and S).

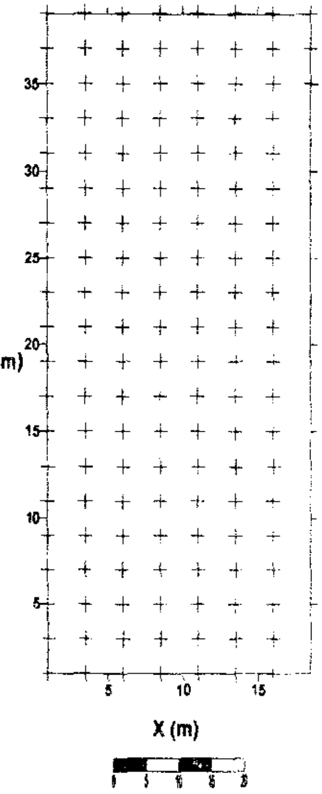

Fig. 1-b. Location of observation soil and plant samples according to Georeferenced.

Geostatistical analysis

Variogram analysis

The semi-variogram is the most single important tool in geostatistical applications to soil. It represents the average rate of change of a property with distance, and its shape describes the pattern of spatial variation in terms of its magnitude, scale and general form. The semi-variance is defined as:

$$\gamma (h) = 1/2 \operatorname{Var}[Z(x) - Z(x+h)]$$

where: $Z(x)$ and $Z(x \pm h)$ are the values of a random function representing vector h knowas the lag or interval (Warrick *et al.*, 1986).

In describing soil variations by semi-variogram the best fitting model for a suitable function must be carried out (Webster, 1985; Warrick *et al.*, 1986 and Oliver & Webster, 1991). The semi-variogram model with its parameters is shown in Fig. 2, as an example of how these models and their parameters are illustrated on graphs.

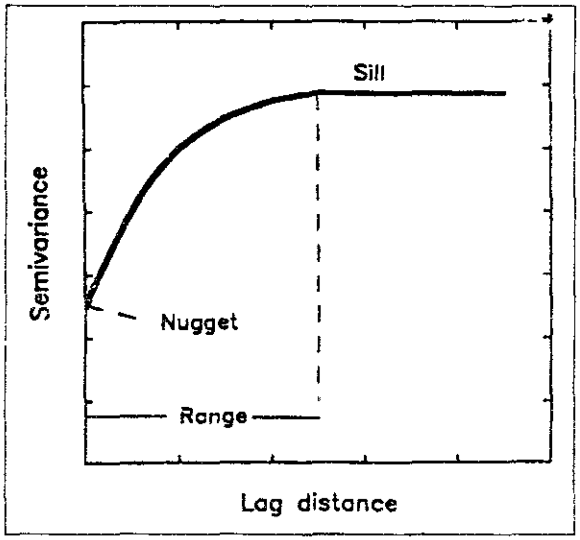

Fig. 2. Typical variogram model and its parameters.

γ: The semi-variogram.
Co: The nugget variance
Co+C: The sill variance.
A_o: The range distance.
H: The lag distance.

The nugget (Co) is the semi-variance values due to short scale or inherited variability, the range (A_o) is the distance at which the semi-variance reaches its maximum, after which there is no spatial dependence occur among the samples, and within it interpolation is worth. The sill (Co+C) is the plateau (constant value) that the semi-variogram reaches (Issaks & Srivastava, 1989). The obtained semi- variance values for each lag were fitted to one of the semi-variogram functions using the GSPLUS geostatistical analysis software, (Gamma Design,1991).

Kriging

Kriging is a method of interpolation using the weighted local averaging. It is optimal in a sense that the weights are chosen to give unbiased estimates, while keeping the estimation variance at minimum (Webster, 1985). Kriging maps were calculated and drown using Gamma Design (1991), software and 3D using Surfer software (1994).

Correlogram (Autocorrelation) analysis

The correlogram (autocorrelation) $\rho(h)$ of the regionalized variable Z is defined by the equation:

$$\rho(h) = \mathrm{Cov}\,[Z(x), Z(x+h)] / \sigma^2$$

The covariance "Cov" is for any two values of Z at a distance h apart and σ^2 is the variance of Z. Thus, the correlogram is a series of correlations for a common variable where each couple is separated by distance h. In general, x and h are vector quantities and ρ will depend on the direction as well as the magnitude of h. The correlogram can have possible values from -1 to 1 just as can an ordinary correlation coefficient (Warrick *et al.*, 1986) (Fig. 3). The obtained autocorrelation values for each lag were calculated using SPSS (2000).

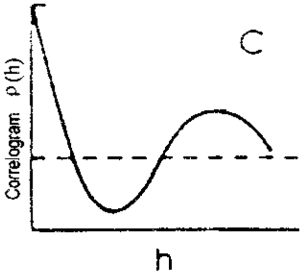

Fig. 3. Idealized correlogram: a cyclical system.

Precision agriculture cycle

Precision Farming is a cycle that mostly starts at the harvest of a crop (Fig. 4). Based on the yield map, the critical areas in the field can be discovered. Based on the soil properties, weather conditions and the yield map, the farmer takes his management decisions. He decides were to have what seed and fertilizer rate. By the end of the season, a new map is created and variability in time can be evaluated. Areas that have the same response (clusters) can be derived and the amount of soil samples can be reduced (www.precionag.com)

Results and Discussion

Descriptive statistical analysis

Table 1 showed that the variance values of available and uptake of P and Fe in tillering and heading stages and grain yield represent the highest variance among different variables under study. The variance values of available P were 205.72 and 22.608, while its values of available Fe were 3.14 and 11.21 in tillering and heading stages, respectively. Its value of P-uptake was 57.92. The variance value of grain yield was 25.02.

Generally, under these experimental conditions and from these results, it can be concluded that the high NPS applications led to high heterogenity of soil fertility and crop yield.

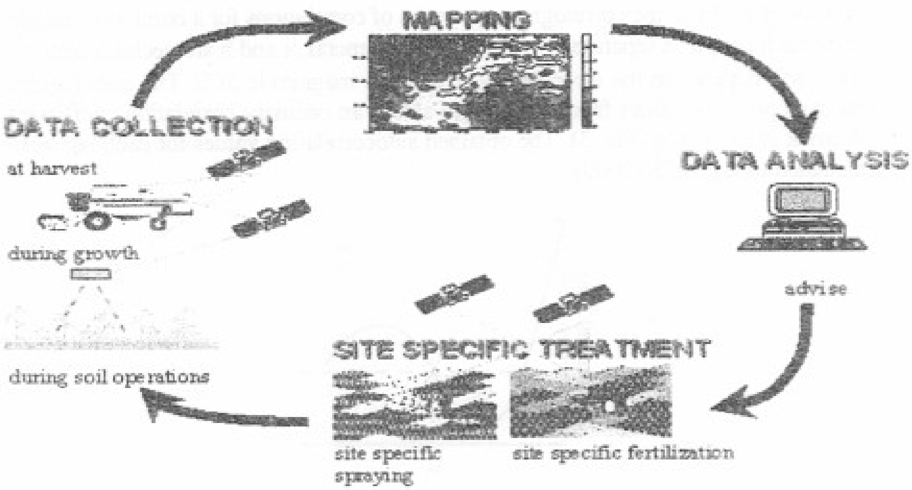

Fig. 4. Precision agriculture cycle.

TABLE 1. Descriptive statistical analysis of soil-plant properties in different stages and yield.

	Minimum	Maximum	Range	Mean	Std.	Variance	Skewness	Kurtosis
Tillering stage								
pH	7.35	8.87	1.52	8.11	0.28	7.68	-0.21	0.08
EC (dS/m)	0.24	2.31	2.07	1.08	0.40	0.16	0.47	-0.10
Available P (mg/kg)	4.50	89.00	84.50	20.46	14.34	205.72	2.00	4.78
Available Fe (mg/kg)	0.26	15.81	15.55	7.32	1.77	3.15	0.01	3.12
Heading stage								
pH	7.20	8.70	1.50	7.94	0.47	0.22	-8.54	106.89
EC (dS/m)	0.25	3.90	3.65	1.09	0.70	0.50	1.37	1.49
Available P (mg/kg)	4.20	28.84	24.64	11.49	4.76	22.61	0.97	0.57
Available Fe (mg/kg)	6.80	25.80	19.00	15.83	3.35	11.21	-0.49	0.75
P uptake (kg/fed.)	2.92	41.60	38.68	19.72	7.61	57.92	0.39	0.02
Fe uptake (kg/fed.)	0.35	2.80	2.45	1.36	0.48	0.23	0.54	0.09
Harvest stage								
Grain yield (Ardab/fed.)*	2.89	19.93	17.04	12.40	5.00	25.03	-0.58	-1.02
Straw yield (ton/fed.)	0.89	5.08	4.19	3.05	0.97	0.94	-0.26	-0.59

one Ardab = 150 kg.

Geostatistical analysis

Semi-variogram model and kriging maps

pH and soil salinity: Semi-variance and the best fitting were exponential and spherical semi-variogram models for the soil pH and soil salinity (EC, dS/m) values fitted Gaussian and exponential models in tillering and heading stages (Table 2). Data showed that the nugget variance values of pH and EC were 4.62, 7.62 and 3.60, 4.42 m for the two stages, respectively (Table 2), which reflects medium to strong spatial dependence and inherited variability. Furthermore, the sill variance values which illustrated the structural variance of pH values were 9.62 and 13.80, and EC values were 15.0 and 11.8 m. The results of range which illustrated the spatial dependence over specific lag distance showed the maximum interpolation for pH and EC being 55.27, 23.62 and 21.54, 61.92 m, respectively (Table 2). The kriging maps (Fig. 5 and 6) show the horizontal spatial distribution of soil pH and salinity (EC, dS/m) in tillering and heading stages.

TABLE 2. Semi-variogram parameters: nugget (Co), sill (Co+C), range (A_0) and model type of soil-plant properties in different stages and yield.

Properties		**Model**	**Co (m)**	**Co+C (m)**	**A_0 (m)**	**R^2**
		Tillering stage				
pH		Exponential	4.62	9.62	55.27	0.93
EC	(dS/m)	Gaussian	3.60	15.00	21.54	0.73
Available P	(mg/kg)	Gaussian	39.60	248.40	1.72	0.84
Available Fe	(mg/kg)	Gaussian	0.64	3.71	0.43	0.82
		Heading stage				
pH		Spherical	7.62	13.80	23.62	0.82
EC	(dS/m)	Exponential	4.42	11.18	61.92	0.78
Available P	(mg/kg)	Exponential	25.87	28.32	31.66	0.81
Available Fe	(mg/kg)	Spherical	0.18	5.21	3.80	0.91
P-uptake	(kg/fed)	Exponential	45.40	127.91	71.00	0.81
Fe-uptake	(kg/fed)	Exponential	3.60	8.73	28.57	0.62
		Harvest stage				
Grain yield	(Ardab/fed)	Gaussian	3.93	22.56	4.03	0.99
Straw yield	(ton/fed)	Gaussian	0.16	0.91	3.74	0.83

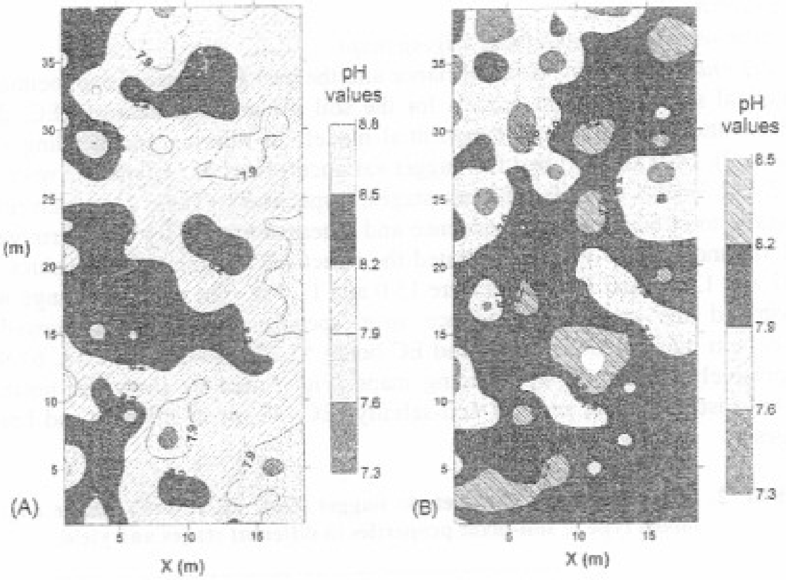

Fig. 5. Kriged spatial distribution of soil pH in tillering stage (A) and heading stage (B).

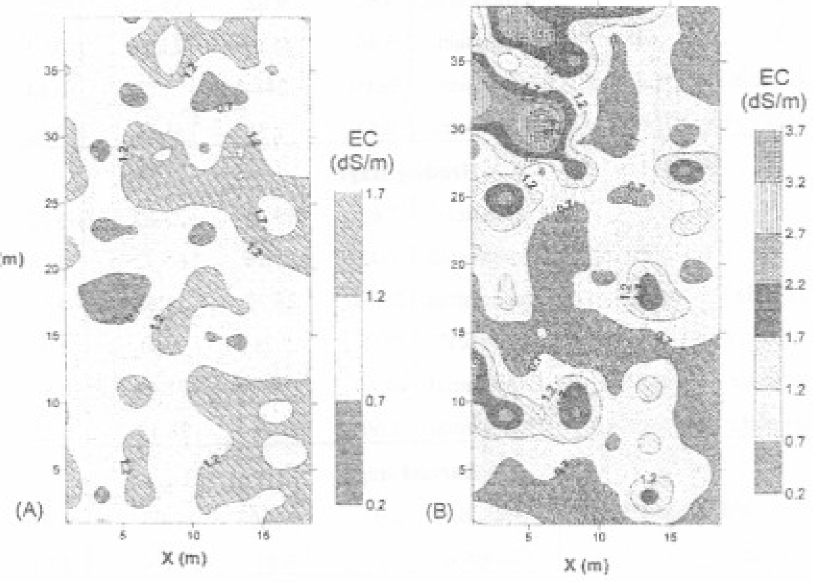

Fig. 6. Kriged spatial distribution of soil salinity (dS/m) in tillering stage (A) and heading stage (B).

Available phosphorus (P) and iron (Fe): Semi-variogram and the best fitting were Gaussian and exponential models for the available P and Fe values fitted Gaussian and spherical models in tillering and heading stages. Data reveal that the nugget variance values of available P were 39.60 and 25.87 m which reflects strong spatial dependence. While available Fe values were 0.64 and 0.18 m (Table 2). Its values had the weak nugget and indicated their weak spatial dependence and low inherited variability. The sill variance of available P and Fe values were 248.4, 28.32 and 3.7, 5.21 m in tillering and heading stages (Table 2). The kriging maps Fig. 7 and 8 indicate the inherited spatial microvariability distribution of available Fe and P (mg/kg) in tillering and heading stages.

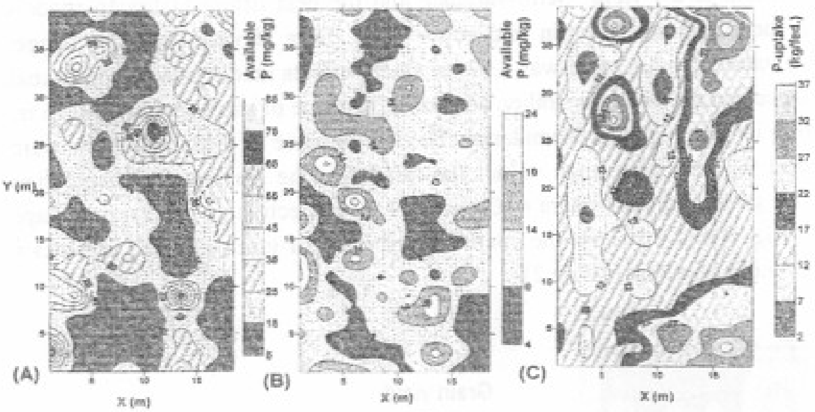

Fig. 7. Kriged spatial distribution of available P (mg/kg) in tillering stage (A), heading stage (B) and P-uptake (kg/fed) in heading stage (C).

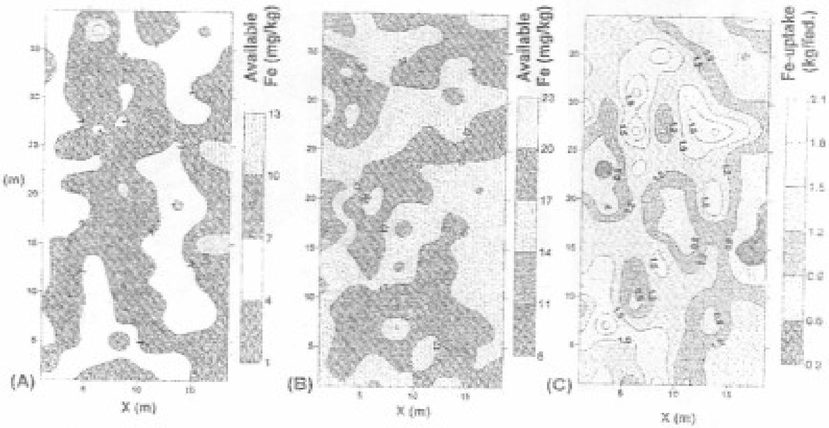

Fig. 8. Kriged spatial distribution of available Fe (mg/kg) in tillering stage (A), heading stage (B) and Fe-uptake (kg/fed) in heading stage (C).

P and Fe uptake: P and Fe uptake fitted to exponential model in heading stage. Data showed that nugget variance value of P uptake was 45.40 m which indicated its strong spatial dependence and high inherited variability. While, Fe uptake was 3.6 m, indicating its medium spatial dependence and inherited variability. The sill variance of P and Fe uptake were 127.91 and 8.73, respectively. The results of range showed that the maximum interpolation for P and Fe uptake (71.0 and 28.57 m). The kriging maps Fig. 7 and 8 show the strong spatial variability distribution of P and Fe uptake (kg/fed).

Grain and straw yield: Semi-variance and the best fitting Gaussian models for the measured wheat grain and straw yield. Data showed that the nugget variance value of grain yield was 3.93 m which reflects medium to strong spatial dependence and inherited variability. Moreover, its value of straw yield was 0.16 m, indicating its weak spatial dependence. The sill variance of grain and straw were 22.56 and 0.91 m. The range values indicated that the maximum interpolation values for grain and straw were 4.03 and 3.74 m, respectively. The kriging maps and 3D Fig. 9 and 10 show the spatial distribution of grain (kg/fed) and straw (ton/fed) yield of wheat (Table 2).

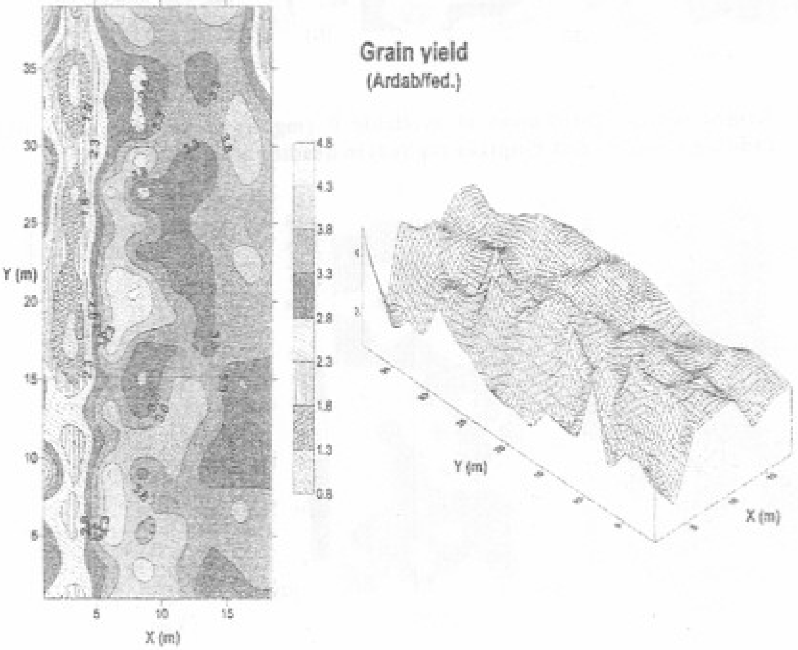

Fig. 9. Kriged spatial distribution and 3D of wheat grain yield (Ardab/fed).

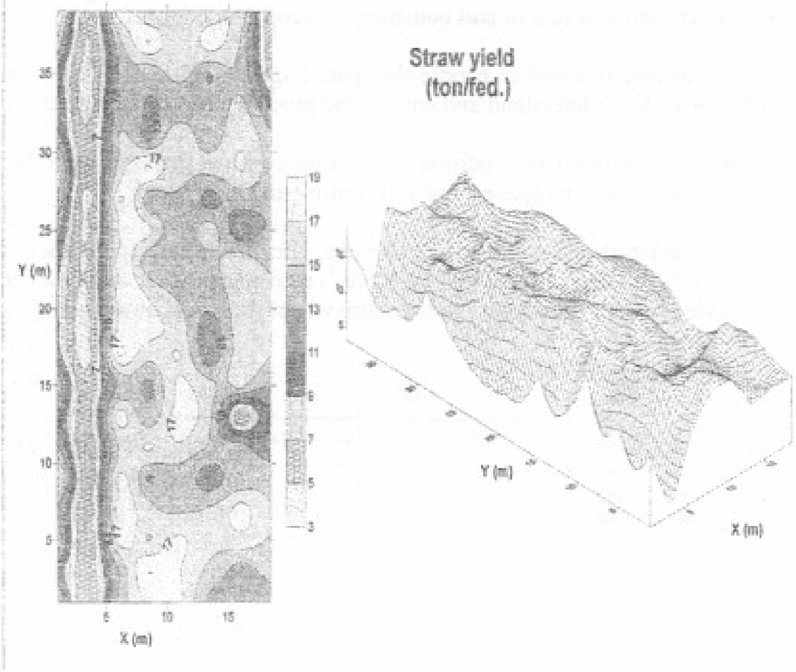

Fig. 10. Kriged spatial distribution and 3D of wheat straw yield (ton/fed).

Autocorrelation (Correlogram)

Data tested for spatial correlation using autocorrelation function (Fig. 11) showed that the autocorrelation values of grain yield gradually decreased from 0.76 to -0.09 with increasing the distance (lag). The estimated values were small negative values as insignificant correlations. Fig. 12 indicated the cross autocorrelation values of grain and straw yield. The data showed significant spatial correlation with lag, while its values with decreasing the distance (lag). The cross autocorrelation values of grain and straw yield increased with distance, indicating that spatial correlation in experimental exists between plots even at large separation distance. Cross autocorrelation has proven useful in determining grain and straw yield and its spatially correlated to crop yield with distance. Generally, the spatial correlation analysis showed that the high soil and yield heterogeneity due to a uniform application of fertilizers of field trial.

Conclusion

Analysis of spatial response of crop growth to the variability of soil properties, such as nutrient uptake in response to variation of soil salinity and nutrient parameter, may further contribute to the agronomists understanding the role of spatial effects on soil-crop relations. Adaptation of volume-variance relationships to the agronomic situation offers the potential for spatial interpretation of critical levels of soil constrains to crop production.

Precision farming is a tool to handle the spatial and temporal variability and creates a framework to understand and control the processes in the field trial.

Under these experimental conditions, the results show that the high NPS applications led to high heterogeneity of soil fertility and crop yield.

Generally, under this experiment conditions, the combined application of $N_3P_2S_2$ (120 kg N, 20 kg P_2O_5 and 400 kg S fed^{-1}) proved optimum and balanced rates for growing wheat. It resulted in maximum wheat grain and straw yield.

```
Autocorrelations: (Ardab/fed )
        Pr-Aut-   Stand
 Lag    Corr.     Err. -1   -.75   -.5 -.25    0   .25  .5   .75   1
                        |----|-----|----|------|----|----|-----|-----|
  1     .761     .065                        .  |**.************
  2     .293     .065                        .  |**.***
  3     .086     .065                        .  |**.
  4     .192     .065                        .  |**.*
  5    -.031     .065                        . *|  .
  6    -.112     .065                        .**|  .
  7     .035     .065                        .  |* .
  8     .009     .065                        .  *  .
  9    -.096     .065                        .**|  .
 10    -.092     .065                        .**|  .
 11     .001     .065                        .  *  .
 12     .009     .065                        .  *  .
 13    -.041     .065                        . *|  .
 14    -.042     .065                        . *|  .
 15    -.080     .065                        .**|  .
 16    -.088     .065                        .**|  .
 Plot Symbols:        Autocorrelations   *    Two Standard Error Limits.
 Total cases: 302         Computable first lags: 239
```

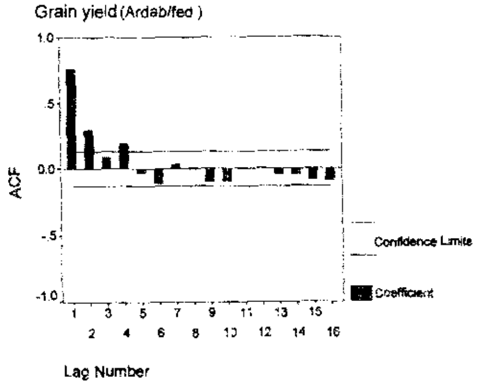

Fig. 11. Autocorrelation of spatial distribution of wheat grain yield (Ardab/fed).

```
Cross Autocorrelation
                                  Grain yield, Ardab/fed
                                  Straw yield, ton/fed
      Cross  Stand.
Lag   Corr.   Err. -1   -.75   -.5 -.25    0    .25  .5   .75   1
                    |-----|-----|-----|-----|-----|-----|-----|-----|
 -7    .434    .066                    .    |**.******
 -6    .490    .065                    .    |**.*******
 -5    .555    .065                    .    |**.********
 -4    .610    .065                    .    |**.*********
 -3    .589    .065                    .    |**.*********
 -2    .664    .065                    .    |**.**********
 -1    .721    .065                    .    |**.***********
  0    .914    .065                    .    |**.***************
  1    .683    .065                    .    |**.***********
  2    .642    .065                    .    |**.**********
  3    .580    .065                    .    |**.*********
  4    .576    .065                    .    |**.*********
  5    .497    .065                    .    |**.*******
  6    .419    .065                    .    |**.*****
  7    .378    .066                    .    |**.*****

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .
Total cases: 302          Computable 0-order correlations: 240
```

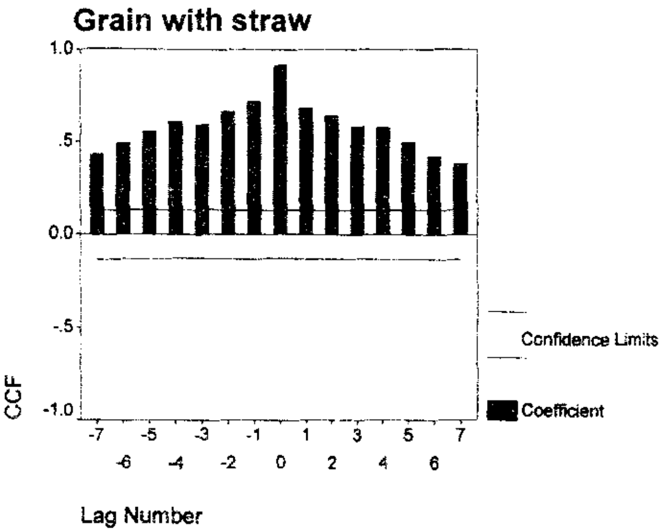

Fig. 12. Cross autocorrelation of spatial distribution of grain (kg/fed) with straw (ton/fed) yield of wheat.

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الإختلافات المكانية والزمنية لخصوبة التربة لإدارة المحصول تحت ظروف الأراضى الجيرية

هانى محمد رمضان و محمد عصمت الفيومى
معهد بحوث الأراضى والمياه والبيئة – مركز البحوث الزراعية – القاهرة – مصر.

أقيمت تجربة حقلية لمحصول القمح بقرية التنمية بمنطقة بنجر السكر بغرض دراسة تأثير إضافة معدلات من أسمدة النتروجين والفوسفور والكبريت الزراعى على الإختلافات المكانية والزمنية لمستويات العناصر بالتربة وإنعكاس ذلك على الإختلافات الفراغية للمحصول. وتتلخص النتائج فيمايلى:

أ- التحليل الإحصائى الوصفى: أوضح أن قيم التباين Variance للفوسفور والحديد المتاح والممتص بواسطة النبات فى مرحلة التفريغ وطرد السنابل ومحصول الحبوب تمثلت فى أعلى قيم للتباين بالنسبة لباقى الصفات المدروسة.

ب- التحليل الجيوإحصائى المكانى Geostatistics

١. التباين مع المسافة Variogram

- رقم الحموضة والقلوية وملوحة التربة :

أوضح نموذج الـ Semi-variogram لرقم الحموضة والقلوية Exponential و Spherical بينما لملوحة التربة Gaussian و Spherical فى مرحلتى التفريغ وطرد السنابل على الترتيب.

رقم الحموضة والقلوية وملوحة التربة كانت تمثل إختلافات تباين Nugget variance متوسطة إلى شديدة وكانت بالنسبة لرقم الحموضة (٤,٦٢ ، ٧,٧٢م) وملوحة التربة (٣,٦ ، ٤,٤٢م).

- الفوسفور والحديد المتاح فى التربة

الفوسفور والحديد المتاح تمثل فى نموذج Gaussian و Spherical فى مرحلتى التفريغ وطرد السنابل.

قيم الفوسفور المتاح تمثل فى إختلافات تباين مع المسافة مرتفعة (٣٩,٦،٢٥,٨٧م) .

قيم الحديد المتاح كانت منخفضة للتباين مع المسافة (٠,٦٤ ، ٠,١٨م).

الفوسفور والحديد الممتصة بواسطة النبات

الفوسفور والحديد الممتص بواسطة النبات فى مرحلة طرد السنابل تمثل فى نموذج Exponential.

قيم التباين مع المسافة للفوسفور الممتص كانت (٤٥,٤ ، ٣,٦م) والتى مثلت أعلى إختلافات تباين للصفات المدروسة بينما قيم الحديد الممتصة كانت ٣,٦م والتى تمثل إختلافات متوسطة.

محصول القمح

محصول الحبوب والقش تمثل فى نموذج Gaussian وقيم التباين مع المسافة لمحصول الحبوب كانت ٣,٩٣م وتمثل إختلافات متوسطة إلى مرتفعة بينما محصول القش كان ٠,١٦م وتمثل إختلافات ضعيفة.

٢. خرائط Kriging

تم رسم خرائط Kriging لتوضيح التوزيعات الفراغية (المكانية) لكل من رقم الحموضة وملوحة التربة والفوسفور والحديد المتاح فى التربة والممتص بواسطة النبات وكذلك محصول الحبوب والقش للقمح.

٣. التلازم مع المسافة Correlogram

تم دراسة التلازم مع المسافة للتغيرات المكانية لمحصول الحبوب والقش. وأوضحت الدراسة أن التلازم مع المسافة لمحصول الحبوب يقل كلما إزدادت المسافة بينما التلازم المركب لكل من محصول الحبوب والقش يزداد بزيادة المسافة ممايعكس إختلافات العناصر بالتربة التى إنعكست على المحصول.

ويعتبر مفهوم الزراعة الدقيقة Precision farming أداة هامة لإدارة التغيرات الفراغية والزمنية للتربة والتى ينعكس على الإدارة المحصولية.