Pak. j. life soc. Sci. (2013), 11(1): 29-35 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

RESEARCH ARTICLE

Evaluation of Management Zones for Site-Specific Application of Crop Inputs

Hafiz Umar Farid[1,*], Allah Bakhsh[1], Niaz Ahmad[1] and Ashfaq Ahmad[2]
[1]Department of Irrigation and Drainage, University of Agriculture, Faisalabad, Pakistan
[2]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan

ARTICLE INFO

Received: Jan 06, 2013
Accepted: Jan 18, 2013
Online: Feb 17, 2013

Keywords
Management zones
Water use efficiency
Wheat yield

***Corresponding Author:**
farid_vjr@yahoo.com

ABSTRACT

Management zones can be used as a method to apply agricultural inputs more efficiently within the field for minimizing offsite transport of agri-chemicals. A two years (2010-11 to 2011-12) field experimental study was conducted at the Postgraduate Agricultural Research Station of the University of Agriculture, Faisalabad, Pakistan, to evaluate management zones by applying different urea fertilizer rates. Six urea fertilizer treatments were applied across all management zones; such as, T_1 (173 kg-urea/ha), T_2 (123 kg-urea/ha), T_3 (74 kg-urea/ha), T_4 (control; no urea application), T_5 (variable rate of urea fertilizer application), and T_6 (247 kg-urea/ha). The results indicated that evaluation based on normalized wheat yield data showed variability in grain yield emphasizing importance of management zones. The coefficients of variation (CV) were found to be 3%, 6%, 7%, 10%, 11%, and 16% for treatments T_5, T_2, T_3, T_6, T_1 and T_4, respectively. These results also indicated that treatment T_5 (variable amount of urea fertilizer application) showed less variation across the management zones for grain yield data than those of treatments T_4, T_1, T_6, T_3 and T_2, respectively. These results suggest that each management zone can be treated by applying variable amount of urea fertilizer rates for promoting site specific application of crop inputs.

INTRODUCTION

The delineation of management zones (MZs) can be used as a method to apply agricultural inputs precisely within the field (Schepers et al., 2004). A number of studies have been conducted to delineate the sub-areas within a field for site-specific application of inputs using soil and landscape attributes (Jaing et al., 2012; Orteqa and Santibanez, 2007; Kitchen et al., 2005). Fleming et al. (2004) utilized a farmer's experience in combination with aerial photos to define areas of similar soil properties. Soil zones based on topography have also been used for developing MZs (Franzen et al., 2000). Some researchers have used elevation and other topographic attributes i.e. spatial data to delineate MZs (Jaing et al., 2012; Orteqa and Santibanez, 2007; Kitchen et al., 2005; Schepers et al., 2004). Abdul et al. (2007) found that MZs based on the soil nitrogen provided useful information for site specific application of nitrogen fertilizer. Soil EC has also been used to delineate the MZs and to investigate the yield variability within the zones due to soil water differences (Bansod et al., 2012).

In the past decade, many researchers have used different methods to delineate semi homogenous zones within the fields. In this context, cluster analysis procedure in Site-Specific Crop Management (SSCM) application have been used to identify the sub-areas within the filed, which have homogenous soil and landscape properties (Fraisse et al., 2001). Kitchen et al. (1998) has compared the traditional soil survey maps and map overlay approaches to delineate the MZs based on the topsoil depth and elevation. Yield mapping is also another approach to delineate MZs. Yield mapping across the fields can be helpful for adopting precision agriculture technology (Pierce and Nowak, 1999).

In fact, the management zones are areas within the fields having homogeneous landscape attributes and soil properties. The homogeneity of attributes in management zones can lead to the similar crop yield potential, input use efficiency and environmental impact (Schepers et al., 2004). Therefore, there is a need to evaluate the delineated management zones by applying site specific agricultural inputs. Keeping in view the environmental repercussions being caused by offsite transport of agricultural chemicals, the present study was designed with the following specific objectives to:

- Compare the response of management zones on wheat grain yield data and water use efficiency for verifying their spatial variability effects.
- Evaluate effects of variable rates of fertilizer application on wheat grain yield based on management zones for promoting site specific application of crop inputs.

MATERIALS AND METHODS

Study area

Field experimental studies were conducted at the Postgraduate Agricultural Research Station (PARS) of the University of Agriculture, Faisalabad, Pakistan during wheat growing seasons of 2010-11 and 2011-12. The study area is located in *Rachna Doab* (land between Rivers Ravi and Chenab) with coordinates having longitude of 73^{o}0′ E and latitude of 31^{o}2′ N. The field has been traditionally under wheat cultivation over the years. The study area is a part of the Indus Plain, which consists of alluvial deposits, brought by the Indus River and its tributaries from the Himalayas. The soils of the study area are predominantly medium to moderately coarse. The soils are generally low in organic matter contents having pH in the range of 7.0 to 8.5 (Mehdi et al., 2011; Tanvir, 2010; Manzoor et al., 2008; Ali et al., 2005). The maximum daily summer temperature has been reported to be 48^{o}C and minimum daily winter temperature of about 4.8^{o}C. The average normal precipitation at the study area is 386 mm (ASP, 2010). The climatic conditions during the growing seasons (2010-11 and 2011-12) are given in Table 1.

Soil sampling

The field was divided into regular grids of 24 × 67 m in size. A total of 48 soil samples were collected from top 30 cm of soil at random from each grid of 24 × 67 m in size using augers prior to sowing of the wheat (Tsirulev, 2010; Irmak et al., 2001; Franzen and Cihacek, 1998). These soil samples were analyzed in laboratory for determining percent sand, silt, clay, soil EC, pH, soil nitrogen and phosphorus (Table 2). Based on the textural analysis, soil of the study area was classified into five classes i.e. clay loam, clayey, sandy clay loam, sandy loam and silt clay loam.

Topographic survey

Topography plays an important role in agricultural fields in terms of shaping the spatial variability of soils, surface and subsurface hydrology, and crop yields. Soil properties vary with topographic settings (Iqbal et al., 2005). Topographical information can be helpful in site-specific management for delineating areas where crop yields are more sensitive to extreme weather conditions (Kravchenko and Bullock, 2000). Therefore, topographical survey of the field was conducted at 48 data points, following a regular grid of 24 ×67 m in size using optical surveying dumpy level (Sokkia C330) along with a GPS receiver (GARMIN 60. The highest elevation of 185.9 m, above mean sea level (amsl), occurred in east corner of the field whereas the lowest elevation of 185.0 m was found in west corner of the

Table 1: Climatic conditions during growing seasons

Date	2010-11				2011-12			
	Temperature (^{o}C)			Rain-fall (mm)	Temperature (^{o}C)			Rain-fall (mm)
	Max	Min.	Avg.		Max	Min.	Avg.	
November	27.08	10.52	18.80	0.00	27.63	13.32	20.48	0.00
December	20.77	5.85	13.31	1.00	20.85	4.19	12.52	0.00
January	15.89	4.32	10.10	0.00	17.29	3.19	10.24	3.80
February	20.16	8.66	14.41	20.6	18.45	4.57	11.51	8.00
March	26.37	13.15	19.76	6.80	25.94	11.71	18.82	1.50
April	32.02	17.22	24.84	20.90	32.70	17.95	25.33	10.50
May	40.65	24.85	32.75	14.60	38.94	26.52	32.73	0.00
Average	26.13	12.08	19.14	9.12	25.97	11.64	18.80	3.40

Table 2: Initial conditions of soil properties

Statistics	pH	EC (dS m^{-1})	Soil N (%)	Soil P (ppm)	Sand (%)	Silt (%)	Clay (%)	Elevation (m)
N	48	48	48	48	48	48	48	48
Mean	8.462	0.578	0.028	4.786	47.271	31.229	21.500	185.730
SD	0.299	0.328	0.006	4.131	11.851	6.895	8.158	0.174
C.V.	3.537	56.743	24.253	86.298	25.071	22.079	37.944	0.094
Minimum	7.800	0.170	0.015	0.000	20.000	12.000	10.000	185.000
Maximum	9.000	2.300	0.039	22.940	68.000	50.000	45.000	185.960

field, showing slope of 0.34% in the direction from east towards west.

Management practices

Wheat was grown in the field of 7.72 ha in size during growing seasons of 2010-11 and 2011-12. A Disc plough and tine cultivar were used for primary and secondary tillage operations, respectively. Seed drill was used for sowing wheat in rows spaced at 15 cm. Weeds were controlled using herbicide.

Treatments description

The year-wise urea fertilizer treatments were applied as given below. These fertilizer treatments were designed to investigate effects of urea fertilizers application on wheat yield in management zones.

Treatments for 2010-11 and 2011-12

Treatment 1 (T_1) = 173 kg-urea/ha in single application with 1st irrigation

Treatment 2 (T_2) = 123 kg-urea/ha in single application with 1st irrigation

Treatment 3 (T_3) = 74 kg-urea/ha in single application with 1st irrigation

Treatment 4 (T_4) = control, no urea fertilizer was applied

Treatment 5 (T_5) = variable rate of urea fertilizer application. Urea fertilizer application rates for variable treatments were determined based on the recommended dose of urea fertilizer application rate for the study area, by the Provincial Department of Agriculture, minus 50% of the soil nitrogen, considered as available to the crop during growing season.

Treatment 6 (T_6) = 247 kg-urea/ha @ three split applications with 1st, 2nd, 3rd irrigations.

Management zones

The Management Zone Analyst (MZA) software V1.0 was used to identify the naturally occurring clusters in the data. The landscape attributes such as elevation, soil EC, soil nitrogen %clay and %sand were used as input variables in MZA software because during ANN analysis, these variables were found to be the most influencing for wheat yield variability (Farid et al., 2013). The field was divided into four management zones using the same landscapes attributes as input variables in MZA (Fig. 1). The management zone 1 in northern part of the field showed higher %sand contents (54%), lower %clay (27%), lower soil EC (0.454 dS/m), lower soil nitrogen contents (0.022%) and elevation in the medium range of 185.24-185.48 m amsl. The management zone 2 showed lower soil EC (0.427 dS/m), higher soil nitrogen contents (0.029%), elevation in the medium range of 185.24-185.48 m amsl and 47-52% sand contents in the southern part of field. The management zone 3 shows higher elevation (185.80 m), higher soil EC (0.848 dS/m), higher soil nitrogen contents (0.031%), and higher % clay (35%) and lower % sand (37%) contents in eastern part of the field. Similarly, zone 4 in western part of the field has relatively lower elevation (185.68), higher soil nitrogen contents (0.032%), lower soil EC (0.584 dS/m) and medium range of 43-52% sand contents. The delineated management zones were evaluated using wheat grain yield and water use efficiency data (Davis et al., 2007; Bianchini and Mallarino, 2002; Ferguson et al., 2002).

Grain yield analysis in each management zone

The mean normalized yield data were calculated for each zone to determine the yield variability across management zone. The treatments response to wheat grain yield in management zones was also investigated.

Water use efficiency (WUE_{GY}) analysis for each management zone

The water use efficiency (WUE_{GY}) based on the total water (irrigation + rainfall) was calculated for wheat grain yield in each management zone. The amount of irrigation water applied for each management zone was measured by using cut-throat flume and rainfall data for both the growing seasons were obtained from the agro-meteorological observatory of Department of Crop Physiology, University of Agriculture, Faisalabad. The following relationship was used to estimate WUE_{GY} ($g/m^2/mm$) for wheat grain yield.

$$WUE_{GY} = \frac{Grain\ Yield}{Irrigation + Rainfall} \quad (1)$$

RESULTS AND DISCUSSION

Fig. 2 shows average normalized yield within four management zones for growing seasons of 2010-11 and 2011-12. The zone 4 produced the highest average normalized yield of 0.65, which was 75% more than that of zone 3 for both the growing seasons. The higher yield in zone 4 may be due to lower elevation, lower soil EC and higher soil nitrogen contents within the zone in western part of the field. The lower elevation levels have been reported to be associated with higher soil moisture availability throughout the growing season (Bakhsh et al., 2000; Tahir et al., 2012). The zone 2 also produced 45% higher yields when compared with that of zone 3 which may be associated with higher soil EC contents in zone 3. The zone 3 has higher elevation and higher soil EC in eastern part of the field and it produced lower yields of 0.37 (Fig. 2), which may be associated with less soil moisture availability due to higher elevation in that zone and also seem to be affected by these landscapes attributes (Fig. 2) as reported by Jaing et al., (2012); Chiericati et al., (2007); Kitchen et al., (2005); Ferguson et al., (2002); Dinners et al., (2002); Fraisse et al., (2001). The analysis also show the zone to zone difference in the average normalized yield over the growing seasons showing effects of landscapes attributes within the zones and need of delineated four management zones within the field. These results suggest that these four delineated management zones may be helpful for site specific application of inputs in precision agricultural practices.

Treatments response to grain yield in management zones

Fig. 3 and 4 show wheat grain yield against the urea fertilizer treatments for both the growing seasons of 2010-11 and 2011-12. The wheat grain yield response to the urea fertilizer treatment was variable over the growing seasons. During 2010-11, wheat grain yield of 3477 kg/ha was observed for treatment T_1, whereas, during 2011-12 maximum wheat grain yield of 3725 kg/ha was found for treatment T_6 (Fig. 4). The variation in climatic conditions might have affected the wheat yield over the growing seasons (Table 1). The wheat grain yield in management zone 4 is higher than that of other management zones showing varying production potential across the management zone for both growing seasons. In management zone 4, treatment T_1 and T_6 produced higher wheat grain yield than that of other treatments during 2010-11 and 2011-12. In general, results based on two years (2010-11 and 2011-12) data, the wheat grain yield response to urea fertilizer treatments indicated that treatments T_5 and T_6 produced better yields in management zone 1. In management zone 4, the treatment T_1 gave better wheat grain yield. It was also observed that treatment T_5 (variable amount of applied urea fertilizer) produced better average wheat grain yield in the range of 3550 to 3848 kg/ha across the four management zones and showed little variation for both the growing seasons. Treatment T_5 (variable amount of urea fertilizer application) showed less variation in grain yield than that of T_4. The CV value (grain yields) of 3.04% for T_5 has lesser CV value of 16% for treatment T_4 (Fig. 3 and 4). These results suggested that each management zone can be treated by applying variable rate of crop inputs.

Water use efficiency across management zones

Water use efficiency (WUE_{GY}) was calculated for growing seasons of 2010-11 and 2011-12 in each management zone (Fig. 5). The response of wheat grain yield to total water applied varied considerably among the management zones for both the growing seasons. The maximum WUE_{GY} of 0.95 and 0.99 g m^{-2} mm^{-1} were observed in management zone 4 for growing seasons of 2010-11 and 2011-12, respectively. While minimum WUE_{GY} of 0.74 and 0.76 g m^{-2} mm^{-1} were observed in management zone 1 for both the growing seasons, respectively. The analysis showed that the WUE_{GY} in management zone 1 was significantly different than that of management zone 4 at P=0.05. The analysis also indicated that management zone 3 showed WUE_{GY} higher than those of management zones 1 and 2 while zone 3 produced lower wheat grain yield (Fig. 5).

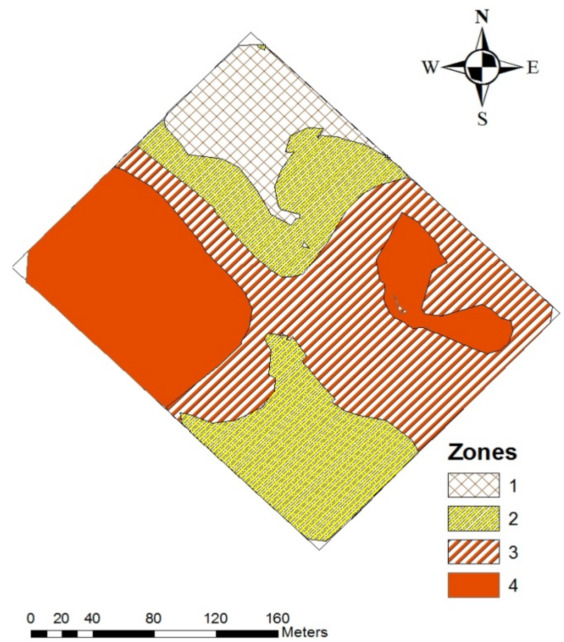

Fig. 1: Proposed four management zones based on landscapes attributes (EC, %sand, %clay, Elevation and Soil Nitrogin)

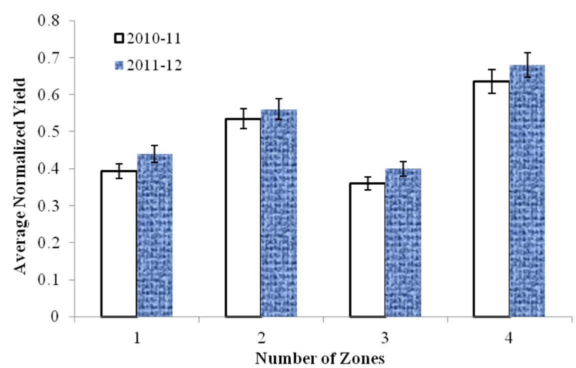

Fig. 2: Average normalized yields of four management zones for growing season of 2010-11 and 2011-12

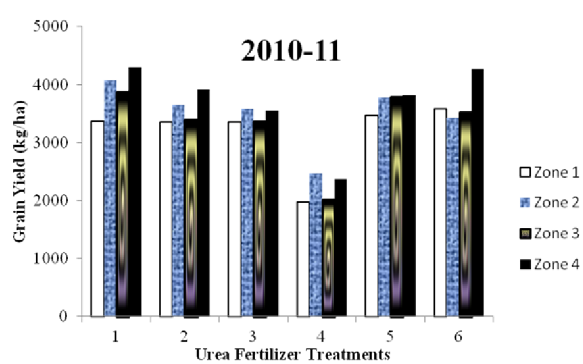

Fig. 3: Grain yield for urea fertilizer treatments within management zones during 2010-11

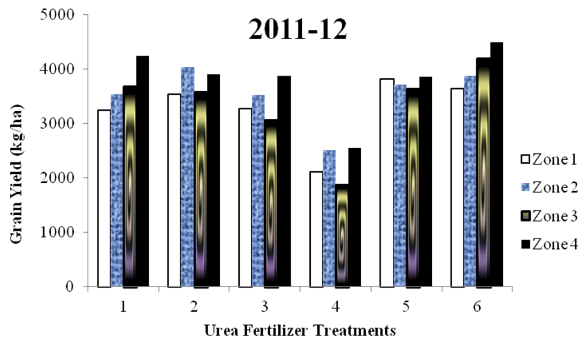

Fig. 4: Grain yield for urea fertilizer treatments within management zones during 2011-12

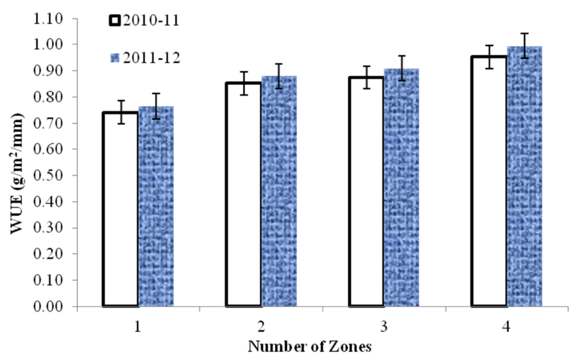

Fig. 5: Water use efficiency (WUE_{GY}) in mangement zones

During irrigation application, zone 3 had less irrigation time for each block than the other three management zones and consequently received lesser amount of irrigation water. The lesser irrigation time for zone 3 was due to relatively higher clay contents resulting in lower infiltration rates. The higher WUE_{GY} in management zone 3 than that of management zones 1 and 2 may be due to the higher clay contents in this zone because clayey soil has better ability to store soil moisture in the root zoon than other type of soils (Lithourgidis et al., 2006). On the other hand, minimum WUE_{GY} was observed in management zone 1. This may be due to higher % sand contents in zone 1 in northern part of the field. The sandy soil has lower soil moisture storage capacity due to larger pore spaces and higher infiltration rates (Lithourgidis et al., 2006). The higher WUE_{GY} in management zone 4 may be due to higher soil moisture and nutrients availability during growing season. Bakhsh et al. (2000) reported that the lower elevation and higher soil nitrogen contents affected the grain yield.

Similarly, the comparisons were also carried out for both growing seasons of 2010-11 and 2011-12. No significant difference was observed for both the seasons. However, WUE_{GY} of growing season of 2011-12, was slightly higher than that of growing seasons of 2010-11 in each management zone. The slight difference in the WUE_{GY} over the growing seasons may be due to difference in growing season's rainfall (Table 1). The overall analysis indicated that management zones have impact on WUE_{GY} which need to be managed according to the soil type, available soil nitrogen, soil electrical conductivity (EC) and elevation of each management zone.

Conclusions

Based on the two years crop data, following conclusions are drawn:

- The evaluation based on normalized wheat yield data showed variability in grain yield data across the management zones indicating importance of management zones.
- Variable amount of urea fertilizer application treatment (T_5) showed less variation in grain yield data than that of T_4 showing CV value of 3.04% for T_5 and 16% for T_4.
- The maximum WUE_{GY} of 0.95 and 0.99 g m^{-2} mm^{-1} were observed in management zone 4 for growing seasons of 2010-11 and 2011-12, respectively whereas minimum WUE_{GY} was observed in management zone 1 indicating the appropriateness of management zones.

These results suggested that each management zone has the potential to be treated separately by applying variable rate of agricultural inputs.

Acknowledgements

The authors wish to express their sincere thanks to Pakistan Science Foundation (Project No. PSF/Res/P-AU/Engg.53) for providing financial assistance and the University of Agriculture, Faisalabad, Pakistan, for their cooperation and assistance, to facilitate the field experimental work at the Postgraduate Agricultural Research Station, Faisalabad, Pakistan.

REFERENCES

Abdul RA, JG Kah, BH Tee and HA Osumanu, 2007. Transforming spatio-temporal yield maps to classified management zone maps for efficient management of oil palm. American Applied Science, 5: 1392-1396.

Ali A, MS Zia, F Hussain, M Salim, IA Mahmood and A Shahzad, 2005. Efficacy of different methods of potassium fertilizer application on paddy yield, K uptake and agronomic Efficiency. Pakistan Journal of Agricultural Sciences, 42: 1-2.

ASP, 2010. Agricultural Statistics of Pakistan, 2008-09, Ministry of Food, Agriculture and Livestock, Govt. of Pakistan, pp: 81-87.

Bakhsh A, TS Colvin, DB Jaynes, RS Kanwar and US Tim, 2000. Spatio-temporal analysis of yield variability for a corn-soybean field in Iowa. Transactions of the American Society of Agricultural Engineers, 43: 31-38.

Bansod BS, OP Pandey and NL Rajesh, 2012. Analysis and delineation of spatial variability using geo-sensed apparent electrical conductivity and clustering techniques. International Journal of Agriculture and Biology, 14: 481-491

Bianchini AA and AP Mallarino, 2002. Soil-sampling alternatives and variable-rate liming for a soybean-corn rotation. Agronomy Journal, 94: 1355-1366.

Chiericati M, F Morari, L Sartori, B Ortize, C Perry and G Vellidis, 2007. Delineating management zones to apply site-specific irrigation in Venice Lagoon watershed. *In* Stafford, J. V. (Ed.), Precision Agriculture,07-Proceeding of sixth European Conference on Precision Agriculture (6ECPA), Skiathos, Greece, pp: 599-605.

Davis D, S Fountas, K Aggelopoulou, T A Gemtos and G Vellidis, 2007. Management zones for high valued crops in Greece. In: Aggelopoulou, A., S. Blackmore, T. Gemtos, S. Fountas (Eds.), Poster Proceedings of the Sixth European Conference on Precision Agriculture (6ECPA), Skiathos, Greece, 6pp.

Dinners DL, DL Karlen, DB Jaynes, TC Kaspar, JL Hatfield, TS Colvin and CA Cambardella, 2002. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. Agronomy Journal, 94: 153-171.

Farid HU, A Bakhsh, N Ahmad, A Ahmad and A Farooq, 2013. Spatial Relationships of Landscape Attributes and Wheat Yield Patterns. Journal of Agricultural Science, 5: 271-294.

Ferguson RB, GW Hergert, JS Schepers, CA Gotway, JE Cahoon, and TA Peterson, 2002. Site-specific nitrogen management of irrigated maize: Yield and soil residual nitrate effects. Soil Science Society of America Journal, 66: 544-553.

Fleming KL, DF Heermann and DG Westfall, 2004. Evaluating soil color with farmer input and apparent soil electrical conductivity for management zone delineation. Agronomy Jounal, 96: 1581-1587.

Fraises CW, KA Sudduth and NR Kitchen, 2001. Delineation of Site Specific Management Zones by Unsupervised Classification of Topographic Attributes and Soil Electrical Conductivity. Transactions of the American Society of Agricultural Engineers, 44: 155-166.

Franzen DW, AD Halvorson and VL Hoffman, 2000. Management zones for soil N and P levels in the Northern Great Plains. *In* P.C. Robert et al. (ed.) Proc. 5th Intl. Conf. on Precision Agriculture, Bloomington, MN [CD-ROM]. 16-19 July 2000. ASA, CSSA, and SSSA, Madison, WI.

Franzen DW and LJ Cihacek, 1998. Soil sampling as a basis for fertilizer application. SF-990 (Revised). North Dakota State Coop. Ext. Serv., North Dakota State Univ., Fargo. (Available on-line with updates at http://lib.ndsu.nodak.edu/repository/bitstream/handle/10365/9209/SF990_1998.pdf?sequence=1).

Iqbal J, JA Thomasson, JN Jenkins, PR Owens and FD Whisler, 2005. Spatial variability analysis of soil physical properties of alluvial soils. Soil Science Society of America Journal, 69: 1338-1350.

Irmak A, JW Jones, WD Batchelor and JO Paz, 2001. Estimating spatially variable soil properties for application of crop models in precision farming. Transactions of the American Society of Agricultural Engineers, 44: 1343-1353.

Jiang HL, GS Liu, SD Liu, EH Li, R Wang, YF Yang and HC Hu, 2012. Delineation of site-specific management zones based on soil properties for a hillside field in Central China. Archives of Agronomy and Soil Science, 1-16.

Kitchen NR, KA Sudduth and ST Drummond, 1998. An evaluation of methods for determining site-specific management zones. In proceedings of the North Central Extension-Industry Soil Fertility Conference, Potash and Phosphate Institute, St. Louis, Missouri, pp: 133-139.

Kitchen NR, KA Sudduth, DB Myers, ST Drummond and SY Hong, 2005. Delineation of productivity zones on claypan soil field using apparent soil electrical conductivity. Computer and Electronics in Agriculture, 46: 285-308.

Kravchenko AN and DG Bullock, 2000. Correlation of corn and soybean grain yield with topography and soil properties. Agronomy Journal, 92: 75-83.

Lithourgidis AS, CA Damalas and AA Gagianas, 2006. Long-term yield patterns for continuous winter wheat cropping in northern Greece. European Journal of Agronomy, 25: 208-214.

Manzoor Z, TH Awan, M Ahmad, M Akhter and FA Faiz, 2008. Effect of split application of potash on yield and yield related traits of basmati rice. Journal of Animal and Plant Science, 18: 120-124.

Mehdi, SM, M Sarfraz, ST Abbas, G Shabbir and J Akhtar, 2011. Integrated nutrient management for rice-wheat cropping system in a recently reclaimed soil. Soil and Environment. 30: 36-44.

Ortega RA and OA Santibanez, 2007. Determination of management zones in corn (*Zea mays* L.) based on soil fertility. Computers and Electronics in Agriculture, 58: 49-59.

Pierce FJ and P Nowak, 1999. Aspects of precision agriculture. Advances in Agronomy, 67: 1-85.

Schepers AR, JF Shanahan, MA Liebig, JS Schepers, SH Johnson and AJr Luchiari, 2004. Appropriateness of management zones for characterizing spatial variability of soil properties and irrigated corn yields across years. Agronomy Journal, 96: 195-203.

Tanvir MA, 2010. Performance of various tree species as irrigated by urban wastewater. PhD Thesis, Department of Forestry, Range Management and Wildlife, University of Agriculture, Faisalabad, Pakistan.

Tahir, M, U Saeed, A Ali, I Hassan, M Naeem, M Ibrahim, H Rehman, HMR Javeed, 2012. Optimizing sowing date and row spacing for newly evolved sesame (*Sesamum indicum* L.) variety TH-6. Pakistan Journal of Life and Social Sciences, 10: 1-4.

Tsirulev A, 2010. Spatial Variability of Soil Fertility Parameters and Efficiency of Variable Rate Fertilizer Application in the Trans-Volga Samara Region. Better Crops, 94: 26-28.