



Full Length Article

Variable Rate Herbicide Application Using the Global Positioning System for Generating a Digital Management Map

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ABSTRACT

This study was conducted to develop a precision method of application for cyanazine, a pre-emergence herbicide which eventuates to save herbicide and reduce its adverse effects on the environment and agricultural products. For this purpose a digital management map (DMM) using the global positioning system (GPS) for variable rate application (VRA) was generated. Uncultivated field of about 6500 m² was selected and local and Universal Transverse Mercator (UTM) coordinates of the field were determined using total station surveying equipments and four static GPS receivers. Data processing was performed using a personal computer equipped with COMPASS software. Soil characteristics were determined by sampling and analyzing these samples. By considering manufacture recommendations for herbicide application based on soil organic matter content (OMC) and soil texture, four management zones with four different herbicide application rates as 1.4, 1.7, 2.9 and 3.5 L ha⁻¹ were determined and eventually a DMM was generated. Using the generated DMM and VRA, total required herbicide for the selected field was determined to be 1.6 L. It was concluded that herbicide application can be decreased up to 13% in compared with a uniform herbicide application rate for the entire selected field.

Key Words: Digital management map; Soil organic matter; Soil texture; Pre-emergence herbicide; Precision farming

INTRODUCTION

Herbicides are important agricultural chemicals in modern farming systems. Agricultural Ministry of Iran reported that the mean application rate of herbicides for wheat and corn during 2005 were 0.99 and 4.44 kg ha⁻¹, respectively (Iran Statistical Yearbook, 2006). However, the values for Qazvin province were 2.06 and 5.10 kg ha⁻¹, respectively indicating relatively high application rate of herbicides in Qazvin province. This necessitates optimizing the application rates keeping in view the site specific requirements of the field. Site-specific crop management (SSCM) has, in fact, an important role in precision farming (Abbaspour-Gilandeh *et al.*, 2006; Jafari *et al.*, 2006). Variable rate technology (VRT), where agricultural inputs such as water, fertilizers, chemicals and so on are applied based on the requirements of each section of the field (Nishiwaki *et al.*, 2004), is a key tool in precision farming. VRT can be helpful in precision farming to reduce agricultural inputs mainly the chemicals. Qiu *et al.* (1994a) reported 50% reduction in pre-emergence herbicide application in corn production using the variable rate application. Carrara *et al.* (2004) reported 29% decrease in

herbicide application in wheat production by means of herbicide application management map.

Soil properties affect herbicide application rate (West *et al.*, 1989; Bauer & Schefcik, 1994). Al-Gaadi & Ayers (1999) reported that the appropriate herbicide application rate of different sections of a small field varied up to 50% based on the soil properties. Herbicide application time depends on crop type, herbicide kind, protection method and weather conditions. However, herbicide application before crop planting (pre-emergence application) is low-priced and simple. This method of application also reduces adverse effects of herbicide on the crops. The most important pre-emergence herbicides are trifluralin (Treflan) and cyanazine (Bladex). When herbicide is applied on the soil, destination of herbicide is determined by many processes such as adhesion, mobility and decomposition. Surface adhesion hints sticking of herbicide particles to surface of solid particles of soil. Negative particles of clays and organic matters provide these surfaces in the soil. Some herbicide molecules that adhere to soil colloids are not available for control of weeds. Adherence of herbicide in soil depends on kind of soil colloid and its amount, ionic properties of herbicide and soil moisture content (Rastgar, 2000).

Spatial variability of soil properties recommends variable rate application of herbicides in various locations of field. The most important factors which affect pre-emergence herbicide application rate are soil texture and soil Organic Matter Content (OMC). Herbicide activity is highly correlated to both soil OMC and soil clay content suggesting that herbicide application rates should be determined in accordance with these soil properties (Weber *et al.*, 1987; Blumhorst *et al.*, 1990; Qiu *et al.*, 1994b).

Variability of soil properties has led to develop technologies for site-specific chemical application (Fisher *et al.*, 1993). Many site-specific chemical application systems use global positioning system (GPS) to determine sprayer position in the field in which chemical application rate is metered and applied using an electronic control system that receives its information from a digital management map (DMM) of soil properties or other affecting factors. GPS accuracy in determining sprayer position or generating soil DMM has an important influence on accuracy of VRA of chemicals (Fisher *et al.*, 1993; Al-Gaadi & Ayers, 1999). Ollila *et al.* (1990) developed a liquid chemical sprayer system with a direct injection module interfaced with a laptop microcomputer. This system was capable of applying specific chemical rates to specific locations based on a predetermined rate map. Map-based herbicide application approach has many preferences as compared with sensor-based approach. In map-based approach, herbicide application rate can be estimated before going to the field. Time lag between soil sampling operation and herbicide application also permits to analyze soil data and evaluate reliability and accuracy of them. Moreover, in this approach we do not encounter the problem of particular sensors lack (Loghavi, 2004). For measuring soil properties, methods other than direct soil sampling and Remote Sensing (RS) technology have been developed. Corwin and Plant (2005) and Sudduth *et al.* (2005) used electrical conductivity (EC) for measuring some physical and chemical properties of soil. Sirjacobs *et al.* (2002) measured on-line soil mechanical resistance and correlated it with soil physical properties. The main objective of this study was to develop a DMM based on soil texture and soil OMC using the GPS that can be used as input data for electronic control system of smart sprayers for VRA of cyanazine pre-emergence herbicide.

MATERIALS AND METHODS

Generation digital field map in local and Universal Transverse Mercator (UTM) coordinates. An uncultivated field about 6500 m² at Research Farm of Qazvin Agricultural Research Center, south-west of Qazvin province was selected to generate a DMM. Three weeks before surveying, the field was prepared by performing primary and secondary tillage operations using a moldboard plow, an offset disk harrow and a land leveler. To reduce soil penetration resistance and soil sampling difficulties, the

selected field was irrigated two weeks before surveying.

For surveying, four benchmarks were delineated on the selected field using the 30 × 20 × 20 cm concrete blocks. The settlement location of these blocks was arbitrary so that these blocks were used later as locations for settlement of total station surveying equipments and four static GPS receivers. Using total station surveying equipments, local coordinates of four benchmarks were determined so that coordinate (1000, 1000, 100) was allocated to B₄ benchmark and then relative coordinates of three other benchmarks, i.e., B₁, B₂ and B₃ were determined concern to benchmark B₄ as shown in Fig. 1.

The local coordinates and the contours of the selected field were obtained by settling total station surveying equipments on benchmark B₄ and settling reflector on various locations of the selected field. Then, the preliminary local map of the selected field was generated using the LAND software. By means of the LAND software a 42-cell grid was also created and laid out on the selected field. Each cell of the grid was 14.8 m². As the coordinates obtained by the total station surveying equipments were local and could not be used in the precision farming, these coordinates were converted to UTM coordinates. For this purpose four static GPS receivers with 5 mm accuracy were used for positioning of the four benchmarks. Fig. 2 shows a static GPS receiver used in this study. Receivers were installed on tripods and their heights were measured manually.

Observation of satellites was last almost 4 h so that more position data and consequently more accuracy was obtained. The number of data received by the static GPS receivers was 14676, 14934, 15024 and 2991 for the B₁, B₂, B₃ and B₄ benchmarks, respectively. The number of data received by the static GPS receiver installed on the B₄ benchmark was less than those of other benchmarks due to possibly less observation of the GPS satellites.

For the purpose of processing the data the data were transferred to a personal computer using HC LOADER software (Bauer & Schefcik, 1994). Handling and processing of GPS data was performed by using of COMPASS software (Al-Gaadi & Ayers, 1999). First the height of antenna was defined for software and this work was performed for the four antennas. Then, the software automatically processed GPS data and data processing was performed in WGS84 coordinate system (Bauer & Schefcik, 1994; Al-Gaadi & Ayers, 1999). After processing longitude, latitude and altitude of the four benchmarks were determined. Table I shows longitude, latitude and altitude of the four benchmarks.

LAND software was used again to convert local coordinates to UTM coordinates. In this stage UTM coordinates of all grid points were obtained by defining UTM coordinates of the four benchmarks in the LAND software and obtaining vector of position transfer. Fig. 3 shows the three-dimensional contour map generated for true perception of grid points' position.

Soil sampling. In order to generate DMM for cyanazine

pre-emergence herbicide application, soil texture and soil OMC were determined in the center of all cells of the grid which was laid out on the selected field. All soil samples were collected by bulking augured core (internal diameter 7.5 cm) from the 0-20 cm soil layer. Soil depth of 20 cm is the average depth for expansion of roots (active crop root zone). After collection, soil samples were placed in airtight polyethylene bags and transported back to the Soil and Water Laboratory, Qazvin Agricultural Research Center. Finally, texture and OMC of all soil samples were determined as described by Soil Survey Staff (1996).

The laboratory test results indicated that the minimum, maximum and range of OMC of soil samples were 0.43%, 1.25% and 0.82% (by weight), respectively. In addition, the mean and standard deviation of OMC of soil samples were 0.86% and 0.18%, respectively. Also, texture of soil samples varied between loam, sandy loam and loamy sand.

Conformity of UTM position layer with herbicide application rate layer. After obtaining test results of soil samples, soil texture and soil OMC in the center of each cell of the grid were assigned to UTM position of the center of each cell. In order to extend soil texture and soil OMC of center of each cell to other grid points, the Kriging interpolation method was used in this study (Bauer & Schefcik, 1994; Al-Gaadi & Ayers, 1999). This method of interpolation uses two traits i.e., data variation gradient and data variation rate in the field which increases accuracy of the method.

RESULTS AND DISCUSSION

Cyanazine pre-emergence herbicide application rate DMM was generated based on the manufacture recommendations for application rate for different soil textures and soil OMC (Table II). Herbicide application rate increased with increasing soil OMC and as soil texture varied from sand and sandy loam to clay loam and clay. Considering manufacture recommendations and soil test results, which indicated soil OMC ranged from 0.43% to 1.25% and soil texture varied between loam, sandy loam and loamy sand, four management zones with four different herbicide application rates as 1.4, 1.7, 2.9 and 3.5 L ha⁻¹ were determined and eventually cyanazine pre-emergence herbicide application rate DMM was generated as two-dimensional and three-dimensional maps (Fig. 4) showing four distinct zones corresponding to the different soil conditions and consequently different herbicide application rates. As shown in two-dimensional and three-dimensional DMM 6.40, 25.1, 67.9 and 0.60% of the selected field needed application rates as 1.4, 1.7, 2.9 and 3.5 L ha⁻¹, respectively. These results are in agreement with those of West *et al.* (1989), Bauer and Schefcik (1994) and Al-Gaadi and Ayers (1999), who concluded that soil properties affect herbicide application rate of different sections of a small field.

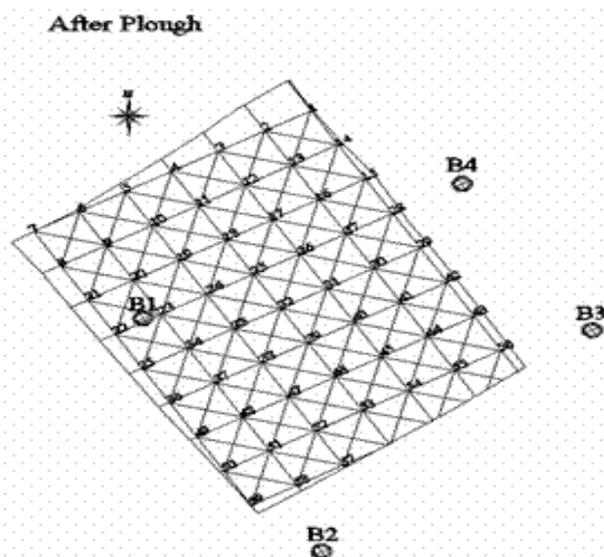
Table I. UTM position of the benchmarks

Benchmark	Longitude	Latitude	Altitude (m)
B ₁	49:54:37.28 E	36:05:00.39 N	1292.329
B ₂	49:54:39.26 E	36:14:57.56 N	1288.264
B ₃	49:54:42.16 E	36:15:00.22 N	1287.967
B ₄	49:54:40.79 E	36:16:02.14 N	1293.663

Table II. Recommended application rate (L ha⁻¹) of cyanazine pre-emergence herbicide based on soil texture and soil organic matter content range (Blumhorst *et al.*, 1990; Rastgar, 2000)

Soil texture	Soil organic matter content range (%)					
	<1.0	1.0	2.0	3.0	4.0	≥5.0
Sand	0.60	0.75	1.25	1.50	1.75	2.00
Sandy Loam	0.75	1.25	1.50	1.75	2.00	2.25
Loam, Silty Loam, Silt	1.25	1.50	1.75	2.00	2.25	2.50
Sandy Clay Loam, Clay Loam, Silty Clay Loam	1.50	1.75	2.00	2.25	2.50	2.75
Sandy Clay, Silty Clay, Clay	1.75	2.00	2.25	2.50	2.75	3.00
Peat or muck	Not recommended					

Fig. 1. Field grid and position of the four benchmarks



Based on the generated DMM and VRA, total required herbicide for the entire selected field was determined to be 1.6 L. If herbicide application is based on the DMM and VRA instead of 2.9 L ha⁻¹, which is the herbicide application rate of 67.9% of the selected field, herbicide application can be decreased up to 13%. Also, herbicide application can be done economically, and suppressing of weed growth in all management zones will be successful and without further adverse effects on the environment and agricultural crops. These results are in agreement with those of Qiu *et al.* (1994a), who concluded that VRA decreases herbicide application. Carrara *et al.* (2004) also suggested that herbicide application management map can decrease herbicide application.

Table III. Comparison of uniform and variable rate application (VRA) of herbicide

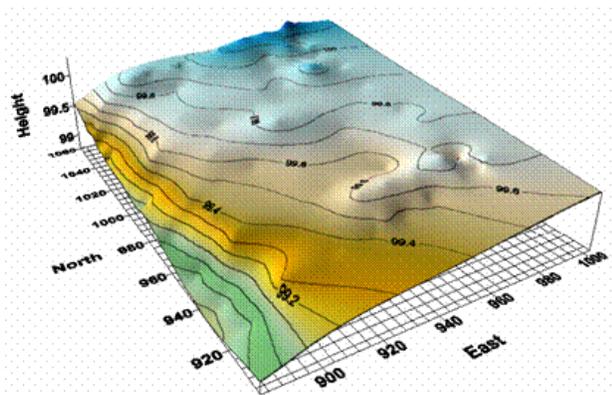
Management zone No.	Area (ha ²)	Area ratio (%)	Herbicide application rate (L ha ⁻¹)	Needful herbicide (L)	A	B	C
1	0.0408	6.40	1.4	0.05712	0.90132	0.71298	44.16 Decrease
2	0.1616	25.1	1.7	0.27472	1.09446	0.51984	32.20 Decrease
3	0.4374	67.9	2.9	1.26864	1.86702	-0.25272	15.65 Increase
4	0.0040	0.60	3.5	0.01400	2.25330	-0.63900	39.58 Increase

A: Required herbicide for the entire selected field based on uniform rate application of each management zone (L); B: Difference between column A and required herbicide for the entire selected field based on variable rate application i.e. 1.6 L (L); C: Increase or decrease of required herbicide for the entire selected field based on column B and 1.6 L (%)

Fig. 2. Static GPS receiver

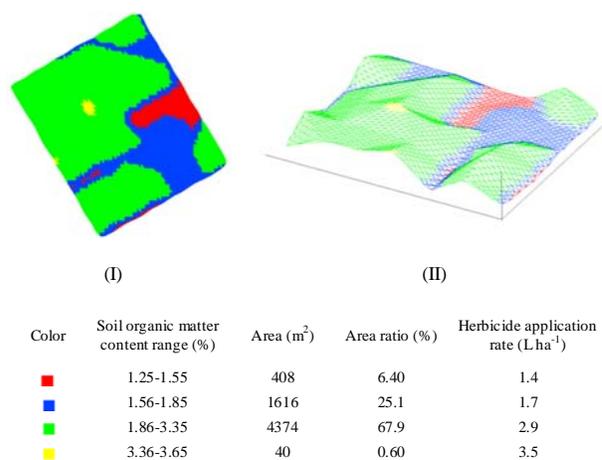


Fig. 3. Contour map of the field



If herbicide application rate of 1.4 and 1.7 L ha⁻¹ is considered as herbicide application rate of the entire selected field, herbicide application can be decreased as 44.2% and 32.2%, respectively (Table III). However, suppressing of weed growth in some management zones may be unsuccessful. Conversely, if herbicide application rate of 2.9 and 3.5 L ha⁻¹ is considered as herbicide application rate of the entire selected field, herbicide application can be increased as 15.7% and 39.6%, respectively (Table III). In this situation suppressing of weed growth in all management zones can be successful, but additional herbicide application will have adverse effects on the environment and agricultural crops.

Fig. 4. Two-dimensional (I) and three-dimensional (II) cyanazine pre-emergence herbicide application rate digital management map (DMM) on perfect cells of grid



At present, many farmers apply more herbicide than the manufacture recommendations for herbicide application rate in order to reach secure results for suppressing of weed growth. But using digital management map (DMM) for variable rate application (VRA), herbicide application can be done economically and suppressing of weed growth will be successful and without further adverse effects on the environment and agricultural crops.

REFERENCES

Abbaspour-Gilandeh, Y., R. Alimardani, A. Khalilian, A. Keyhani and S.H. Sadati, 2006. Energy requirement of site-specific and conventional tillage as affected by tractor speed and soil parameters. *Int. J. Agric. Biol.*, 8: 499-503

Al-Gaadi, K.A. and P.D. Ayers, 1999. Integrating GIS and GPS into a spatially variable rate herbicide application system. *Trans. ASAE*, 15: 255-262

Bauer, W.D. and M. Schefcik, 1994. Using differential GPS to improve crop yields. *GPS World (February)*, pp: 38-41

Blumhorst, M.R., J.B. Weber and L.R. Swain, 1990. Efficacy of selected herbicides as influenced by soil properties. *Weed Technol.*, 4: 279-283

Carrara, M., A. Comparetti, P. Febo, S. Orlando, 2004. Spatially variable rate herbicide application on durum wheat in Sicily. *Biosystems Engineering*, 87: 387-392

Corwin, D.L. and R.E. Plant, 2005. Applications of apparent soil electrical conductivity in precision agriculture. *Computers and Electronics in Agric.*, 46: 1-10

Fisher, K.B., G.J. Shropshire, C.L. Peterson and E.A. Dowding, 1993. *A Spatially Variable Liquid Fertilizer Applicator for Wheat*. ASAE Paper No. 93-1074. St. Joseph, Mich.: ASAE

- Iran Statistical Year Book, 2006, Statistical Center of Iran, Available at: http://amar.sci.org.ir/index_e.aspx
- Jafari, A., S.S. Mohtasebi, H.E. Jahromi and M. Omid, 2006. Weed detection in sugar beet fields using machine vision. *Int. J. Agric. Biol.*, 8: 602–605
- Loghavi, M., 2004. *The Precision Farming Guide for Agriculturists*, Agricultural Extension, Education and Research Organization, Iran
- Nishiwaki, K., K. Amaha and R. Otani, 2004. Development of positioning system for precision sprayer. In: *Proc. of "Automation Technology for Off-Road Equipment" Conf., 7-8 October 2004, Kyoto, Japan*. ASAE Publication No.: 701P1004
- Ollila, D.G., J.A. Schumacher and D.P. Frochlich, 1990. *Integrating Field Grid Sense System with Direct Injection Technology*. ASAE Paper No. 90-1628. St. Joseph, Mich.: ASAE
- Qiu, W., G.A. Watkins, C.J. Sobolik and S.A. Shearer, 1994a. A feasibility study of direct injection variable-rate herbicide application. *Trans. ASAE*. 41: 291–299
- Qiu, W., S.A. Shearer and G.A. Watkins, 1994b. *Modeling of Variable-rate Herbicide Application Using GIS*. ASAE Paper No. 94-3522. St. Joseph, Mich.: ASAE
- Rastgar, M., 2000. *Herbicides and Control Methods*, 2nd Edition. Academic Publishing Center, Tehran, Iran
- Sirjacobs, D., B. Hanquet, F. Lebeau and M.F. Destain, 2002. On-line soil mechanical resistance mapping and correlation with soil physical properties for precision agriculture. *Soil Till. Res.*, 64: 231–242
- Soil Survey Staff, 1996. *Soil Survey Laboratory Methods Manual, Soil Survey Investigations Rep. 42*. Version 3.0. U.S. Government, Print, Washington, DC
- Sudduth, K.A., N.R. Kitchen, W.J. Wiebold, W.D. Batchelor, G.A. Bollero, D.G. Bullock, D.E. Clay, H.L. Palm, F.J. Pierce, R.T. Schuler and K.D. Thelen, 2005. Relating apparent electrical conductivity to soil properties across the north-central USA. *Comput. Electron. Agric.*, 46: 263–283
- Weber, J.B., M.R. Tucker and R.A. Isaac, 1987. Making herbicide rate recommendations based on soil tests. *Weed Technol.*, 1: 41–45
- West, C.P., A.P. Mallarino, W.F. Weider and D.B. Marx, 1989. Spatial variability of soil chemical properties in grazed pastures. *Soil Sci. Soc. America J.*, 53: 784–789

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