GENERATION DIGITAL MANAGEMENT MAP FOR HERBICIDE APPLICATION IN VRA SPRAYING BY USING GPS

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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 m^2 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.

Keywords: Variable Rate Application (VRA); Global Positioning System (GPS); Digital Management Map (DMM); Soil Organic Mater Content (OMC); 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 (Iranian Ministry of Agriculture, 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 agricultural 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 lead 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 & 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 m^2 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 B_4 benchmark and then relative coordinates of three other benchmarks, i.e., B_1, B_2 and B_3 were determined concern to benchmark B_4 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 B_4 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 m^2. As the coordinates obtained by the total station surveying equipments were local, and could not be used in the precision faming, 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.

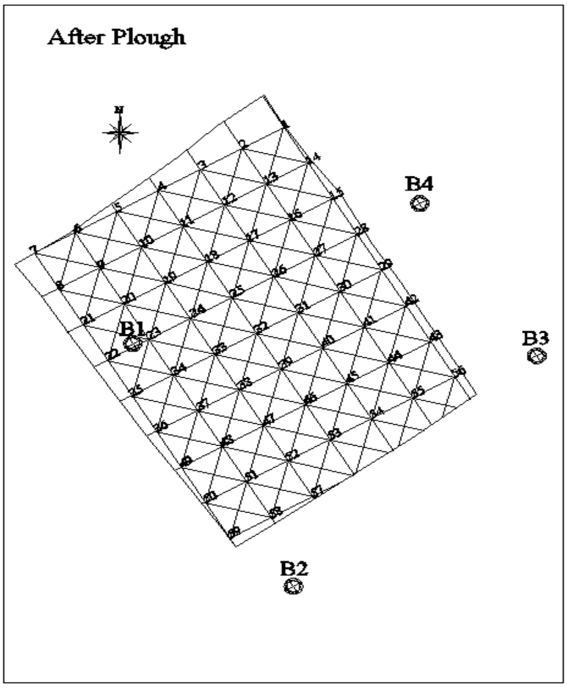


Fig. 1: Field grid and position of the four benchmarks

Fig. 2: Static GPS receiver

Observation of satellites was last almost 4 hours 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 B_1, B_2, B_3 and B_4 benchmarks, respectively. The number of data received by the static GPS receiver installed on the B_4 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 1 shows longitude, latitude and altitude of the four benchmarks.

Table 1. 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

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.

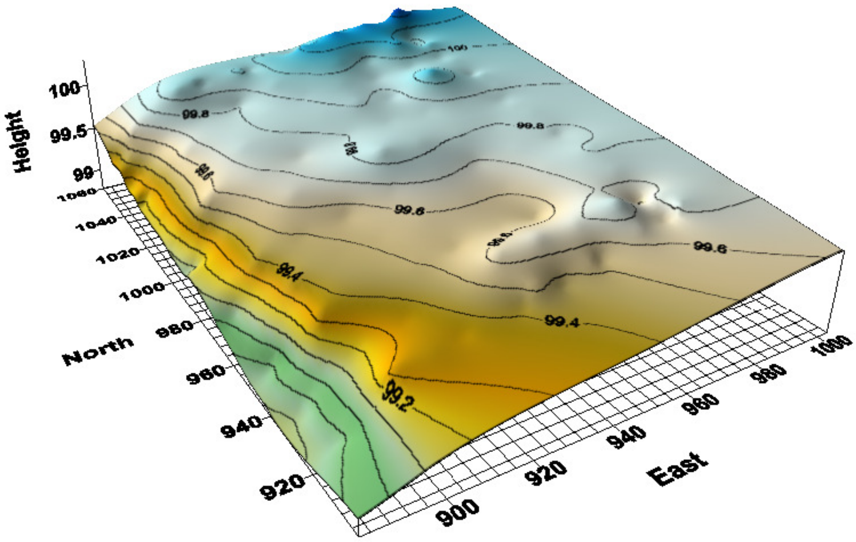


Fig. 3: Contour map of the field

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.

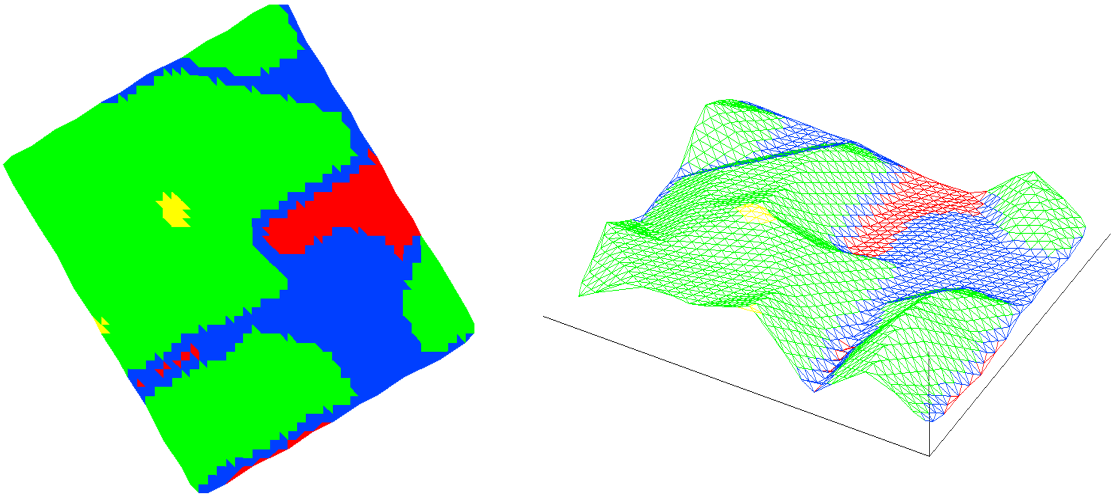
Conformity of UTM position layer with herbicide application rate layer: After obtaining test results of soil samples, soil texture and soil OMC in the center of each cell of the grid were assigned to UTM position of the center of each cell. In order to extend soil texture and soil OMC of center of each 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 2). 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 & Schefcik (1994) and Al-Gaadi & Ayers (1999), who concluded that soil properties affect herbicide application rate of different sections of a small field.

Table 2. 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					



(I) (II)

Color	Soil organic matter content range (%)	Area (m^2)	Area ratio (%)	Herbicide application rate (L ha^{-1})
	1.25-1.55	408	6.40	1.4
	1.56-1.85	1616	25.1	1.7
	1.86-3.35	4374	67.9	2.9
	3.36-3.65	40	0.60	3.5

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

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.

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 3). 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 3). 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.

Table 3. Comparison of uniform and variable rate application (VRA) of herbicide.

Management zone No.	Area (ha)	Area ratio (%)	Herbicide application rate (L ha^{-1})	Needful herbicide (L)	A	B	C

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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 (%)

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.

CONCLUSION

The most important proviso of acceptance VRT for agricultural inputs application is significant variability in factors affecting on these inputs. Preemergence herbicide variable rate application is acceptable providing spatial variability of OMC and soil texture be significant. The laboratory results showed that range, maximum and minimum of soil organic matter content (OMC) is 0.8187, 1.2493 and 0.4306 respectively. OMC has a normal distribution with an average of 0.86% and standard deviation is equal to 0.1783%. Also soil texture varies between Loam, Sandy Loam and Loamy Sand. By considering manufacture recommendations of herbicide application based on OMC and soil texture, four zones were determined for herbicide application rate as 1.4, 1.7, 2.9 and 3.5 l/ha and then a digital map was generated. By considering this map it was determined that herbicide application can be decreased up to 13%. Considering the low temporal variability of OMC and soil texture, the generated map in this study will be good for at least 10 years for VRT.

Despite information available in the soil analyzer organizations, further studies must be done on actual variability of effective soil properties along with positioning field points to generate management maps. These studies will get an useful guidance to choose or deselect VRT for agriculturists that it will be an important step in precision farming.

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