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Effect of Spatial Distribution of Nitrogen Element on Wheat Crop Performance Based on Yield Monitoring System

Hoda KARGARPOUR, Jalil RAZAVI, Mahmood Reza SALAR
Isfahan University of Technology, Department of Agricultural Machinery Engineering, College of Agriculture,
Isfahan 8415683111, IRAN
hodakargarpour@yahoo.com

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Abstract: Performance of wheat crop is influenced substantially by the supply of nitrogen from soil and fertilizer sources. The existence of spatial variability within fields points to considerable benefits if inputs applied to arable crop production are targeted according to locally determined requirements. While yield mapping has become an important part of precision farming strategies the goal of this paper is to plot a yield map by the application of yield monitoring components and the map of nitrogen distribution then analyse these two plots. The best location to evaluate productivity levels, by measuring yield and quality of grain and straw, is the combine harvester. The system consists of an impact flow sensor determining the mass flow of grain, the GPS receiver determining position of the machine, two shaft encoders measuring the speed of the combine, an ultrasonic sensor measuring the actual cutting width, and a data logger which displays values and saves them on a MMS card. A JD combine equipped by yield mapping components harvested a 5-hectar wheat field in Fereidoonshahr, Esfahan province, Iran. The yield data were used with information generated by the GPS receiver and a yield map was created by the use of ArcGIS 9.3 software. 47 soil samples were taken from the field while the spatial properties of the soil samples also were taken by the GPS receiver. The nitrogen content were measured by Keldal method then the variability map of this element was plotted in ArcGIS 9.3 environment. Comparison of statistical analysis and variability maps showed the influence of nitrogen element on wheat crop yield and performance.
Key words: Global Positioning System (GPS), spatial variability, yield map, Keldal method, mass flow sensor

INTRODUCTION

Precision agriculture and site-specific management (SSM) try to address variability within the field instead of treating the whole field as one homogeneous management unit. One of the most important objectives of farmers is the optimization of profit for each field. One approach is to minimize inputs. This benefit is directly correlated to yield and crop quality. While yield is normally thought of on a per acre basis, it is usually determined by dividing the total yield from a field to area harvested. Miller et al. (1999) list three criteria that must be satisfied in order for SSM to be justified. These are, (1) that, significant within field spatial variability exists in factors that influenced crop yield, (2) that, causes of this variability can be identified and measured, and (3) that, the information from these measurements can be used to modify crop-management practices to increase profit or decrease environmental impact. Yield mapping is a technique in which the actual yield is measured across the entire field. By measuring the yield at each location within the field, a better picture can be obtained of the field's true variability. Yield monitor combined with GPS technology is an electronic tool that collects site specific data on crop performance in a given year. The underlying principle of yield mapping is the continual recording of the harvested crop mass, operating width and forward speed as the harvester moves across the field. The yield is calculated from these recorded parameters. Inexpensive sensors and microprocessors coupled with integrating software, mobile power sources, and satellite communications now enable farmers and natural resource managers to collect vast amounts of geo-referenced data (Auernhammer, 1994; Jahns, 2000). Further downstream processing of that data produces meaningful information and ultimately, knowledge (Udinkten Cate and Dijkhuizen, 1999).The most common form of output of yield monitor data is the familiar color-coded thematic yield map (Pierce et al., 1997).By far, the most well developed yield monitoring technology is that for combine harvested crops, especially, small grains. Borgelt (1993) provides a review of various types of grain-flow-rate monitor. Most modern systems measure mass-flow rate by measuring the force of grain impacting a plate located at the top of the clean grain elevator. Birrell et al. (1996) compared different methods and found that the impact-plate method most closely approximated a continuous sampling system.

The performance of wheat crops is influenced substantially by the supply of N from soil and fertiliser sources. Manipulation of the N supply is an important strategic tool that wheat growers can use in response to variations in weather conditions during crop growth to maximise their profit (Jamiason and Semenov, 2000). So, there is no doubt that understanding the way N affects production and quality of wheat is important. Consequently, the literature abounds with studies of the effects of N on wheat (e.g. Blacklow and Incoll, 1981; Morgan, 1984; Green, 1987; Angus and Fischer, 1991; Martin et al., 1992; Whitfield and Smith).

The response of wheat to nitrogen fertilizer is quite variable. This variation has been attributed to differences in climate, soil, crop variety and husbandry practices (Gallagher and Biscoe, 1978a). Generally, early nitrogen application promotes tillering and leaf growth, whereas late application prolongs leaf area duration and expansion (Spierz, et al, 1984). The amount of nitrogen applied also affects the pattern of N uptake by the crop (Sylvester-Bradley, 1990b).

Site-specific yield mapping provides a means of matching fertiliser applications to crop requirements and reducing potential adverse environmental impacts of fertiliser use (Ebertseder et al., 2003, Wong et al., 2001). Site specific management should improve farm gate nutrient balances, although effective as a means of minimizing the offside effect of N use can be improved by targeting specific areas whithin the farm (Wong et al., 2004).

The objectives of this research were to design a monitoring system for combine harvester to provide yield map. Furthermore, the map of nitrogen distribution was also plotted to understand the relation between yield and nitrogen variations. So, these steps have been taken:

- Design a monitoring system with all necessary components.
- Test the system in the field.
- Take soil samples to measure their nitrogen,
- Plot yield and nitrogen distribution maps of the field.

MATERIALS and METHOD

The system consisted of an impact flow sensor determining the mass flow of grain, the GPS receiver determining position of the machine, two shaft encoders measuring the speed of the combine, an ultrasonic sensor measuring the actual cutting width, and a data logger which displays values and saves them on a MMS card.

Over ten years ago, research for precision farming sensors on combines started with the grain flow sensor. Whereas various sensors are marketed around the world, research is still ongoing. An impact type sensor was designed to measure mass flow of wheat on a John Deere 955 combine harvester, so, a load cell manufactured by BONGSHIN® company, model OBU series, with 1 kg capacity was selected and an impact curved plate was used. In these types of sensors the impact force or moment caused by the change in momentum of the grain flow, is measured. The plate can be flat or curved or just be consisted of a pair of fingers.

After the system was developed, it was placed on top of the clean elevator positioned in the transition housing between the paddle elevator of the clean grain elevator and the loading auger of the clean grain tank. Figure 1 shows the linkage and set-up of the sensor.

After positioning the sensor, it was calibrated statically and dynamically, then calibration curve was plotted which related the mass flow to load cell signal.

A data logger, designed and developed by Industrial Control and Automation Division in Isfahan University of Technology, Iran named DL7718 was used to receive and store signals of every component of the system with periods of 5 seconds. The data logger was located beside driver's seat.

To plot an accurate yield map, an accurate GPS receiver that can observe the combine location while it is moving is required. A Leica GPS receiver model SR-20 was chosen for the purpose. The GPS receiver had two antennas; one of them was placed on top of the combine which recorded rover data every 5 seconds and the other one that was as a reference, collected spatial property of one point during the harvest. The errors were less than 1 meters after the GPS data was processed with Leica Geo Office software.

One of the components of a yield monitoring system is ground speed sensor. Two shaft encoders manufactured by Tabriz Peguh Co. were placed on the rear wheels of the combine to minimize drive wheel slippage effect. The harvested area is determined by multiplying the actual operating width of the machine by its forward travel speed between data points. The actual operating width was obtained by means of an ultrasonic sensor produced by Industrial Control and Automation Division. It was located on the tip of the combine cutting platform.

To compare yield data of the system with actual yield of the field, some parts of the field were harvested by hand. Thus, a quadrate frame 1*1m and a sickle were used for hand harvesting.

After installation of all components on combine, the harvest was begun. One approximately 5-hectar wheat field in Fereidoon-shahr, Isfahan Province, Iran, was chosen for the purpose. The yield data were all recorded on a MMC card to be analyzed for yield mapping. Figure 2 shows the block diagram of the system.

After harvesting the field, 47 soil samples were taken and the spatial properties of each sample were also determined by the GPS reciever. The samples were air-dryed and transferred to a soil testing labratorary. The nitrogen of the soil samples was measured by Keldal method. A Tecator, model KJELTEC-1030 Analyzer was used to determine soil nitrogen levels.

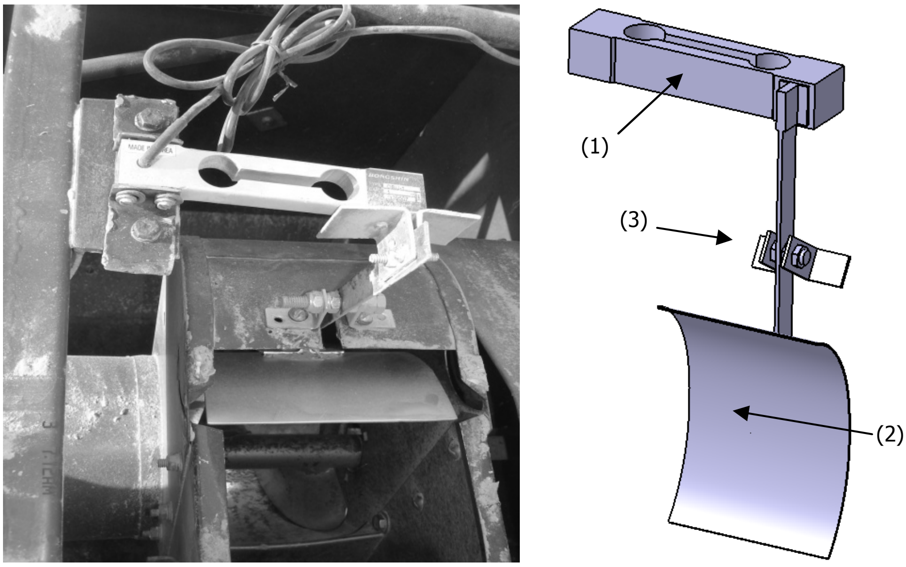

Figure 1. Sensor linkage and its position on the combine, (1) load cell; (2) impact plate; (3) support

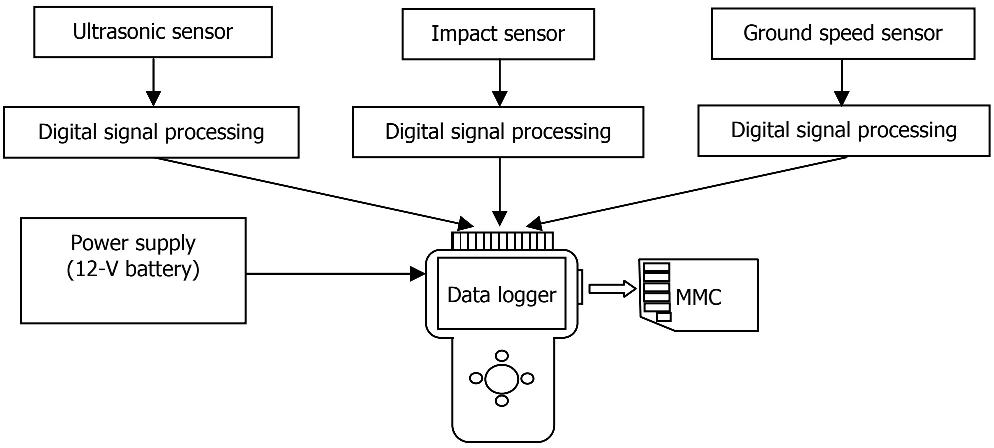

Figure 2. The block diagram of the yield monitoring system components

RESULTS and DISCUSSION

The load cell data had been influenced by the harvester vibration and it had noise on its frequency. The data was filtered by Finite Impulse Response (FIR) in MATHLAB 2008.a software as it is shown in figure 3.

The yield and the nitrogen in any point were calculated. Table 1 shows the descriptive statistics of the two parameters. The geostatistical analysis of data was conducted using ArcGIS 9.3 software. To achieve this, ordinary kriging with different transformation was used. The maps and the histograms are shown in Figure 4.

The yield of the field varied between 2.6-9.4 ton/ha and the C.V. of the data was 19.8% which showed the variation of this parameter in the field. The nitrogen content of the field varied between 0.013-0.17 % and the C.V. of the data was 40.42% indicating a large variation in N levels across the field.

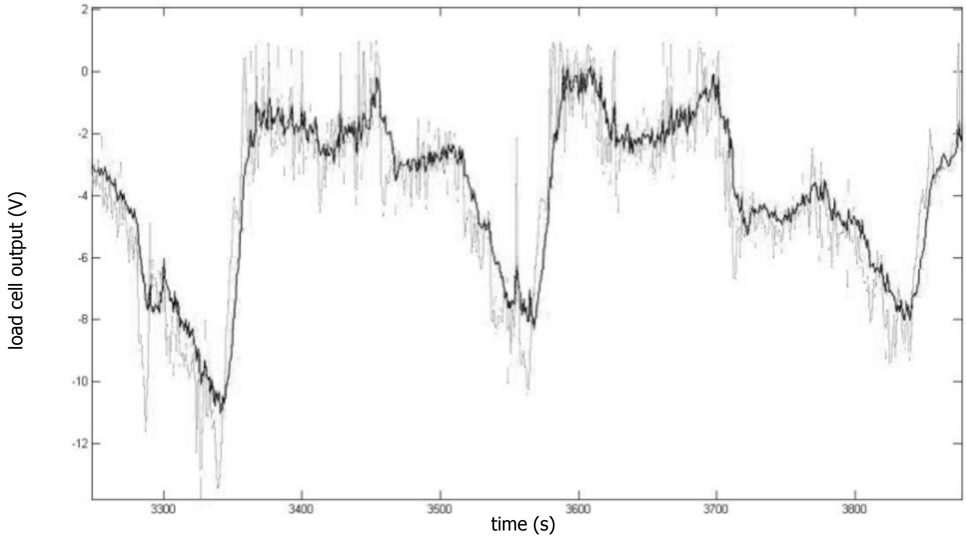

Figure 3. A part of the load cell output (light line), and filtered data (dark line)

Table 1. Statistical descriptive of the two parameters

Parameter	average	Standard deviation	Coeff. of Variation	skewness	kurtosis	Trans. Func.
Nitrogen (%)	0.08	0.032	40.42	-0.3	3.8	arcsin
Grain yield (ton/ha)	7.01	1.3	19.8	-0.5	3.6	Box-Cox

Table 2. Variogram properties of the two parameters

Parameter	Anisotropy	Model	Nugget	Partial sill	Lag size	Num. of lags
Nitrogen	None	Exponential	0.00064	0.00048	25.361	13
Grain yield	Yes	Exponential	0.024	0.031	25.361	8

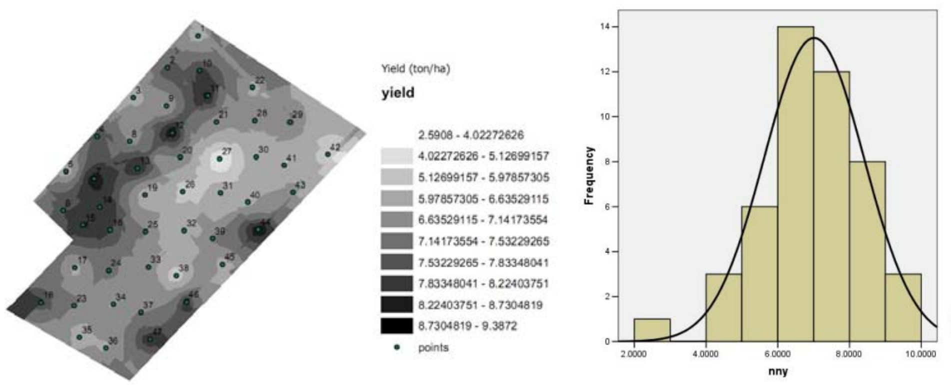

Figure 4. Histogram of yield data (right) and the yield variation map (left)

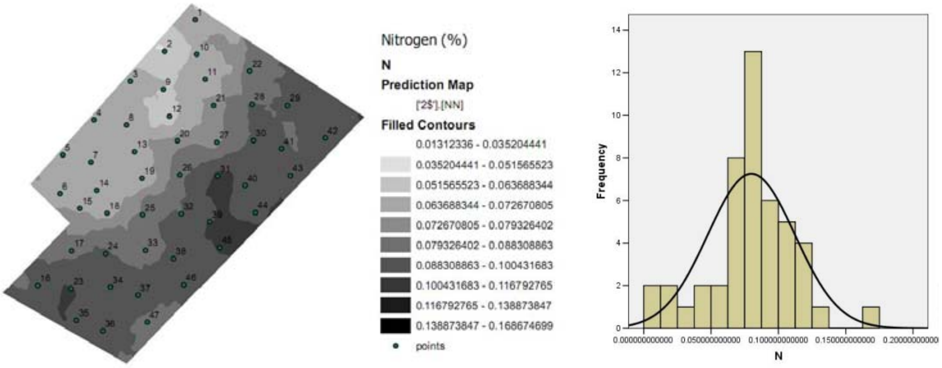

Figure 5. Histogram of the soil nitrogen data (right) and the nitrogen distribution map (left)

In fact, the nitrogen content of the soil after harvesting, shows the unconsumed (residual) nitrogen of the soil by the plant. So,assuming no variation existed after fertigation by sprinkler irrigation, where the residual nitrogen of the soil is low, nitrogen may have been consumed in higher by the plant.

The soil nitrogen content is an essential parameter in wheat grain yield. The variation maps of residual nitrogen of the soil and the yield map shows direct relation between yield and nitrogen consuming.

CONCLUSIONS

The following results may be concluded from this research:

1. The variation in soil nitrogen was more than grain yield.
2. The yield monitoring system satisfacorily measured variation in grain yield in the field.
3. Where the soil nitrogen content was high, the nitrogen consumption by the plant may have been low.
4. The nitrogen consumption and grain yield showed a positive direct relation.

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