

# The Evaluation of Ground Based Remote Sensing Systems for Canopy Nitrogen Management in Winter Wheat – Economic Efficiency

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## ABSTRACT

Three nitrogen strategies are currently used in nitrogen management in winter wheat husbandry (Uniform application, Sensor based and Zonal application). Active and passive ground based remote sensing systems have been used to estimate the variability of nitrogen requirements. This paper reviews economical analyses of two experiments conducted in 2006 in winter wheat fields. First experiment (Wilstead, UK) assessed the two remote sensing systems and the second (Oponice, Slovakia) assessed the three nitrogen application strategies.

From the results of economical analyses it can be concluded that the cost of using the ground based remote sensing sensors in the UK was £11/ha which could be offset by the 15 kgN/ha reduction and a potential small increase of yield by 1%. The use of sensors in Slovakian experiment influenced the costs of fertilising by 7.9% for SENSOR based application and 28.62 % for ZONAL nitrogen application, whilst the overall production costs were increased by 2.67% and 5.21% for SENSOR and ZONAL respectively. The variable application (at this field and for this growing season) did not bring any economic benefit

**Keywords:** Economical analyses, precision farming, site-specific nitrogen management, ground based remote sensing systems

## 1. INTRODUCTION

The management of the spatial and temporal variability of the crop canopy characteristics (e.g. Nitrogen) is a key factor for improving grain yield. The crop requirements or Nitrogen have to be matched as closely as possible by the nitrogen rates and the time between crop data acquisition and management decision making has to be as short as possible. These issues are not only important from an economical point of view, but environmental considerations must also be taken into account. To gather the required information it is possible to use satellite, airborne and ground based platforms. These have been subject of research of many authors which assessed their suitability, advantages and disadvantages (Begiening et al., 2005; Wood et al, 2003a, 2003b, Morris, 2006; Scotford and Miller, 2005; Swain, Jayasuriya and Salokhe, 2007).

Despite the presence of some commercial applications of the satellite and airborne techniques (e.g. FARMSTAR, SOYLSense, Nitrosensing), ground based systems offer advantages in terms of ease of availability. The most common passive ground based remote sensing system

in Europe is the Yara N sensor which has limitations in poor light conditions. Active sensors, using their own energy sources, are now available in the market e.g. the Crop Circle (Holland Scientific) and the Yara N sensor ALS.

All inputs and benefit have to be included to assess the true potential of precision farming technology. There were several research projects conducted in order to assess the economical efficiency of precision farming technology. However, their results differ in terms of benefits obtained, what may be caused by not identical methodology and different climate and economical environment (Batte and VanBuren, 1999; Lu and Watkins, 1997; Kilian, 2001). The effects of site specific fertilizing on economic efficiency of crop production under Slovakian conditions was assessed by e.g. by Švarda and Nozdrovický (2005), and Rataj and Havráňková (2006).

On the side of returns, yield is the only factor which can be changed (compared to uniform treatment) excluding the subsidies and other extra payments to farmers. However the potential economic returns from environmental benefits should be included as well.

On the other hand several aspects have to be included to calculate costs of precision farming. An economic analysis of practicing precision farming techniques was conducted by Godwin et al. (2003). The authors state, that the cost depends on:

- the level of technology purchased, i. e. full or partial system,
- depreciation and current interest rates ,
- the area of crop managed.

Godwin et al. (2003) analyzed the area needed to obtain the benefits. They reported typically a farmed area of 250 ha, where 30 % of the area will respond to variable treatment requires an increase in yield on the responsive areas between 0.25 and 1.0 t/ha.

The overall efficiency of precision farming technology depends, alongside the farm size, on several agro-climate conditions (nutrition need, soil fertility, topography, weather, weeds and so on) Daberkow (1997). Pawlak (2003) also stressed that the economic efficiency is influenced by level of machinery costs increase, changes in quantity and quality of production, saving of inputs and environmental benefits. The reduction of fertilizers may lead to reduction of costs and energy used, also improve the environmental impact. The economical benefits of the environmental improvement, traceability and the final product quality of this technology are not possible to calculate (Ancev et al., 2005).

The results of research projects differ depending on climate and economical environment of the country as well as growing conditions. Therefore further research is needed in this area to assess the efficiency in central Europe. Generally it can be concluded that all commercial application of all platforms brought benefit. However, their application was not assessed in central Europe conditions.

## 2. MATERIAL AND METHODS

This paper reviews economic analyses conducted on the data from two field experiments (Wilstead and Oponice) in winter wheat (*Triticum aestivum*) fields in 2006. The experiments were scheduled for the dates of nitrogen fertilization, used in winter wheat husbandry. Both experiments used strip based design. Detail description of the experiment is given in Havráňková (2007).

Experiment in Wilstead (A) compared variable application based on active (CROP CIRCLE) and passive (FIELD SCAN) ground based remote sensing systems with UNIFORM application in nitrogen management. For application of nitrogen, tradition machinery was used.

The second experiment (B) assessed the three management strategies used in nitrogen management (SENSOR, ZONAL, UNIFORM).

#### **A. Wilstead (22 ha) (lat 52.854444, long 0.448055), Bedfordshire, UK;**

The use of ground based sensors influences the overall costs of nitrogen management in the following aspects:

- the cost resulting from the sensor price (cost of sensor and tractor),
- costs of data processing and analyzing, calibration of data and design of fertilizer application protocols,
- costs of equipment needed for variable application,
- the amount of fertilizer applied may be changed due to variable application.

Returns were the influence by resulting crop yield, the economic values of the environmental benefits has not been possible to calculate.

Assumptions used for calculations of economical efficiency:

- depreciation is estimated to 13.5% (Nix, 2005) – 6 years retained and the trade-in value at the end would be 20%,
- repairs and maintenance costs – 4% (Nix, 2005),
- radiometry calibration was estimated as £4.85 per hectare (Godwin et al., 2003),
- cost of sensor use were calculated based on Godwin et al. (2003).

Purchasing costs of sensors used in the calculations were as following:

- Field Scan (sensor and terminal) – £13000,
- Crop Circle (£2500), iPAQ & FarmWorks software (£2000) - £4500 (Morris, 2006).

#### **B. Oponice (38 ha) (lat 48.475697; long 18.155478) Slovakia**

The detail economical analyses of this experiment were aimed especially at costs of variable nitrogen application by SENSOR and ZONAL alternative. The costs of nitrogen fertilization, which was conducted in April and May, were divided into:

- costs of nitrogen fertilizer – calculated based on “as applied” maps and assumption of 1kgN Fertilizer ā 19,5SKK (£0.39)
- costs of machinery – based on methodology published by Rataj (2005)
- costs of information – all costs connected with variable application of nitrogen (precision farming technology).

Following costs were considered as costs of information:

- scanning of crop (sensor and data processing),
- sampling and laboratorial analyses,
- creating application map,
- cost of variable application equipment,

- processing of “as applied map” (price of contractor).

All these cost items were calculated based on methodology proposed by Rataj – Havráňková (2006). The assumption of N sensor purchasing cost was 650000SKK (£13000). To assess the influence of adoption of the three strategies, the overall costs of production were calculated. Costs of machinery, labour and material were calculated based on Rataj (2005). Costs of all operation were following:

- soil preparation 346,10 SKK
- seeding 502,60 SKK (Seeding material 2320,00 SKK)
- first fertilizing 311,40 SKK (Fertilizer 1048,00 SKK)
- spraying 199,70 (Mustang 575,40 SKK)
- contract harvesting 1970,00\* 2170,00\*\*
- baling 1200,00

\* UNIFORM, \*\* SENSOR and ZONAL

In terms of harvesting cost, a yield monitoring system was included for the SENSOR and ZONAL alternatives as these are linked to precision farming technology. This added a value of 200 SKK.ha-1 (£4) to the cost of the combine harvester.

### 3. RESULTS AND DISCUSSION

#### A. Wilstead

The annual costs of Field Scan and single Crop Circle sensor per unit area for a range of arable areas were analyzed at first. The costs initially decrease rapidly with increasing the area over which they are used (Figure1, Figure 2).

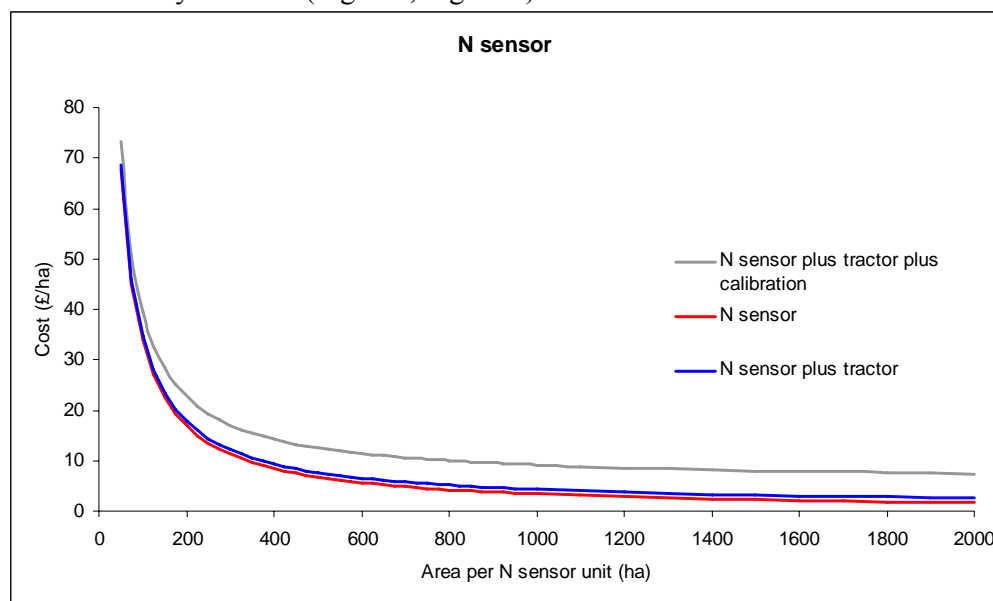


Figure 1 Costs of N sensor (Field Scan) sensor per area

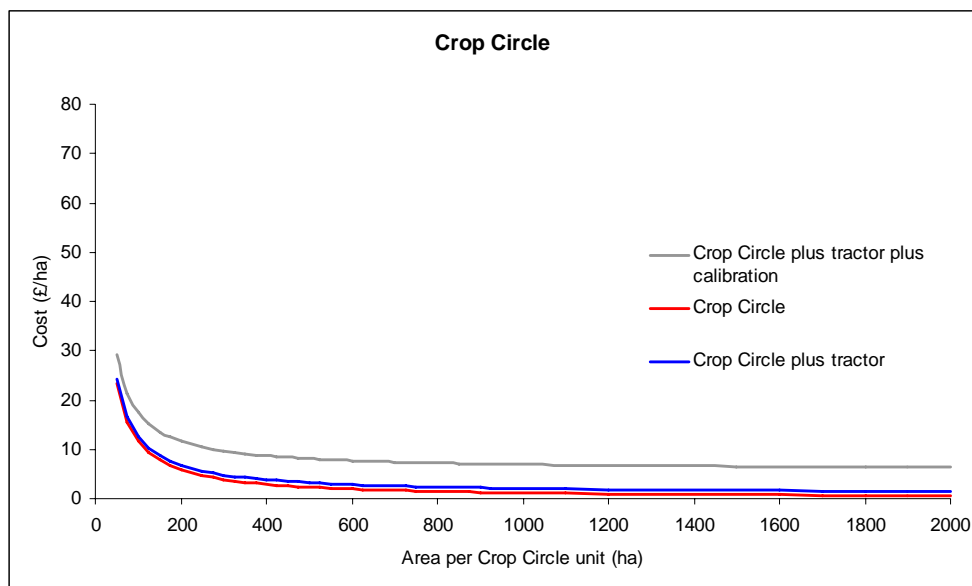


Figure 2 Costs of Crop Circle sensor per are

Cost of nitrogen application for all three treatments was calculated with assumption of area of 600 ha, which is modest but could be practically achieved. The analysis assumes that the conventional farm machinery will be used. New cost item is cost of scanning (using the scanned to assess the variability in crop) and cost of ground calibration of sensor values. After Morris (2006) one Crop Circle sensor has to be used on each side of the sprayer, therefore two Crop Circle sensors are included in the analysis (Table 1). The costs of sensors, including the ground calibration of the sensors of £4.85 /ha (Godwin, 2003), are given in Table 1. However, cost of data processing and analyzing should be included as well.

Considering the average saving on Nitrogen per hectare at 15 kg at £0.43/ kg brings benefit of almost £6 per hectare. The difference which should be covered by benefit (yield increase or environmental benefit) is for Crop Circle £3.65/ha and for Field Scan £5.38 / ha. At the price level of £80 (Bullen, 2007) per tone of winter wheat, it means increasing the yield by 0.05 to 0.07 t. Having the average yield 8 t/ha it gives the increase by 0.5% - 1%. Considering the overall costs of nitrogen fertilization, based on Nix (2005), the cost items of nitrogen application for all treatments could be estimated as given in Table 2.

Table 1 Costs of sensors for scanning of the crop

	Crop Circle + iPAQ	Field Scan
Sensor price, £	4500	13000
Cost of sensor use, £/ha	1.95	5.63
Sensor + tractor use per hectare, £/ha	2.85	6.53
Sensor + tractor + calibration use per hectare, £/ha	7.7 (one sensor) 9.65 (two sensors)	11.38

Table 2 Costs of nitrogen fertilization for all alternatives

	UNIFORM	FIELD SCAN	CROP CIRCLE
<b>Costs of :</b>			
Fertiliser	220kg*£0.43/kg= £94.6/kg	220kg*£0.43/kg= £94.6/kg	220kg*£0.43/kg= 94.6£/kg
machinery (sprayer) (usually 3 application )	£8.25/ha*3= £24.75/ha	£8.25/ha *3 = £24.75 /ha	£8.25/ha*3= £24.75 /ha
Use of sensor (for three application)	-	£11.3/ha*3= £33.9/ha	£9.65/ha*3= £28.95/ha
<b>Overall cost of nitrogen application</b>	£119.35/ha	£153.27 /ha	£148.3/ha

However, using the commercial application of N sensor would result in a 10% decrease in the cost of nitrogen application from £153.27/ha to £137.35/ha (the costs of N sensor for real time application and calibration by N tester@£1000 would results into £6.06). This is caused by reducing the number of operations because the scanning and the application would be conducted in one pass of the machine. From which, it can be concluded that the Crop Circle system would be more economically effective if it was be integrated into a real time application system.

### B. Oponice

All three categories of nitrogen fertilizing costs (fertilizer, information and machinery) were analyzed (Table 3). The proportion of costs of the information from the total costs of fertilizing was 19% for SENSOR and 30 % for ZONAL application. However, the total cost of Nitrogen application was increased by 7.9% for the SENSOR and by 28.62% for the ZONAL application.

Table 3 Costs of Nitrogen fertilization in April and May for the three alternatives

Costs	Alternative					
	SENSOR		UNIFORM		ZONAL	
SKK. ha <sup>-1</sup> (£1 = 50 SKK)	SKK	%	SKK	%	SKK	%
Costs of information	351	19	235	14	644,2	30
Costs of machinery	399,4	22	399,4	24	399,4	19
Costs of fertiliser	1050	59	1033	62	1101	51
<b>Sum</b>	<b>1800,4 (£36)</b>	<b>100</b>	<b>1667,4 (£33)</b>	<b>100</b>	<b>2144,6 (£42,9)</b>	<b>100</b>

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Table 4 Average values of economical indicators of production

<b>Costs/Returns</b> <b>SKK.ha<sup>-1</sup></b>	<b>Alternative</b>		
	<b>SENSOR</b>	<b>UNIFORM</b>	<b>ZONAL</b>
Costs of production	10325.07 (£206.50)	10056.35 (£ 201.13)	10580.72 (£ 211.61)
Returns (3900 SKK/t or £ 78/t of wheat)	22 111,96 (£ 442)	21 757,83 (£435)	22 186.35 (£ 443.73)
Gross profit	11786.89 (£235.74)	11701.47 (£234.03)	11605.63 (£232.11)
Gross Profit / costs	1.14	1.16	1.10

The total costs of winter wheat production were calculated in order to express the overall economical efficiency of the three treatments. The increasing of the overall costs of production (Table 4) was 2.67% for the SENSOR and 5.21% for the ZONAL application.

The returns increased by up to 2% (Table 4), assuming the price of wheat at 3900 SKK/t (£78/t). However, because of the cost increase, the Gross profit increase only by 0.73% for the SENSOR and decreased by 0.82% for ZONAL treatment.

These economics indicators are, however, influenced by the economical environment of the country and by the climate and growing conditions of the particular year, which were in this case extremely bad. However, considering other published results (Leading Farmers, 2006) and the average range of yield for that region (5.3 t/ha – 7 t/ha), there is a yield increase potential in the central Europe especially at fields with greater variability in soil conditions. Therefore more research work should be done in fields of greater variability and over a larger period of time

#### 4. CONCLUSIONS

A. Application machinery with the integrated real time application system is critical to be able to use the economic advantage from Crop Circle. In addition the potential economic benefits could be found in environmental benefits and benefits from data for the traceability of Nitrogen fertilizer application levels.

B. The variable application (at this field and for this growing season) did not bring any economic benefit. The most profitable alternative appears to be the UNIFORM and then the SENSOR. The economic indicators, however, are influenced by the economical environment of the country. These values are influenced by climate and growing conditions of the particular year, which were for 2006 year extremely bad because of the long winter. The use of sensors does influence the costs of fertilizing by 7.9% for SENSOR and 28.62 % for ZONAL, whilst the overall production costs were increased by 2.67% and 5.21% for SENSOR and ZONAL respectively (the costs of training and developing the overall skills of the manager were not included).

More research work should be done in fields of greater variability and over a larger period of time.

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