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PREREQUISITES FOR THE ADOPTION OF NEW TECHNOLOGIES – THE EXAMPLE OF PRECISION AGRICULTURE

Martin Schneider, Peter Wagner
Martin-Luther-University of Halle, Institute of Agriculture Economics, Farm Management Group, Halle, Germany

Abstract: With the development of the global positioning systems (GPS), geographical information software (GIS) and various sensors and actuators, the possibility of initiation information-guided plant production is never been grater. The assumption is that the more information and precision is put into cultivation management, the higher the profit will be. During recent years, there has been no significant increase of precision agriculture (PA), with only a low share of farmers employing PA applications. However, there are many suppliers of PA hardware and software. What are the reasons for this gap?

INTRODUCTION

With the development of the global positioning system (GPS), geographical information software (GIS) and various sensors and actuators, the possibility of initiating information-guided plant production has never been greater. The assumption is that the more information and precision is put into cultivation management, the higher the profit will be. During recent years, there has been no significant increase of precision agriculture (PA), with only a low share of farmers employing PA applications (Reichardt and Juergens, 2006). However, there are many suppliers of PA hardware and software. What are the reasons for this gap?

Before a new technology is put into practice, the question of cost and benefit has to be answered. In the case of PA, there are, at present, problems in answering this question completely. In addition to the existence of sensors and actuators, decision rules must be present for linking site specific sensor information with recommendations for controlling the actuators. These rules answer the question of which recommendation should be given based on the respective site specific information. The challenge is to optimize the factor input according to a maximized gain.

For some selected PA technologies (e.g. nitrogen fertilization) different decision rules already exist and are more or less put into practice. This can be done through online approaches, with sensor-included decision rules (e.g. Link et al., 2002), offline approaches (e.g. Wenkel et al., 2002) or online approaches with map overlay (e.g. Weigert, 2006).

For other PA technologies (e.g. sowing, tillage or fungicide application) those rules are still in the development stage or are missing completely. If decision rules are available, the question is whether the additional costs for the PA technology can be covered by the additional benefits. To determine this, economic studies have to be conducted. Many studies have been published during recent years dealing with profitability. Unfortunately, there is no clear answer whether there is any economical potential in using PA.

Some of these studies deal with simulations, *ex post* examinations or model calculations (e.g. Hurley et al., 2002; Pedersen et al., 2002; Albert et al., 2003; Bongiovanni et al., 2000; Ebelhar et al., 2002). In such examinations, the question of the theoretical potential of PA is being answered. In reality, the actual potential could be much lower. Reasons for this are the real farming resolution (e.g. boom width) of the application technology, the state of knowledge of the real site specific conditions and the quality of the decision rules. Thus, only the direct comparison of PA technologies with uniform field management in field trials can demonstrate the potential of the state of the art. In other studies, calculations are not transparent and comprehensible and it is not always obvious which costs and benefits are taken into account.

The objective of this paper is to examine, on a whole farm background in eastern Germany, site specific nitrogen fertilization from an economic point of view.

MATHERIAL AND METHODS

To calculate the economic effects, only the costs and outputs related to the new technology must be taken into account. In the case of PA, the additional costs can be divided into four groups. (Table 1)

Table 1: Classification of cost drivers by time of appearance and cost categories

origin time	costs for data collection	costs for data processing	costs for the application of inputs	costs for additional means of production
annual		data management decision making consulting		fuel, seed, fertilizer
annual – several years	yield mapping* soil testing* sensoring*			
several years		software hardware	updating the technique**	

* including all costs for equipment, soil sampling and analyzing, labor time
** e.g. update of fertilizer-, drilling- and spraying- technique with precision farming technology

The first group summarizes all costs for collecting site specific information. There can be various types of sensors, e.g. yield mapping or soil investigation. The next group characterizes the costs for obtaining site specific management recommendations. The costs depend on the degree of automation of generating and using the decision rules.

The third group includes the costs for putting the site specific recommendations into action. For example, it can be necessary to update the application technique for automatically changing the fertilizer amount during spreading.

If there is an additional need for means of production (e.g. fertilizer) compared to the uniform treatment, these additional costs are placed into the last group.

The result is positive from an economic point of view if these costs are covered by the additional output. This could be due to yield increase, savings on means of production or quality improvement.

To examine the effects of site specific fertilization, calculations are based on an average farm in Eastern Germany. Table 2 shows the ratio of such a farm's cultivated crops.

Table 2: The typical cultivation pattern of farmland in Saxony-Anhalt (Eastern Germany) (Statistisches Bundesamt, 1999)

Crop	Share relative	Absolute share for a farm with a size of...		
		500 ha	1,000 ha	2,000 ha
Grain	58.86 %	293.4	586.8	1,173.6
Corn	10.06 %	50.3	100.6	201.2
Rape seed	12.45 %	62.3	124.5	249.0
Others	18.63 %	93.2	186.3	372.6

In the region Köthen, close to Leipzig, a field trial was carried out, to check the effects of PA on costs and outputs. Strips with different fertilization strategies were laid out. Three different site specific treatment strategies (Online, Offline, and Offline with map overlay) are compared with the uniform treatment. All measures were made by on-farm technology.

For the online approach, the Yara-N-Sensor® was used for the 2nd and 3rd application. With this optical sensor, the amount of nitrogen is determined by the reflection of the canopy (Link et al., 2002). For the offline approach, the field was divided into three different zones of high, middle and low yield potential. This was done using historic near-infrared aerial pictures of the field taken a few weeks before harvest (Dohmen, 2004). For every zone, the yield target was determined by the knowledge of historic yield maps. For this yield target, the necessary nitrogen fertilizer amount was distributed over three applications. The sensor approach with map overlay is a combination of the first two approaches. At the 2nd and 3rd nitrogen application, the fertilization recommendations of the sensor system were decreased (increased) by 15 kg and 20% N/ha in the lower (higher) zone.

Table 3 summarizes the assumed investment payments for the additional technique and service. For all items a depreciation time of five years was assumed. To calculate the costs per annum, the annuity method is used (interest rate: 8 %).

Table 3: Assumed investment payments for additional PA technique and service

Item	Investment payment (€)	Depreciation time (year)
Yara-N-Sensor with Terminal	22,000	5
Yield mapping hardware	8,500	5
Terminal with GPS	5,950	5
GIS Software	1,500	5
Classification of management zones (service)	2 €/ha	5

RESULTS AND DISCUSSION

Table 4 summarizes the PA costs of the three approaches for various farm sizes. The calculations are based solely on the implementation of site specific nitrogen management on grain fields (Table 2). The capital costs of the yield mapping systems are calculated based on the area of the grain-harvested fields. An average life of five years is assumed for depreciation. For example, for a 500 ha farm with a sensor approach for nitrogen fertilization on grain fields, the additional outputs have to cover costs of at least 17.39 €/ha to have benefits of PA. For a farm of 2,000 ha, these costs sink to 4.35 €/ha. The most expensive is the sensor with map overlay approach. This approach needs the greatest amount of information to recommend the site specific fertilizer amount.

In Table 4, the result of the field trial is presented. With respect to yield and additional output, in this year and on this field, all site specific fertilization strategies reached a better result than the uniform treatment.

After deducting the additional precision farming costs, all fertilization strategies on all farm sizes (500, 1,000 and 2,000 ha) still reach a better result than the uniform field treatment, with the online approach providing the best result. Despite the greatest information base, the online approach with map overlay doesn't reach the best result. One explanation could be the quality of the used decision rules.

Table 4: Additional precision farming costs of three approaches for different farm sizes (nitrogen fertilization to grain)

	ha	**Data collection costs (€/ha)**		**Data processing costs (€/ha)**		**Application costs (€/ha)**		**Sum**
Online approach	500	17.39	Yara-N-Sensor with Terminal					17.39
	1000	8.69						8.69
	2000	4.35						4.35
Offline approach	500	5.32	Classification of management zones (service), Yield mapping*	0.86	Planning of nitrogen amount	4.70	Terminal with GPS	10.88
	1000	5.32		0.43		2.35		8.10
	2000	4.10		0.21		1.15		5.49
Online approach with map overlay	500	5.32	Classification of management zones (service), Yield mapping*	0.86	Planning of nitrogen amount	17.39		23.57
	1000	5.32		0.43		8.69		14.44
	2000	4.10		0.21		4.35		8.66
			Yara-N-Sensor with Terminal					

* 500 ha: one yield mapping system; 1,000 ha: two yield mapping systems; 2,000 ha: three yield mapping systems

Table 5: Result of the field trial

	Uniform treatment	Online approach			Offline approach			Online approach with map overlay		
Average* Yield (dt/ha)	71.77	83.1			81.81			81.78		
Protein (% RP in dm)	14.2	11.9			11.1			11.6		
Turnover** (€/ha)	718	748			736			736		
Nitrogen Costs (€(ha)	99	65			82			74		
NCfT*** (€/ha)	619	683			655			662		
Farm size (ha)		500	1000	2000	500	1000	2000	500	1000	2000
Additional output (€/ha)	0	+46.6	+55.3	+59.7	+25.1	+27.9	+30.5	+19.4	+28.56	+34.3
* yield analysis by consideration of the means of yield map points in the strips ** Turnover with regard to protein content *** Turnover less Nitrogen Costs										

CONCLUSION

The additional costs for precision farming hardware are manageable for the observed farm sizes. In the future it is conceivable that these costs will continue to decrease. For example, the tractor (combine harvester) could be standardly-equipped with a GPS device and a terminal (yield mapping). In this case, these costs are almost negligible. By accessing PA service providers with the proper equipment, smaller farms can profit from these technologies as well. Then utilizing the various precision farming technologies only depends on the existence of efficient decision-making rules.

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PREDUSLOVI ZA USVAJANJE SAVREMENIH TEHNOLOGIJA - PRIMER PRECIZNA POLJOPRIVREDA

Martin Schneider, Peter Wagner

Martin-Luther-University of Halle, Institute of Agriculture Economics, Farm Management Group, Halle, Germany

Sadržaj: Sa razvojem sistema globalnog pozicioniranja (GPS), geografskog informacionog sistema (GIS) i drugih različitih senzora i aktuatora, mogućnost informaciono-vođene biljne proizvodnje nikada nisu bile realnije i veće. Pretpostavka je da će se profit pojedinca povećati ako se u proizvodni proces uđe sa što više informacija i preciznosti. Tokom poslednjih godina beleži se značajan napredak na polju precizne poljoprivredne proizvodnje, sa jedna strane, i vrlo slab "odziv" farmera u smislu direktne primene ovih sistema. Bez obzira na ovo, sve je veći broj dobavljača mehanizacije koji u svojoj ponudi imaju širok spektar tehnološko-tehničkih rešenja namenjenih konceptu precizne poljoprivredne proizvodnje. Jedno od pitanja je kako je to moguće ako farmeri nisu zainteresovani?

Cilj ovog rada je ispitivanje lokalno-specifične aplikacije hraniva u regionu istočne Nemačke, sa ekonomskog aspekta.

Ključne reči: *poljoprivredna proizvodnja, precizna poljoprivreda, lokalno-specifična aplikacija hraniva, profit.*