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Spatial accuracy of online yield mapping

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Spatial accuracy of online yield mapping

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Abstract

Accuracy problems of online yield mapping are well known and since its introduction in 1990 many error sources were found and ever then tried to overcome. The objectives of this paper were to quantify the time lag between cutting the crop and measuring the grain yield by the sensor. Pre harvested segments were used to calculate this time lag using a Flowcontrol yield monitor mounted on a Massey Ferguson combine harvester at two harvests of oats in 2000 and 2001. Analysing the extracted yield data, a time lag of approximately 18 seconds, corresponding with 20 meters, was determined. The investigations confirm the complexity of grain flow dynamics within the combine harvester and therefore non-linear models need to be developed for overcoming these problems. This requires not only further investigations into grain flow dynamics, but also practical solutions to other sources of errors influencing the quality of yield data. Despite these restrictions, yield maps derived from online yield sensoring devices offer valuable information about spatial variations of crop productivity within agricultural fields if cleaning processes of erroneous data are applied.

Key words: yield mapping, True Yield Position (TYP), precision agriculture, accuracy

Fehlerquellen bei der Bestimmung der räumlichen Zugehörigkeit von online Ertragsdaten

Zusammenfassung

Seit der Einführung der online Ertragskartierung im Jahre 1990 wurden verschiedene Fehlerquellen bei der Ertragsaufzeichnung beschrieben und versucht, Techniken und Methoden zur Vermeidung bzw. Verminderung dieser Fehler zu entwickeln. Ziel des vorgestellten Versuches war die Bestimmung der Zeitverzögerung zwischen dem Schneiden des Getreides und dem Messen des Ertrages durch den Sensor. 2000 und 2001 wurden experimentelle Ertragskartierungen im Hafer mit einem Massey Ferguson Mähdrescher mit Flowcontrol Ertragskartierungssystem durchgeführt. Vor Beginn des Druschvorganges wurden jeweils zwei Streifen des Schlages geerntet, um die Zeitverzögerung bis zum Erreichen des Nullertrages zu messen. Die Versuche ergaben Zeitverzögerungen von etwa 18 Sekunden, was ca. 20 Metern entspricht. Außerdem zeigte sich, dass die komplexen dynamischen Vorgänge des Korns im Mähdrescher eine lineare Korrektur der Ertragsdaten nicht zulässt, so dass weitergehende Forschung auf diesem Gebiet notwendig ist. Andere Fehlerquellen bei der Aufzeichnung von Erträgen müssen ebenso ausgeschlossen werden. Nach der Bereinigung der Ertragsdaten von fehlerhaften Werten bieten Ertragskarten aber auch heute schon eine wichtige Informationsquelle über Produktionspotenziale eines Schlages.

Schlüsselwörter: Ertragskartierung, True Yield Position (TYP), Precision Agriculture, Aufzeichnungsfehler

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1 Introduction

Online yield mapping has become one of the most widely used methods to gather spatially variable information about field parameters in precision agriculture. Yield maps are used to determine recommendation rates for many applications (Blackmore and Larscheid, 1997; McBratney et al., 2000; Grenzdörffer and Gebbers, 2001) and provide feedback information how crops responded to certain soil and crop management practices though yield data only documents the spatial distribution of crop productivity rather than explaining causal factors. Other fields of applications are the derivation of equifertiles (Schnug et al., 1994) and the identification of sampling locations for directed sampling (Haneklaus et al., 2000a; Panten, 2002).

Since the introduction of geocoded online yield mapping in 1990 accuracy problems are known. Thylén et al. (1997) and Arslan and Colvin (2002) classified the sources of errors inherent to yield data into four categories: sensor errors, errors due to operating conditions, operator errors and and yield mapping errors. Major errors are caused by deviations from the pre-defined cutting width, grain lag time, positioning errors from GPS, mingling of grain in the combine, grain losses as well as validity and accuracy of the calibration of the yield sensor (Blackmore and Marshall, 1996). Out of these problems, Haneklaus et al. (2000b) identified the TYP (True Yield Position) and TCW (True Cutting Width) as the major uncertainties in yield mapping. In addition, Blackmore and Moore (1999) mentioned error sources inherent to yield maps due to smoothing, narrow finishes, harvester fill and finish mode and grain losses. The objectives of this paper are to quantify the time lag between cutting the crop and measured grain yield by the sensor in order to estimate errors caused by TYP.

2 Materials and Methods

A Massey Ferguson (MF) combine harvester with a cutting platform of 6 m width and a Flowcontrol (MF) yield monitoring system was used. A detailed description of this type of sensor is given by Murphy et al. (1995). The positioning was carried out by a DGPS system using a differential correction signal, provided by the German ordnance survey.

Experimental yield mapping was carried out on two fields of the experimental farm of the Institute for Animal Science of the FAL in Mecklenhorst near Hanover, Lower Saxony, Germany. In 2000, field 'Schlag 2/3' (52.508° N; 9.512° E; 4.9 ha) and in 2001, field 'Stall 5 hinten' (52.505° N; 9.483° E; 7.5 ha) were harvested using two different experimental designs. Yield data of the headlands were not included in the experiments. On field Schlag 2/3 two 18 meters wide segments, one orthogonally and one diagonally to the combine harvester cutting direction were removed (Fig. 1). In 2001, on field Stall 5 hinten two parallel segments of 30 and 42 meters width were removed orthogonally to the combine harvester cutting direction (Fig. 2). Then the fields were harvested and the effect of the zero yield segments on the recorded yield data was determined. During both experiments only runs with full cutting width (± 20 cm) were driven.

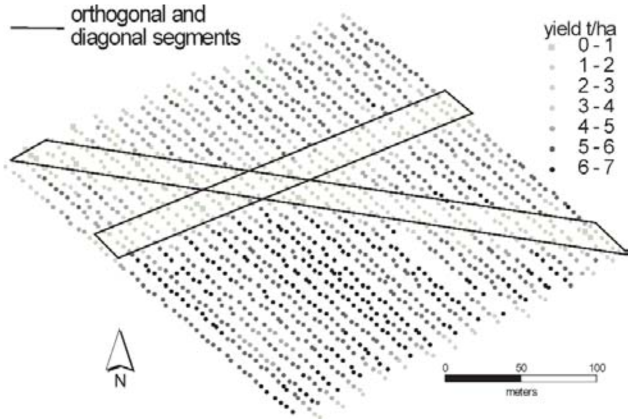

Fig. 1
Design of the harvest experiment on field 'Schlag 2/3' in 2000

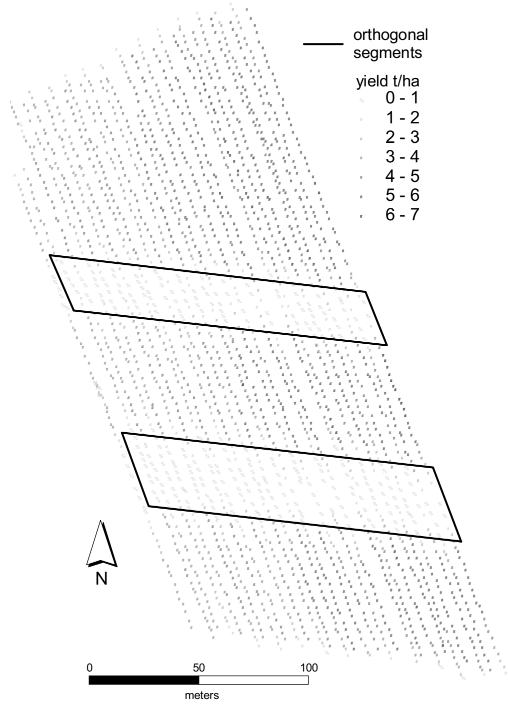

Fig. 2
Design of the harvest experiment on field 'Stall 5 hinten' in 2001

3 Results

The first experiment carried out in 2000 showed that all recorded yield data was >1 t ha^{-1}. These results imply that segments of 18 meters width were still too narrow in order to result in zero yield readings. Fig. 3 reflects typical yield readings of one single combine run.

The experimental design impressively revealed the influence of variations of the actual cutting width on the recorded yield data: in the diagonal zero yield segment cutting width decreased slowly and this again resulted in a slower decrease of the recorded yield data than in the orthogonal zero yield segment (Fig. 3). The longer distance (~25 m) when harvesting across the diagonal zero segment consequently caused lower recorded yield data. Only in the crossing section of the two 18 m segments yield values close to zero were recorded (Fig. 4). Based on these results the second experiment was designed with two broader orthogonal segments in order to determine the travel distance that is required for recording zero yield values.

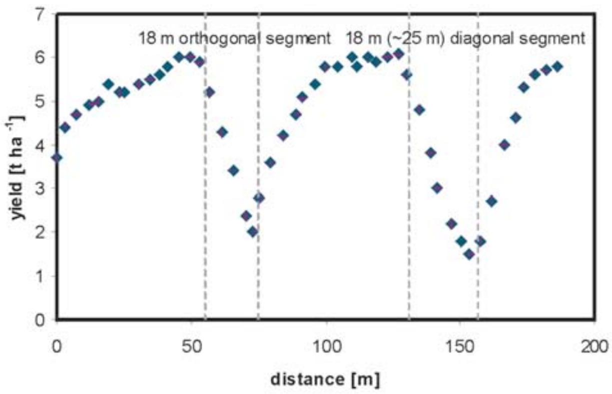

Fig. 3
Effect of zero yield segments on recorded yield data during one combine run on field 'Schlag 2/3' in 2000

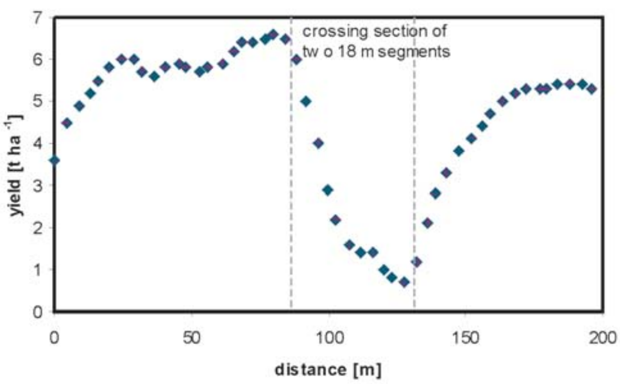

Fig. 4
Effect of two crossing zero yield segments on recorded yield data during one combine run on field Schlag 2/3' in 2000

The results of the second harvest experiment in 2001 are shown in Fig. 5. Yields declined more or less instantly after reaching the zero segments, but the transport of the grain previously cut into the grain elevator caused only a slow decline of the recorded yield so that even in the segments of 42 m width no zero yield readings were determined. These results emphasize that the required time to completely empty the grain elevator is even longer.

Approximately 20 m after entering the zero yield segments the yield sensor recorded yield data of < 1 t ha^{-1} yield. The same distance and time, respectively was necessary for reaching again the yield level after leaving the zero yield segments. Taking into consideration that the next combine run is carried out in the reverse direction, if one combine is operating, results in a mirror-inverted shift of the yield pattern (Fig. 6).

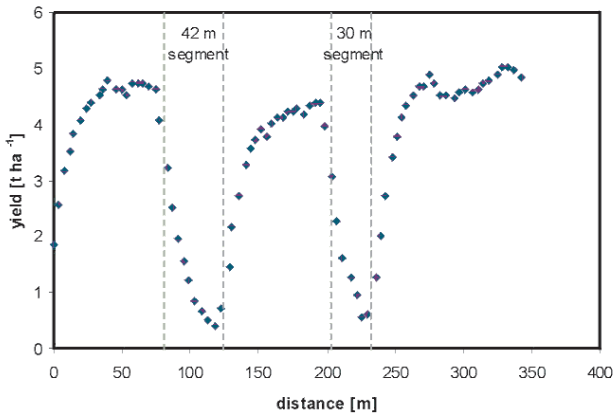

Fig. 5
Effect of zero yield segments on recorded yield data during one combine run on field 'Stall 5 hinten' in 2001

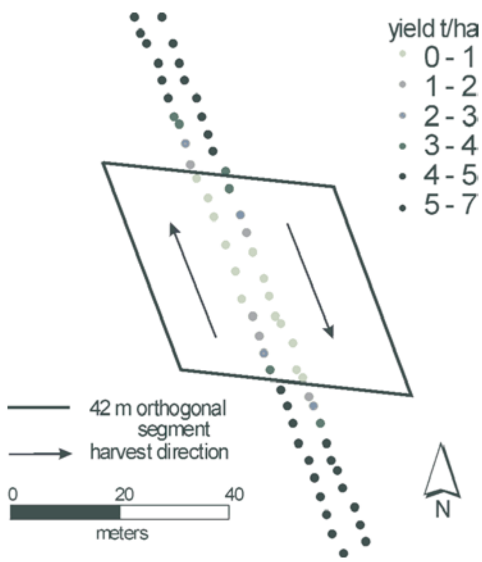

Fig. 6
Effect of two reverse combine runs across zero yield segments on recorded yield data on field 'Stall 5 hinten' in 2001

In other words, at an average speed of 4 km h^{-1} the time lag between cutting and recorded position and yield was about 18 seconds.

4 Discussion

Next to the problem of TYP other factors such as TCW, grain losses, GPS accuracy, sensor accuracy and calibration (Blackmore and Marschall, 1996; Arslan and Colvin, 2002) are influencing the quality and accuracy of yield data which needs to taken into account when the correctness of yield data is discussed.

Online yield measurements were performed in order to determine the TYP error using a MF combine harvester equipped with a Flowcontrol yield monitor. A variety of online grain yield sensors with different techniques (volume or mass flow sensors) to measure the grain flow are commercially available. Variations of yield data depend on factors such as the yield sensor system used, speed, grain type, moisture, quality of calibration. The problem of time lags between cutting and measuring the grain yield however, is similar in all systems. The indirect radiometric measurement method of the MF Flowcontrol yield monitor is only slightly influenced by grain type and grain moisture content (Reyns et al., 2002). Reyns et al. (2002) also reported that the errors caused by TYP increased at low flow rates when testing among others the radiometric sensor system. The results of the presented investigations support these findings as the yield within the zero yield segments hardly decreased below 1 t ha^{-1}. Under practical conditions and after interpolation of the recorded yield data, reverse combine runs might yield a positioning error of yield data of about 40 m with deviations of 20 m in each direction in the worst case. The situation is different at the start of a combine run, because of the missing interpolation points in one direction. If cleaning processes (Haneklaus et al., 2000b) of the raw yield data in these areas can not be carried out all zones at the start and end of each combine run should be excluded before creating yield maps. A simple linear time shift will not overcome the time lag problem, because of the dynamics of the grain flow within the harvester (Whelan and McBratney, 2002). A better understanding of the grain flow dynamics within the harvester is necessary before non-linear models can be used to synchronise the recorded yield data (Pierce et al., 1997). A first approach would be the use of sensors within the combine harvester which measure step by step the actual grain flow.

Despite the problem of TYP, yield maps provide basic and invaluable information about the spatial variation of crop productivity. Additionally yield maps may be used to identify yield limiting factors and to develop strategies for a site-specific crop management. Significant in this context supposedly is whether yield data is used in management zones where the TYP error has most likely a minor relevance or in continuous mode applications where more distinct effects can be expected if yield varies highly and abruptly within space. As Arslan and Colvin (2002) stated, yield data shows trends rather than indicating yield spots.

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