

## **Local Yield Measurement in a Potato Harvester and Overall Yield Patterns in a Cereal-Potato Crop Rotation**

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### **Summary:**

In 1997 and 1998 the commercially available conveyor weighing system Harvestmaster HM500 was evaluated on a trailed, single-row, offset-lifting, bunker-hopper potato harvester on the experimental farm Scheyern. The system worked well and the reached accuracy, with a standard deviation of the relative errors of 4.1 %, was similar to that of yield measurement systems used in combines. Local yield data were corrected by the content of contaminants and yield maps were calculated. Regression analysis of the average relative grid yields of four years showed different yield patterns in comparison to combinable crops on the same two fields.

### **Keywords:**

Potato harvester, yield, measuring system, precision farming.

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# Local Yield Measurement in a Potato Harvester and Overall Yield Patterns in a Cereal-Potato Crop Rotation

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## 1. Introduction

Local yield detection is widely recognized as basic information for management decisions in site specific plant production (Blackmore *et al.*, 1994) or for controlling the effects of spatially variable applications. For yield measurement in combine harvesters commercially available equipment is on the market and has been evaluated under different practical conditions (Auernhammer *et al.*, 1993), as well as on a test stand (Korrmann *et al.*, 1998). Investigations of Auernhammer and Demmel (1997) have shown that for determining yield patterns by defining stable yield zones local yield data for more than two seasons are necessary. To get the needed information as fast as possible local yield detection for non-combinable crops of typical European rotations is an indispensable requirement.

For forage choppers, different developments have been reported in research by Auernhammer *et al.* (1995), Ehlert and Schmidt (1995) and for prototype state (Shinners and Barnett, 1998). Also for the yield monitoring of "conveyor harvested crops", like sugar beets, potatoes, onions and tomatoes, first technical solutions are available. For yield measurement of sugar beet conveyor weighing systems (Walter *et al.*, 1996; Hall *et al.*, 1997; Demmel and Auernhammer, 1998), a mass-flow system measuring the forces on a curved plate (side screen) at a rotating spinner (Broos *et al.*, 1998) or a laser based optical volume flow measuring system (Kromer and Degen, 1998) have been proposed.

For potato harvesters, only the application of a conveyor weighing technique has been reported (Campbell *et al.*, 1994; Rawlins *et al.*, 1995; Schneider *et al.*, 1997). The systems have been installed into the trailer loading elevator of two- or four-row harvesters. In Germany, single-row machines with a bunker-hopper are used. To get knowledge on the accuracy of a yield detection system under such conditions a measurement system for local yield detection was evaluated in the potato harvest seasons 1997 and 1998.

## 2. Materials and Method

Considerations on possible mass-flow and yield measurement systems for potatoes have to start with the analysis of the process of and the machinery used for harvesting. The main goal of harvesting is to collect non damaged potatoes of highest quality without haulm, clods and stones. Therefore the machinery used has a big variation depending on the different conditions of use. In all modern machines, belt type chains or webs and different types of rollers are used for separating potatoes from contaminants. Under difficult harvesting conditions, the process of separating potatoes from the contaminants needs the whole way of the potatoes through the machine. But also on light soils sepa-

ration of the soil should be a slow process to attain a smooth ride on the webs or conveyors to avoid damage. Therefore to get information on the mass-flow or yield of potatoes, not on haulm, clods or stones, yield measurement systems have to be located at the end of the material stream or at the end of their way through the harvester.

Nearly all potato harvesters are tractor-trailed machines. In Germany, most of them are single-row harvesters, more and more offset-lifting, typically with a bunker-hopper. In bigger enterprises in Eastern Germany, Great Britain, France and the Netherlands two-row side-loading potato harvesters are also often used.

Based on the typically used harvester technology, the following mass-flow and yield measurement systems can be considered (Figure 1).

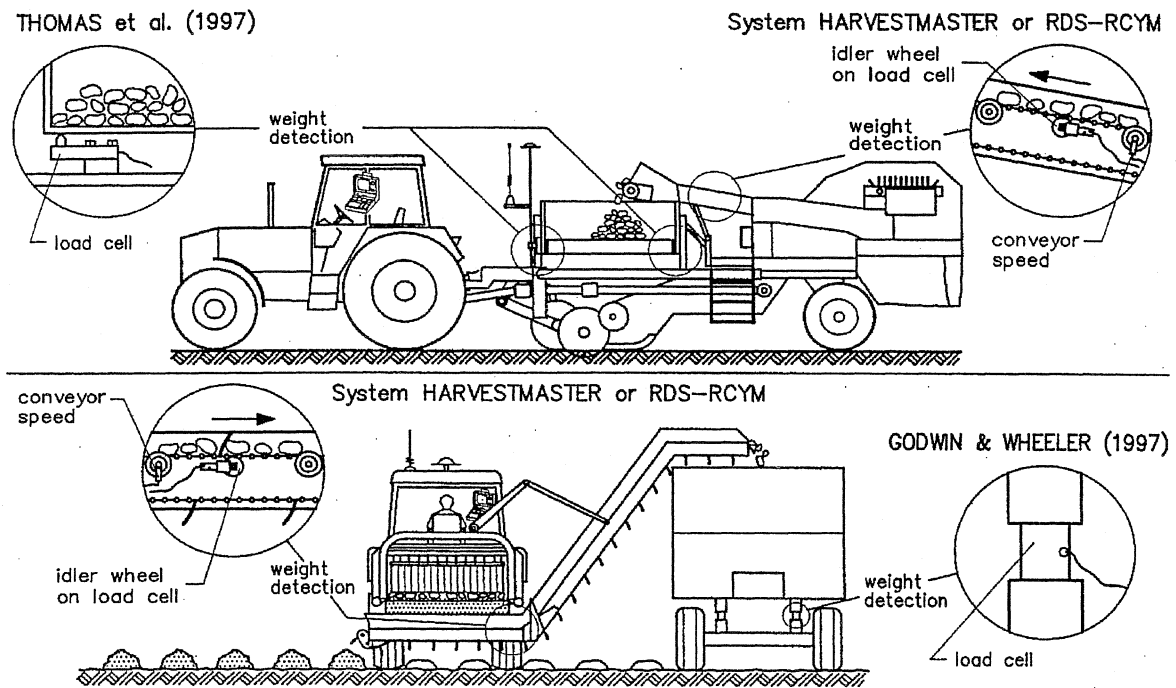


Figure 1: Possibilities of continuously working mass-flow and yield measurement systems for potato harvesters.

A first possibility not shown on the picture would be the weighing of the total harvester using load cells on the half axles and the shaft. This possibility must be rejected because of the contaminants (haulm, soil, clods, stones) of the potatoes which enters and leaves the machine in a non-definable and non-controlable way.

Godwin and Wheeler (1997) have used weighing technology on a trailer with a side loading potato harvester. Their measurement system with four load cells between the trailer box and the chassis was able to estimate the load on a 8 t tipping trailer within 1 kg. The errors with flow rates of 17 kg/s was less than 2.4 %. This solution is limited to side loading potato harvesters but can also be used for harvesting sugar beets and corn silage.

Also for side-loading potato harvesters, mass flow and yield measuring systems based on conveyor weighing technique were developed and tested (Campbell *et al.*, 1994; Rawlins *et al.*, 1995; Schneider *et al.*, 1997). The conveyor belt weighing technology used was installed in the discharge conveyor of two-row, side-loading potato harvesters.

Therefore a pair of the chain supporting idler wheels were mounted on load cells. The weight must be calculated together with the belt speed. The relative errors of the system had a standard deviation of 4.9 %.

A fourth possibility is the weighing of the bunker hopper (if existing). A problem may arise from the bad relation between the increase of weight per time period and the total weight of the bunker-hopper. Calculations show that the low working speed of typical single-row potato harvesters on heavier soils (less than 1 m/s) results in mass flow rates of less than 5 kg/s. Using weighing technology of the whole bunker-hopper with 3-4 t capacity means it would be necessary to weigh the bunker hopper with an accuracy of better than 0.1 % to be able to detect the flow rate with an error less than 10 %. It seems very difficult to realize such a high accuracy under rough conditions in mobile use. Nevertheless Thomas *et al.* (1997) and Perry *et al.* (1998) successfully used this technology for the mass-flow determination in a tractor-pulled peanut combine with a basket. The mass-flow with a four row machine and 1.5 m/s working speed was about 2.8 kg/s. The reached accuracy showed a standard deviation of 3.1 %.

Based on the results of the literature survey and because the project was not planned as development work, but for evaluation of a measurement system on a typical trailed, single-row, offset-lifting, bunker-hopper potato harvester, the use of the commercially available conveyor mass-flow and yield detection system HM 500 from Harvestmaster was decided.

Because there was no trailer loading elevator available for installing the weighing sensors, the pair of load cell mounted idler wheels had to be installed at the end of the sorting (picking off contaminants) and bunker-hopper loading conveyor of a GRIMME 75-40 one-row, offset-lifting, bunker-hopper potato harvester. As part of the HM500 installation kit, a reed switch for detecting the speed of the conveyor was supplied. For georeferencing of the local yield data, a Motorola Oncore 8-channel DGPS receiver with correction data from the local base station was connected to the Harvestmaster data processing unit. Data collection was made with a laptop PC on the tractor with a sample rate of 0.3 Hz.

In 1997 two fields (no. A17, area 6.0 ha, shallow loess on Tertiary sediments, slopes of about 10% facing E and S; no. A19, area 1.9 ha, shallow loess on Tertiary sediments, level) on the experimental farm Scheyern were harvested using the mass-flow and yield measurement system HM500. All 39 trailer loads were counterweighed on a platform scale (calibrated by the Board of Weights and Measures, accuracy 10 kg). In 1998 four potato fields were harvested in the same way, but counterweighing was done only on field A18 (area 6.5 ha, shallow loess on Tertiary sediments, slopes of about 10% facing E and S) with 38 trailer loads. All absolute deviations were converted to relative errors. The mean error as the quality criteria for calibration and the standard deviation of the errors for the measurement accuracy were determined.

All georeferenced yield data were corrected load by load with the contaminant content determined by weighing the potatoes before and after a post-harvest on-farm separating and cleaning and were processed to grid type yield maps.

Regression analysis of the mean relative yields per grid from several years and crops (winter wheat, corn, potatoes) were used to determine the stability of yield patterns in the two fields.

### 3. Results

During the two harvesting seasons the measurement system worked well on the harvester on the medium and heavier soils of the experimental station.

At the beginning of the evaluation in 1997, very high measurement errors were caused by the changing tension of the chain of the sorting conveyor and by lifting the chain from the supporting idler wheels created by the automatic moving swan-neck of the conveyor at the bunker hopper end. That problem was solved by switching off the automatic control and blocking the swan-neck. Four people working on the first two thirds of the sorting conveyor didn't influence the accuracy of the measurement device because the load cell mounted idler wheel where located out of the sorting area.

After solving the mentioned problems the 1997 mean error of 1.6 % showed that the calibration could be improved only by a small amount. The standard deviation of the relative errors as size or criterion for the measurement accuracy was 4.4 %.

In 1998, 38 trailer loads of total 254 t of potatoes (7.71 t per load) of the field A18 have been counterweighed. The mean error was -4.2 %, which means that the calibration of the system was not as good as in 1997. The reason was that a recalibration after changing the sorting conveyor chain at the beginning of the 1998 harvesting season was not carried out. The standard deviation of the relative errors with 3.7 % was a little smaller than in 1997. This development might be caused by adding a mechanical blocking of the swan-neck.

The corrected yield data resulted in potato yield maps (Figures 2 and 3).

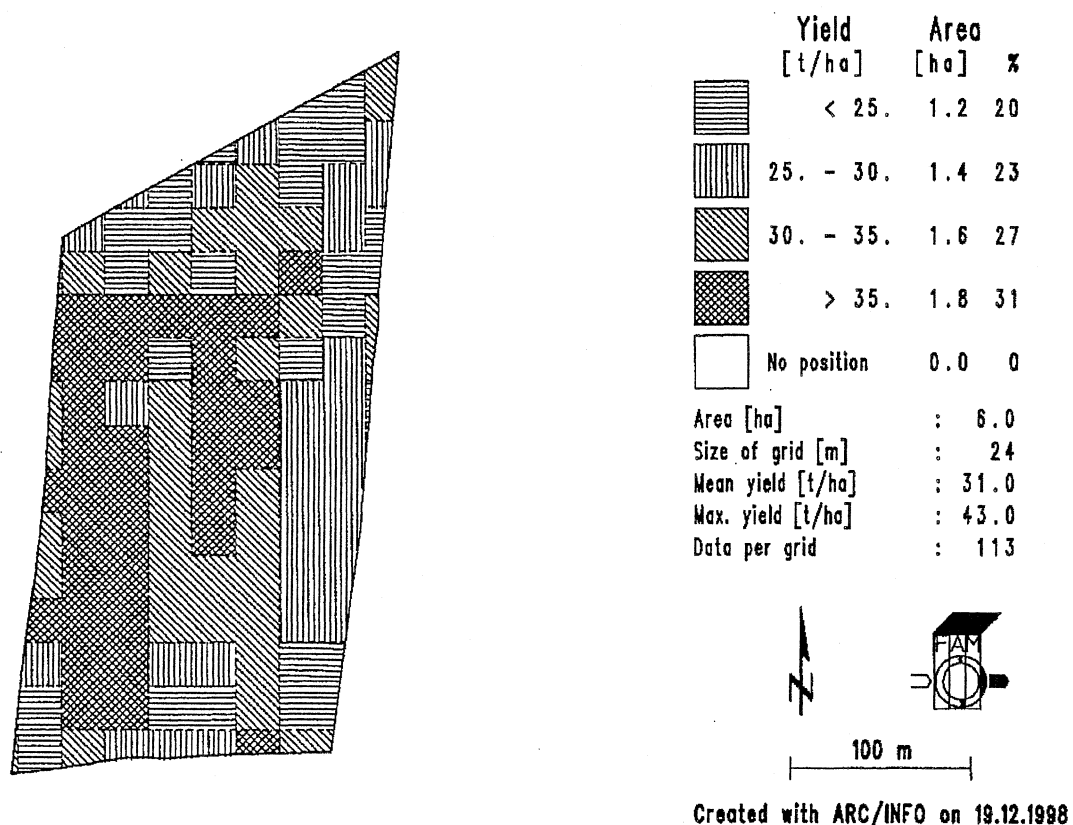


Figure 2: Yield map potatoes field A17, experimental farm Scheyern 1997

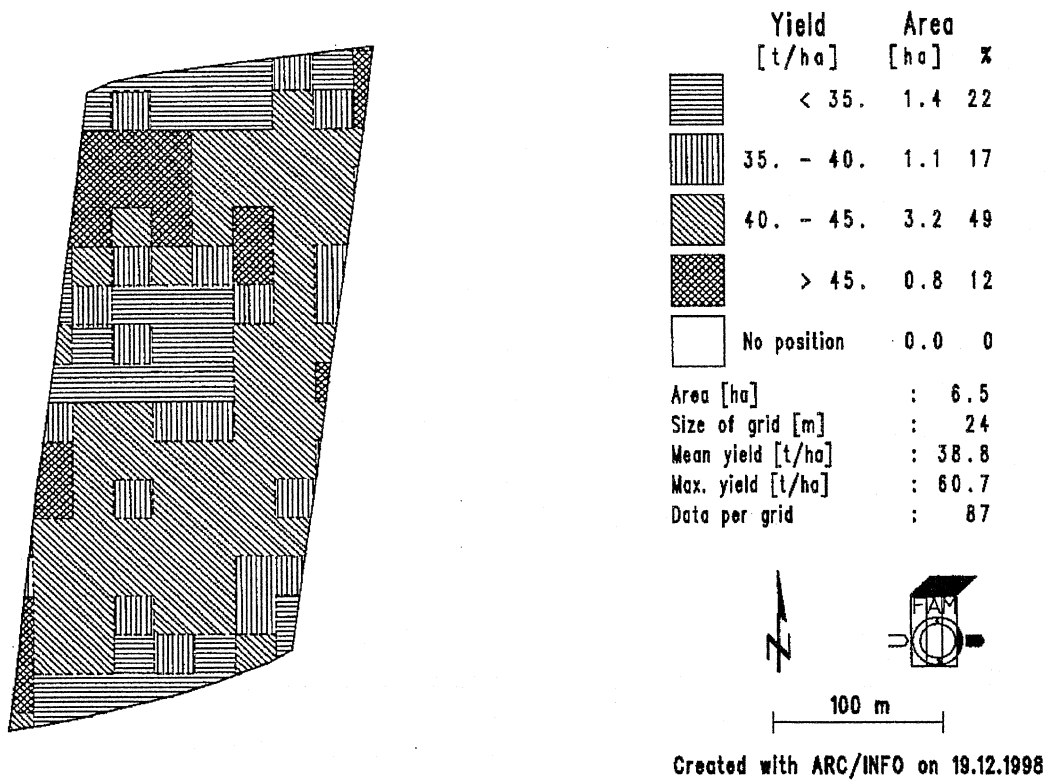


Figure 3: Yield map potatoes field A18, experimental farm Scheyern 1998.

Based on collecting yield data of combinable crops on the experimental farm Scheyern since 1990, potato yield patterns (mean relative yield of field and year correspond to 100 %) were compared to former maps of combinable crops (winter wheat and corn) on the fields A17 and A18 (fig. 4 and 5).

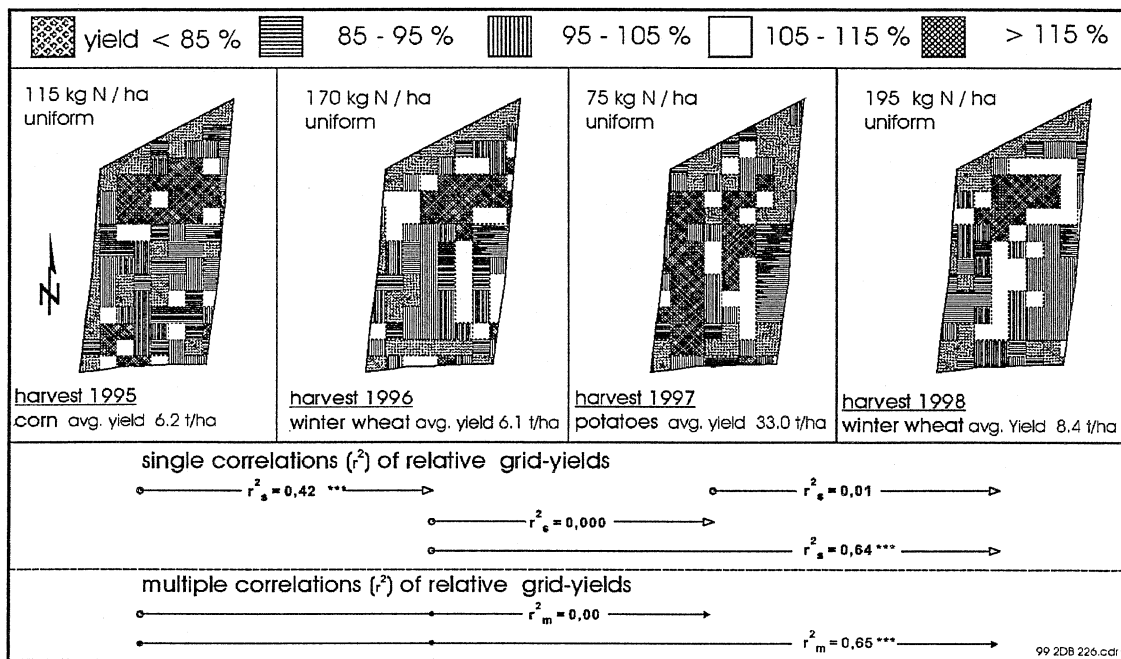


Figure 4: Relative yield maps and correlations of yield patterns of field A17, experimental farm Scheyern 1995, 1996, 1997, 1998.

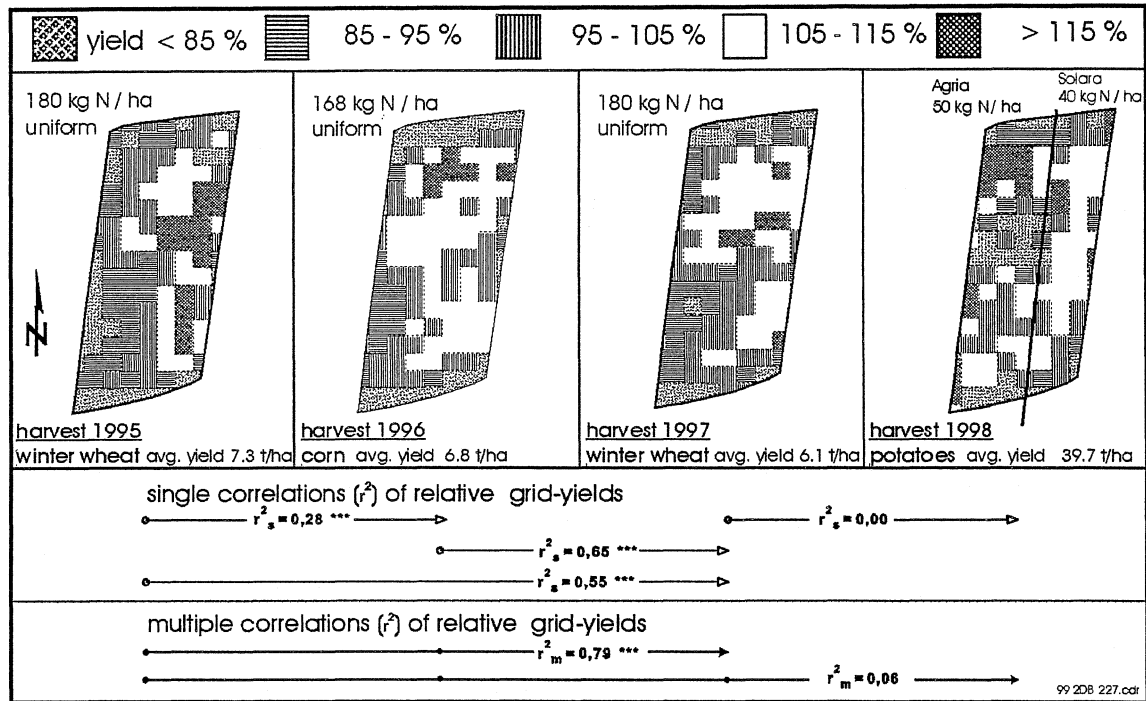


Figure 5: Relative yield maps and correlations of yield patterns of field A18, experimental farm Scheyern 1995, 1996, 1997, 1998.

Comparisons of the average relative yields per grid (24 x 25 m and 50 x 50 m) by regression analysis confirm high correlations between corn and winter wheat yields of different years (1995 and 1996 on A17, 1996 and 1997 on A18) with  $r^2$  of 0.42 and 0.65. Similar correlations (of combinable crops) were determined by Auernhammer and Demmel (1997) on several other fields of the experimental farm Scheyern

Besides the comparison of combinable crops the potato yields differ from any other correlations. On field A17 with potatoes in harvest 1997 the single correlations between the previous and the next year are near to zero. But there seems no influence on the overall yield patterns across all years. So between the both winter wheat yields in 1996 and 1998 again a high correlation of 0.64 is observed.

Also on field A18 same results can be obtained. Again the single correlations ( $r^2$ ) between combinable crops are significant between 0.28 and 0.65. And again there is no correlation between the potato yield pattern in 1998 and the previous once in 1997.

Multiple correlations on both fields confirm earlier results with an increasing value up to 0.80 across three harvests. When the correlations are calculated without the potato yields on A17 the multiple correlation then is 0.65.

#### 4. Discussion

Although developed for higher mass flow of two- or four-row side-loading potato harvesters, the conveyor weighing system Harvestmaster HM500 reached a satisfying accuracy on a single-row machine. The standard deviations of the relative errors of 4.4 % in 1997 and 3.7 % in 1998 were very similar to those reached in a lot of practical tests of

yield measurement systems in combines (Auernhammer *et al.*, 1993, standard deviation of the relative errors between 3.5 and 4.5 %).

The accuracy reached is also comparable and similar to other measurement systems for root crops reported in literature (Table 1).

Table 1: Accuracy of mass-flow and yield measurement systems for potatoe and sugar beet harvesters.

measurement principle	Harvester typ, crop	author	evaluation extent	measured accuracy
mass accumulation system "Silsoe"	Trailer Sugar beet, potatoes	Godwin <i>et al.</i> 1997	1 field 15 loads	avg.= 1.1 % s.d.= 4.0 %
basket weighing system "Tifton"	Trailed two-row basket combine, peanuts	Durance <i>et al.</i> 1998	2 fields 40 loads	avg.= 0.2 % s.d.= 3.1 %
conveyor weighing "Harvestmaster"	trailed two-row side loading, potatoes	Rawlins <i>et al.</i> 1995	1 field 48 loads	avg.= n.c. s.d.= 4.9 %
conveyor weighing "Harvestmaster"	trailed six-row side loading, sugar beet	Hall <i>et al.</i> 1997	1 field 99 loads	avg.= -0.97 % s.d.= 2.2 %
conveyor weighing "Harvestmaster"	trailed one-row bunker hopper, potatoes	Demmel <i>et al.</i> 1998	2 fields 77 loads	avg.= -1.3 % s.d.= 4.1 %
conveyor weighing "Harvestmaster"	self-propelled six-row side loading, sugar beet	Demmel <i>et al.</i> 1998	2 fields 39 loads	avg.= 1.0 % s.d.= 3.7 %
conveyor weighing system "Rottmeier"	self-propelled six-row tanker, sugar beet	Demmel <i>et al.</i> 1998	5 fields 23 loads	avg.= 2.1 % s.d.= 5.6 %
force curved plate system "Leuven"	self-propelled tanker loader, sugar beet	Broos <i>et al.</i> 1998	1 field 19 loads	avg.= 0.4 % s.d.= 1.6 %
laseroptical volume system "Bonn"	self-propelled cleaner loader, sugar beet	Kromer <i>et al.</i> 1998	2 fields 15 loads	avg.= n.c. s.d.= 4.0 %

All yield data of root crops collected with the known measurement systems include errors which occur from soil, clods and stones comming with the potatoes (or beets). They can be partly compensated if the local yield data are corrected by an estimated or during post-harvest on-farm sorting and cleaning process measured contaminant (soil, clods, stones) content (or the contaminat content indicated by the sugar factory for the delivered beets).

In both years and on both fields the potato yield data show no correlation to the previous or following combinable crops ( $r^2$  between 0.01 and 0.18). Such clearly shaped differences between the yield pattern of grain and potatoes have not been expected and reported before and cannot be explained until now. Further analysis integrating all available soil and plant informations (Auernhammer (1999)) and additional years and fields are needed to confirm and to explain this observation.

#### 4. Conclusions

Local yield detection using conveyor weighing technique on a one-row trailed potato harvester with offset-lifting and bunker-hopper using DGPS for positioning worked without any technical problem during two harvesting seasons. The reached accuracy was comparable to the accuracy of yield measurement in combines and to other measurement systems for "conveyor harvested crops".



Errors difficulty to estimate arise from contaminants (halm, clods, stones) which are collected and “weighed” together with the crop. A post-harvest data correction with an estimated or calculated “average” contaminant content will not be able to solve that problem, especially if the proportion of the contaminants is changing within the field. Additional measuring systems to determine the contaminant content will be needed in future, also to automatically control the cleaning process in the harvester.

First comparisons of potato yield maps to those of combinable crops show deviating yield patterns. Further analysis on whole rotations, more fields, over several years and at more locations are needed to confirm this observations .

## 5. Acknowledgements

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