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YIELD MEASUREMENT ON SELF PROPELLED FORAGE HARVESTERS

by

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Summary:

Between 1992 and 1994 a yield measurement device for selfpropelled forage harvesters was developed and tested in the harvest seasons 1993 and 1994. Over 140 ha of whole crop maize and 20 ha of grass silage were harvested. The mass flow measuring system based on a radiometric principle was investigated on reliability, measuring accuracy, range of measurement errors and reasons for measurement errors.

Keywords:

Forage harvester, yield, measuring system, precision farming.

Yield Measurement on Self Propelled Forage Harvesters

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Abstract

Site specific or precision farming requires detailed knowledge on field and soil data. Yield data not only from combinable grains but from all crops are necessary to get information on whole rotations. Therefore a yield measurement system for selfpropelled forage harvesters was developed and tested in the years 1992-1994.

The system is based on a radiometric measurement device placed at the chopper's spout. The speed of the material is registered by a radar sensor. All data are collected, stored and processed by an onboard PC. Together with information on the driving speed and the working width the yield (t/ha) is calculated out of the measurements flow-rate output.

In the year 1993 and 1994 over 140 ha maize have been harvested with local yield detection. The system showed a high reliability. Over 2000 t of maize / 416 trailer loads were weighed on a platform scale. Data from 22 fields with different dry matter contents were analysed with the same system calibration. The mean error of +3.06% shows the offset of the calibration, The standard deviation of the errors was 7.07%. A higher accuracy was reached by controlling and renewing the calibration at the beginning of every new field (mean error -0.11% and standard deviation 3.71% for the "Ammersdorfer Feld" in 1994).

A future analysis of the data of other sensors will show if there are alternative combinations of parameters which also allow to determine the yield in a forage harvester with the same accuracy.

Introduction

Environmentally friendly agriculture has to take care on the variations of the soils and their productiveness. Precision or site specific farm management systems try to fullfill these requirements. Within this systems yields are significant figures that reflect nutrient extraction. Localy measured yields are also parameters to destinguish fieldparts or fieldzones.

Worldwide research work on yield measurement was up today nearly totaly limited on combinable crops [2, 3, 6, 7, 8, 9, 10, 12].

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With a series of yield maps of combinable grains it is for the first time possible to calculate yield equations, to determine yield pattern and to observe their stability (fig. 1).

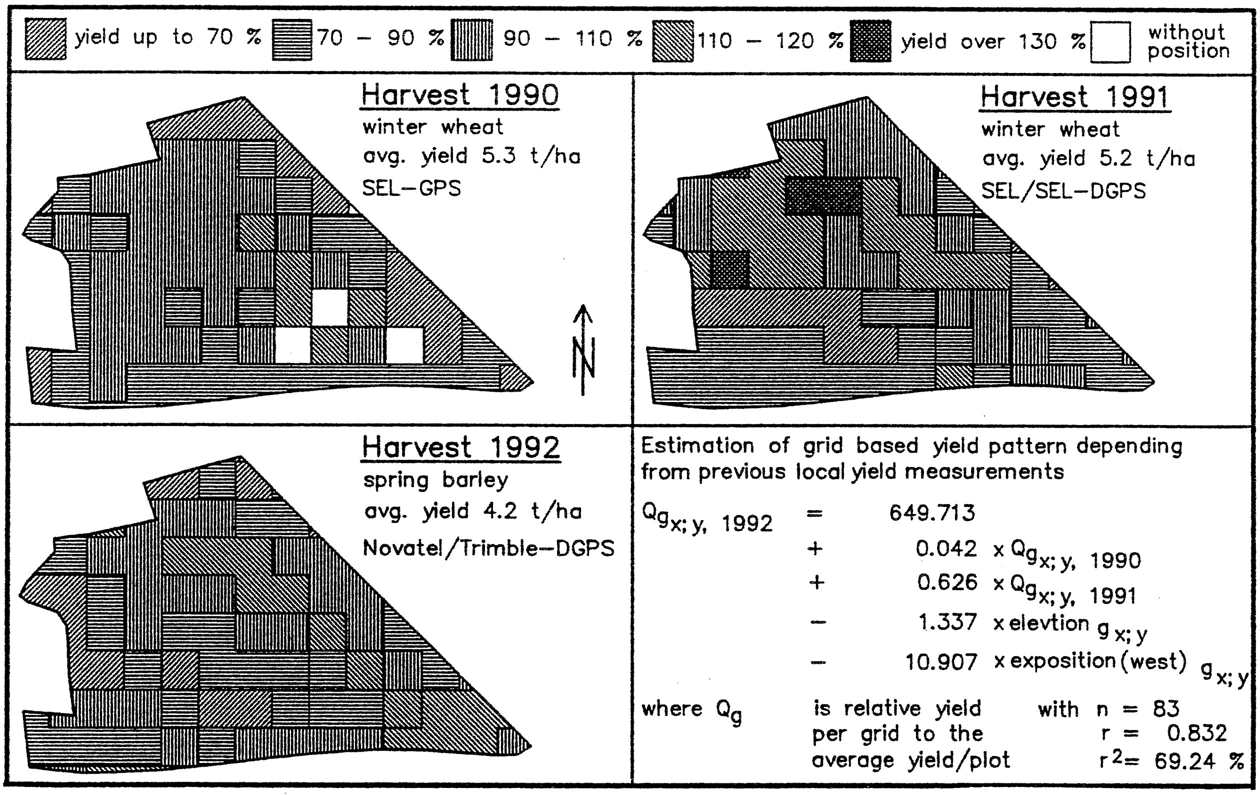

Figure 1: Maps of yield pattern Scheyern "Flachfeld" (16.6 ha, harvest 1990-1992, grid-size 50 x 50 m).

But their are also other crops beside combinable grains in most of the rotations worldwide. For these local yield measurement must also be required. Therefore measurement systems for whole crop harvesting of maize or grass for forage or hay, for sugar-beet, potatoes and also cotton are necessary.

Own research, development and test work was done with self loading trailers and round balers using the weighing technology for yield detection [1, 13].

CAMPBELL et al. and WILKERSON et al. reported 1994 about actual projects on yield measurement for potato and cotton harvesters [5, 14].

The only published attempt on yield measurement with a forage harvester was made by VANSICHEN and BAERDEMAKER 1990 [11].

Objectives

It was the aim to develope and test a yield measurement device for self propelled forage harvesters.

The requirements on the system have been diverse:

- The measurement has to be carried out without disturbing the material flow, otherwise there will be a higher risk of blockage of the chopper or the throwing width would be reduced.
- The system has to be able to work with varying material flow.
- It must be possible to use the equipment for maize and in grass.
- Retrofitting has to be easy.
- A high reliability is required.
- There has to be only little or no need for calibration.

Materials and Methods

After a closer examination on all requirements and possible and available measurement principle, a radiometric measurement system was chosen, similar to the system used in combines [xx].

The system is based on an isotopic source (Americium 241, activity 35 MBq) and a sensor. The reduction of the intensity of the radiation of the source detected by the sensor is depending on the area weight of the material between both. In connection with the speed of the material the material flow can be calculated (fig. 2).

$$Q[\mathrm{t/h}] = (1000 - \ln(q_f/q_{f0}) \cdot 10 \cdot K_2) \cdot \ln(q_f/q_{f0}) \cdot K_1 \cdot n_{mat\_speed} / 10^5$$

Q	= material flow [t/h]
q_{f0}	= radiation sensor "zero" counting rate (no material between source and sensor)
q_f	= radiation sensor "actual" counting rate
K_1	= linear calibration factor
K_2	= non linear calibration factor
n_{mat_speed}	= speed sensor counting rate (material speed)

Figure 2: Equation of the material flow based on a radiometric mass flow measurement system.

The measurement system was mounted on a John Deere 6810 self propelled forage harvester equipped with a 4.5 m row independent cutter head. It was located at the end of the first third of the spout (fig. 3).

For measuring the material speed different sensor have been tested. A radarsensor (DICKEY JOHN Radar II) was at least chosen for the experiments. A second radar sensor (TRW TGSS 012) was used for measuring the harvesters driving speed.

Measuring the clearence between the upper and lower feed rolls, the power consumption of the cutter drum and of the blower should help to find other parameters or parameter combinations to determine the material flow.

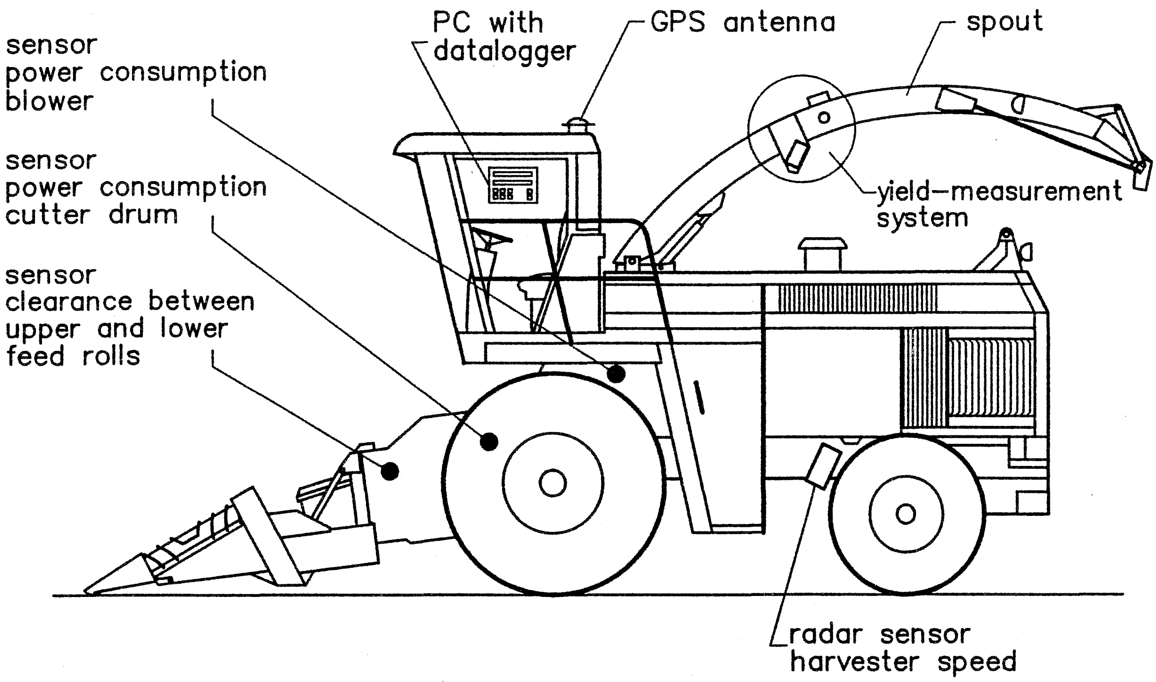

Figure 3: Sensor application for local yield measurement in a self propelled forage harvester.

Out of the material flow (t/h) and the working rate (ha/h), calculated using the speed of the harvester and the working width, the actual yield (t/ha) was determined every second.

These yield data have been georeferenced by an online DGPS system existing of a 12 channel basestation (Ashtech MXII) and an 12 channel mobile station (Ashtech GPS Sensor) connected via modems and FM radios.

Every trailer load was weighed on a platform scale and out of every fifth trailer a sample was collected for determining the moisture content. For one field in 1994 three samples for every trailer were taken to make an exakt determination. The trailer weights were used to calibrate the system and to determine the errors.

Positioning data have been analysed by plotting and controlling the harvester traces. At least yield maps have been calculated out of the georeferenced yield data.

Results

In 1993 and 1994 over 140 ha of maize have been harvested with local yield measurement.

After replacing the material speed sensors basing on different types of wheels below and above the material stream by the radar sensor no malfunction can be reported.

Controlling 416 trailer loads of more than 20 fields with different dry matter contents of the maize in 1993, analysed with the same system calibration, following accuracy can be reported (fig. 4).

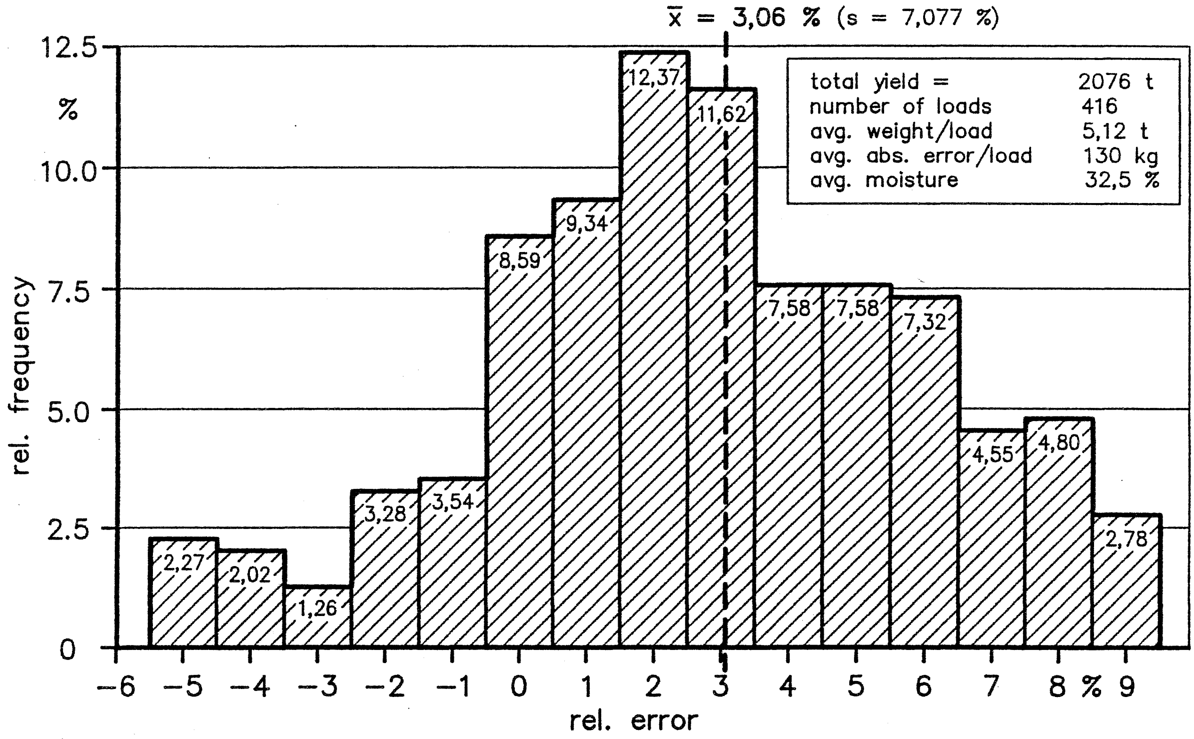

Figure 4: Relative errors of yield detection for silage maize in harvest 1993.

The mean error of +3.06% shows the offset of the calibration. The standard deviation of the error was 7.07%.

A higher accuracy can be reached by making an improved calibration at the beginning of every new field, a procedure which is recommended with all yield measurement systems on combines. In 1994 on the "Ammersdorfer Feld" a mean errors of -0.11% and a standard deviation of the error of 3.71% was reached this way.

The importance for the measurement accuracy of the material speed follows from the equation of the material flow based on a radiometric mass flow measurement system (fig. 2). The determined variation of the material speed depending on the material flow shows figure 5.

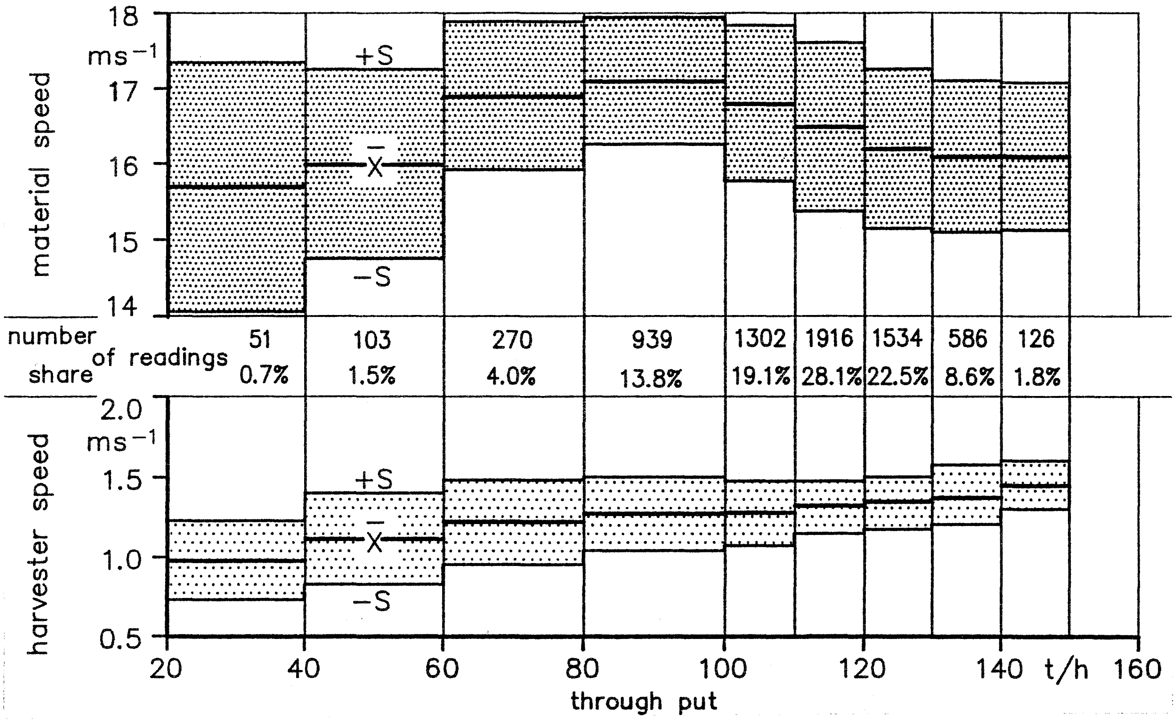

Figure 5: Distribution of the material and harvester speed in connection with different material flow levels.

The high variation of the material speed and its influence on the accuracy of the measurement principle makes an accurate and reliable speed measurement neccessary. In the moment the only possible sensor fullfilling this requirement seems to be the radarsensor.

For the analysis of the traces of the harvester figure 6 shows one example.

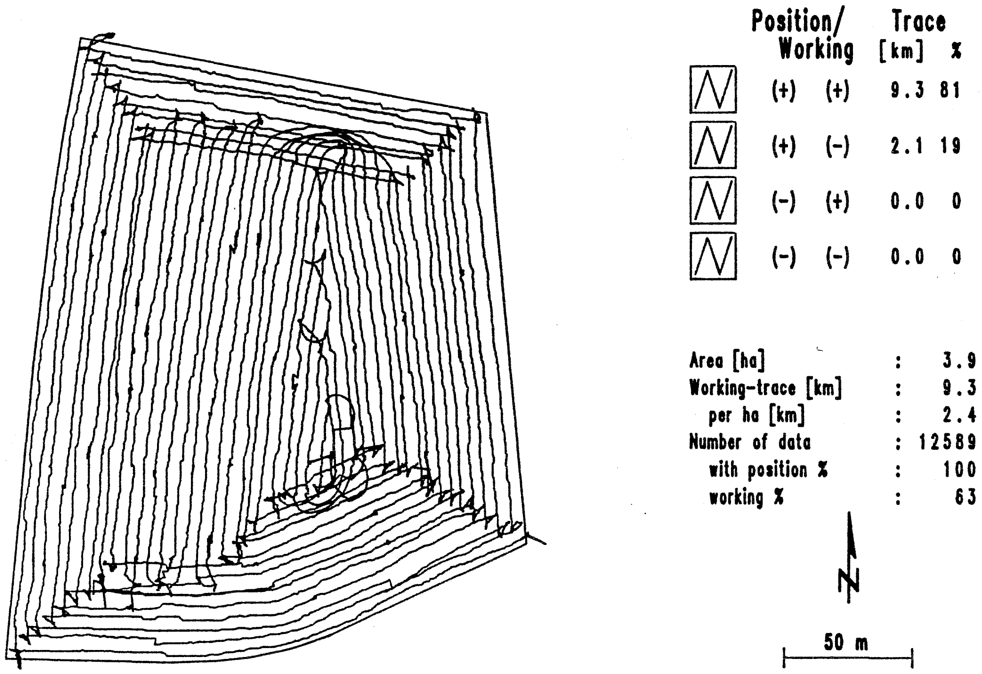

Figure 6: Traces of the selfpropelled forage harvester on Breitsameter "plot 1" (Novatel/Ashtech online DGPS, working width 4.5 m).

Non crossing trails allow the conclusion that the accuracy of the online DGPS is better than ±2 m (half of the cutting width). Further detailed analysis show an error of ±1-2 m.

Using a grid based mapping algorithm the local yiel data where transformed into yieldmaps. For the Scheyern "Eulenwies" the 1993 maize forage yield map was placed into the series of grain yieldmaps with spring barley in 1992 and winter wheat in 1993 (fig. 7).

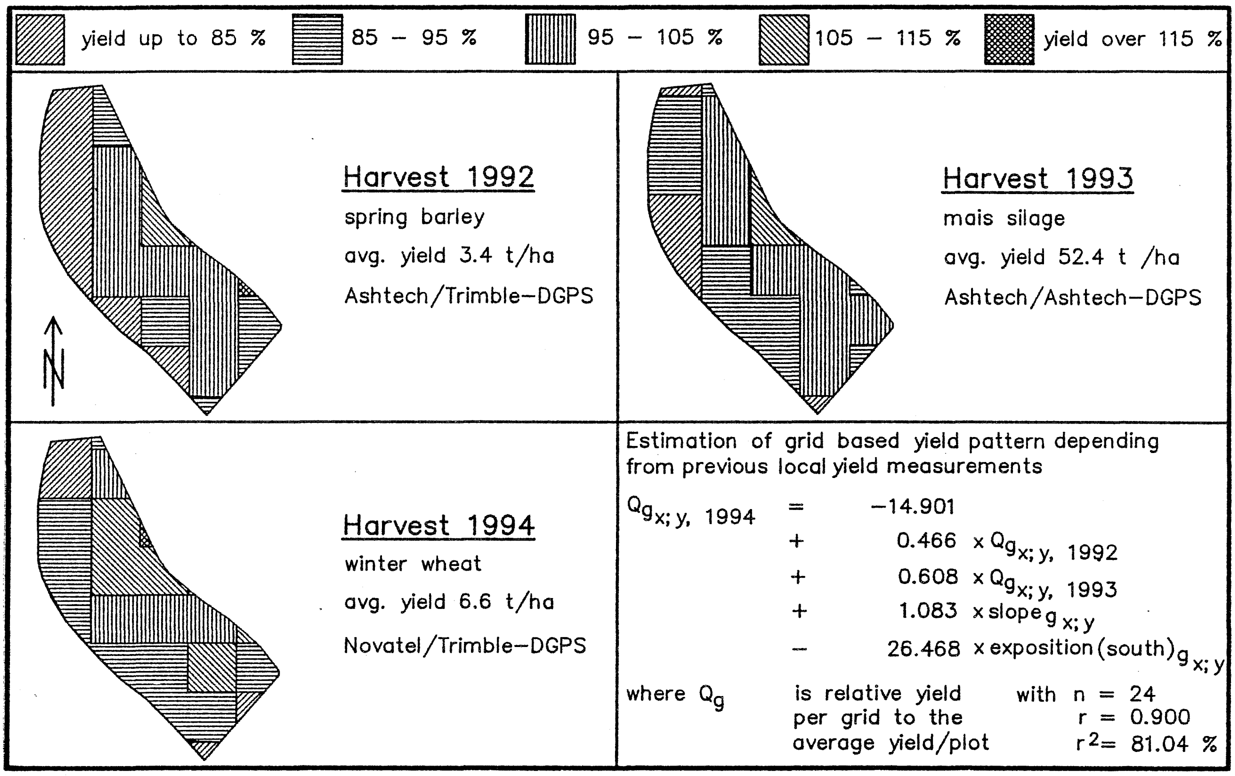

Figure 7: Maps of yield-pattern Scheyern "Eulenwies"
(3.7 ha, harvest 1992-1194, grid-size 50 x 50m).

The yield-pattern build up by the different yield zones show a high similarity. Areas with lower yield are situated along the south western field border (uphill), with higher yield along the north eastern fieldboarder (valley).

Analyzing the three following harvests on the same plot makes it also possible to determine a yield equation. With a multiple regression the influences of the relative annual yields (compared to the annual mean yield) and other available parameters, like exposition, slope, hight obove sea level of every grid on the relative yield of 1994 where calculated.

A very high coefficient of determination (r^2) of about 81% was reached for the Eulenwies. The influnence of the yields of the previous years decrease with their age. Slope and Exposition also show an influence.

The remaining huge amount of data from the several other sensors are still waiting to be analyzed. It will be one aim for future work to find another sensor combination to determine the yield in a forage harvester.

Conclusions

- The developed and tested radiometric mass flow yield measurement system for self propelled forage harvesters showed a very high reliability.
- The system showed no influence on the throughput and the function of the chopper.
- Failures accured only at the beginning of the tests caused by the wheel based material speed senors.
- The high variation of the material speed makes a reliable and accurate speed measurement device neccessary. Reducing short term variation demands a well considered placement of the measurement unit.
- No influence of the material moisture (variying in the bounds of the material) could be detected. On the other hand different materials (maize or grass) require different calibration parameters.
- Procedures for yieldmapping are equal to those for cominable grain. No additional data manipulation is necessary because the measurement errors are similar to the errors of the tested systems in combines.
- Together with yield data of combinable grain from two harvest saisons yield functions and yield-pattern can be estiamted with an coefficient of determination (r^2) of more than 80%.

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