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Comparing Sensor Systems for Nitrogen Application

The systems presented (remote sensing, Crop meter, N-sensor) reflect the existing heterogeneity in the soil and in crop development. More specific than remote sensing systems are real-time systems, since sensing, processing information and applying are carried out in one operation. Of these three systems the N-sensor measures the differences in biomass more precisely. Besides site-specific fertiliser application it provides complete documentation on crop development. The benefits of site-specific application range from nitrogen savings to yield and quality improvement of individual part-fields or of the total plot, depending on intensity and year.

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Keywords

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Plant growth is influenced by various factors (soil, nutrient supply, weather) and their impact intensity. Resulting differentiating effects are measurable in heterogeneity of yield and protein content.

The specific utilisation of soil or crop information for the deduction of technical consequences in production has led to a steady improvement of results and finally of production technology. Heterogeneous plant growth and yield are cause and effect of a site-specific management [1]. Especially the information of growth stage has always been used for nitrogen fertilisation. The amount of N-application correlates with the yield expectation and the latter with the yield potential of the soil [2]. Its heterogeneity requires site-specific fertilisation.

The specific use of soil or crop information for deduction of technical consequences in production has led in the past years to the development and testing of methods for the site specific fertilisation. These methods use models and sensors which directly measure the plant growth and its heterogeneity.

Presently, there are different sensor-based systems available at the market. These can be either remote sensing systems ("off-line") or tractor installed real-time sensors ("online") [3] (*Fig. 1*).

In 2004, the Institute of Agricultural Process Engineering in Kiel has tested different sensor systems in functionality under practical conditions. It was not aimed to test yield effects of different fertilising strategies, but to measure the variations in the results of constantly fertilised wheat. The remote sensing system "Loris-Maps", the pendulum sensor "Crop Meter" and the "N-Sensor" were to be compared. All three systems are already available for the farmers and can be used for demand-meeting N-fertilisation. Each system records different information (colour, bending resistance and N-uptake) and uses this information to recommend the amount of fertiliser to be applied. To begin with, the systems are described at first.

The aerial photograph system Loris-Maps

has been developed by the Finnish fertiliser company Kemira for Northern Germany and

Fig. 1: Pendulum-sensor and N-Sensor on a tractor

consists of a measurement flight in spring and the interpretation of the aerial photograph for the application. Starting from growth stage EC 25 the biomass is measured under clear view conditions with infrared pictures. The biomass data can then be linked with different field information (soil and yield expectation). *Figure 2* represents the relative biomass map of Kemira.

The resolution of the aerial photographs represents approx. 3•3 m for each pixel and the entire field can be recorded. Areas with the same information are combined into management zones for N-fertilisation, growth stabiliser and fungicide application. Each zone receives an application amount for each measure (N2, N3 and plant protection). The focus for the nitrogen fertilisation is laid on the N2-application, which follows a few days after measurement. If it is planned to carry out an application on N3 or N4, further measuring flights are necessary, resulting in higher costs.

It is very interesting to compare the results of the Kemira values with those of the N-Sensor. The Kemira flight naturally took place before the second N-application (N2), the N-Sensor has been used near the dates of N2 and N3. In *Figure 3* there is a high varia-

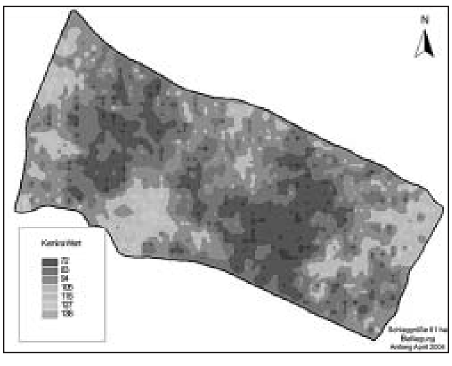

Fig. 2: Biomass map (relative) (KEMIRA)

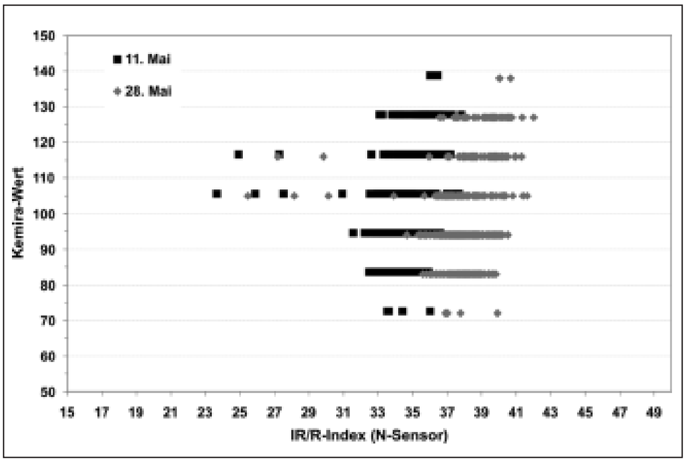

Fig. 3: Kemira versus N-Sensor at two measurement times

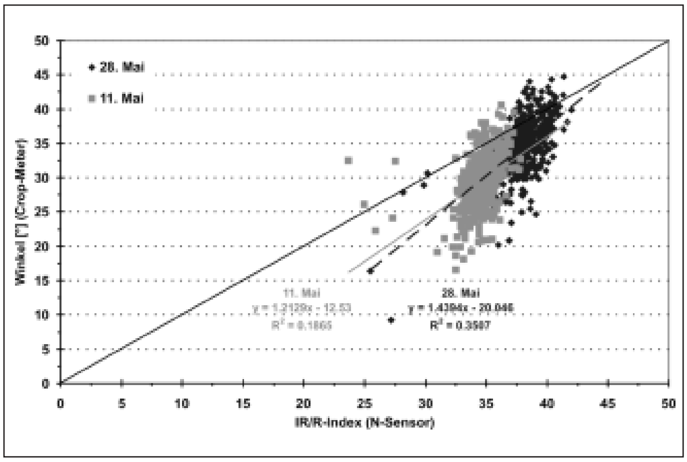

Fig. 5: Crop-Meter versus N-Sensor (15 m grid, winter wheat)

tion in the values. For similar Kemira values the IR/R index varies around 2-3, respectively 10%. The IR/R index is derived from the wavelengths 780/680 nm. Hereby the typical wavelength of the strong chlorophyll absorption (680 nm) and leaf reflection (780 nm) are used. By formation of a quotient, there is a positive correlation between the leaf surface index and chlorophyll content. The values of the infrared-to-red index range from 1 (bare soil) over 3 (isolated plants) up to 50 (very dense crop) [4]. For the same index the Kemira value varies around ± 30 %, which implicates a progressing crop differentiation between the Kemira measurement date and the N-Sensor measurement date.

After calibration the real time sensors Crop Meter and N-Sensor are suited to record the actual biomass in a smaller-scale and thus lead to a more differentiated fertilisation.

The pendulum sensor "Crop Meter"

has been developed by ATB in Potsdam and is now commercially available from the companies AGROCOM and Mueller Electronics. The pendulum is mounted in front of the tractor and measures the bending resistance of the crop by pendulum deflection within the tramline. Increasing resistance implicates that more biomass is present [5]. This sensor can be used earliest at the growth stage of EC 34. The driving speed is very important for the accuracy of measurement and is incorporated into the sensor software. It hardly affected the trials presented here: driving with 10 km/h instead of 5 km/h showed a smaller deflection of the pendulum of 6% and vice versa increasing the driving speed up to 15 km/h augmented the value about 3%. The correct height level of the pendulum has to be fixed at the time of fertilisation. The importance of an accurate height guidance of the equipment is evident, since in the trial the height and thus the effective lever length was changed in a range of ± 10 cm (*Fig. 4*). The tractor drove through two tramlines of the same crop with 10 km/h, accordingly the deflection of the pendulum changed around 1%, respectively 4% with each cm of height difference (Fig. 4).

The N-Sensor

developed by Hydro-Agri, now YARA, has been commercially offered since 2000 by AgriCon. The sensor is mounted on the tractor roof and measures the reflection signal of the plants and the intensity of the actual sun light. Hence, for each measurement a reflection spectrum is recorded and then individual reflection indices for the N-supply and the biomass are computed, which are then used for a fertilisation recommendation. The N-Sensor is the only "on-line" system which is sold with different manufacturer functions for fertilising. These functions are the results of many fertilising trials carried out by the manufacturer. Before application a field calibration has to be carried out. The field calibration needs the selection of a fertilising strategy (good developed crop: higher or smaller fertiliser amount), specification of the fertilisation level and working range (min and max of fertiliser amount). A calibration at the fertilisation date is necessary with all sensors.

The N-Sensor has been available in practice for the longest time, so it is used as a yardstick to evaluate the other systems. Comparing N-Sensor data with Crop Meter data is based on a conjoint grid of 15 m. All data of the two measuring dates are presented in *Figure 5*. If the results of the two sensors are the same, they should lie close to the besetting line. The low coefficient of determination is actually noticeable: with similar IR/R index the deflection scatters approx. between 25° and 45°, respectively ± 30% of the average value. At similar position of the pendulum, the values of the N-Sensor vary between 35 and 40, the average about ±10%. The relevance here is that a 10% change of a single measurement value denotes a change of the application value at the same time.

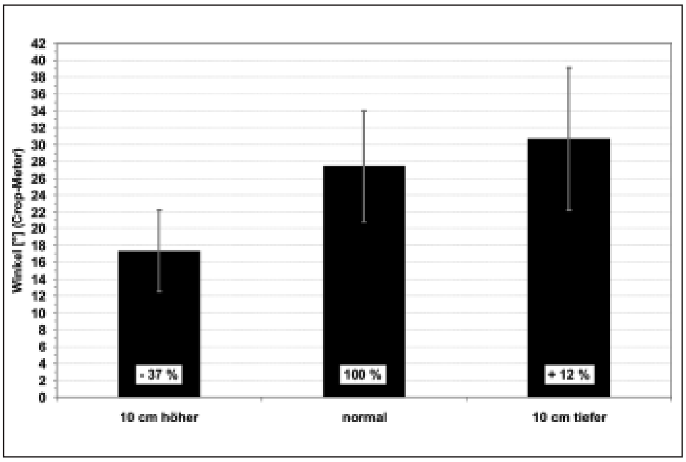

Bild 4: Einfluss der Pendelhöhe im gleichen Bestand und bei konstanter Fahrgeschwindigkeit (10 km/h, Mittelwert aus zwei Fahrgassen mit je 700 m)

Fig. 4: Different pendulum hights in the same population and constant driving speed (10 km/h, average of two tramlines, each 700m length)

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