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Sensor-controlled Nitrogen Application

Site-specific determination of nitrogen demand calls for up-to-date measurement of the nitrogen supply with a good site resolution. This can be achieved by using a reflection sensor on the tractor. It determines the spectral reflection of the crop from reflected sunlight. This makes it possible to calculate the indices of reflection connected with the nitrogen supply. The dosing by the spreader is controlled online during measurement in this way

How can these sensor values be converted to fertilising recommendations? This paper presents a method which takes into account the different nitrogen requirements of each site directly.

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It has long been known that a nitrogen deficit is expressed in the colouring of the crop. The reason for this is above all the green plant pigment chlorophyll. The chlorophyll content of the leaf correlates with the nitrogen supply [1].

The spectral distribution of the reflected light is responsible for the colour of a material. The degree of reflection of the material results from the share of reflected light intensity in relation to the incoming light radiation and is independent of the ambient light.

The optical properties of plant crops can be summarised as follows. As the chlorophyll content rises, the reflection in the red drops and as reflection surfaces increase by a growing leaf area index (leaf area/ground area), the reflection increases in the vicinity of infrared. The available nitrogen causes an increase in both parameters and raises the red-to-infrared ratio.

The inflection or turning point of red-to-infrared increase has proved to be a „good“ reflection index. „Good“ means that interference factors such as sun level, clouds, soil colour and plant geometry have little effect, while in the relevant areas a linear connection with nitrogen supply is shown [2]. This correlation occurs roughly after the grain starts to shoot, so that the use of sensor-controlled nitrogen application is limited to the second and third dose.

The sensor

The sensor system consists of vehicle-supported reflection sensors, one of which faces upwards and measures the spectral solar radiation, while the others face downwards and record the light intensity reflected by the plants. Each reflection sensor measures a number of wavelength ranges in the red and near infrared, from which the degree of reflection is calculated by the share of reflected to incoming radiation intensity.

In this paper the red edge inflection point (REIP) (turning point from red to infrared) was used as inflection index. Its position is calculated with an approximation formula that needs the four degrees of reflection [3].

In the following the difference between the edge inflection point of the measured area and the lowest edge inflection point, $REIP_o$, on the current plot is used as the sensor value SW

$$SW = REIP - REIP_o \qquad (1)$$

The sensor system used always covers an area of about 1 m2 located 6 m to the left and 6 m to the right next to the tractor with a local resolution of 1 m at a typical driving speed of 2 m/s. The position of the sensors is registered via DGPS.

Investigations on conventional fields

Site-specific fertilised winter wheat and winter barley fields in the eastern, Hügelland of Schleswig-Holstein were mapped with the sensor system. The site borders result from the strongly pronounced relief. Interference aspects such as lack of other nutrients and disease were minimised by appropriate measures.

It was examined whether there is a common connection between the sensor values and the nitrogen application on all sites, as is known from plot experiments. [2]. As shown in figure 1, the sensor value for each individual site was recorded by comparison with the varying nitrogen application carried out six weeks before.

On these fields of a type commonly encountered in practice there is hardly any such connection which makes it possible to determine the nitrogen application from the sensor value. In site groups with identical relief and soil types, there is a somewhat closer connection (data not shown) [4].

It is known from plot experiments that on homogeneous areas there is a close connection between the turning point and nitrogen application (dotted line in figure 1). This can also be assumed on really identical sites. However, even two sites with an identical sensor value differ in their properties (relief, soil type, microclimate, harvest residues, ...), so that this connection differs in each case due to the different nitrogen efficiency.

Conclusion

In the usual calibration (allocation of an application quantity to the sensor values) in the form of „low sensor value receives a lot of nitrogen and vice versa“, the different connections between nitrogen and sensor value are not taken into account. This can therefore lead to a situation in which a sandy, low-yield area with sensor value X receives the same high quantity of application as a loamy, high-yield area with the same sensor value X even though the effects of nitrogen application can vary widely on these areas (*fig. 1*).

Site-specific calibration

Ideally, therefore, the sensor system would have to be calibrated on each individual site, e.g. by ascertaining the calibration function via a mini-nitrogen increase experiment on each small site. This led to the idea of examining the response of the plants to an extra supply of nitrogen on a site. If they react with more growth – which can easily be ascertained by sensor – then this is a site which can „do with" more nitrogen and vice versa. This procedure is called site-specific calibration in the following description.

Performance of the experiment

An experiment to demonstrate sensor-controlled nitrogen application with site-specific calibration was set up by applying an additional N_{ref} = 30 kg/ha to a roughly 1 m wide reference strip along the direction of travel in the tramlines for the first nitrogen application. During the second nitrogen application this strip was generally recognisable due to being a darker green than the rest of the crop. The relative distribution of the second application was now carried out according to the difference between the right sensor with the sensor value SW_{ref}, which was addressed to this strip, and the left sensor with a sensor value SW_{norm}, which measured the rest of the crop. This quasi mini-nitrogen increase experiment made it possible to determine and use the calibration function for calculating the quantity to be applied on each site

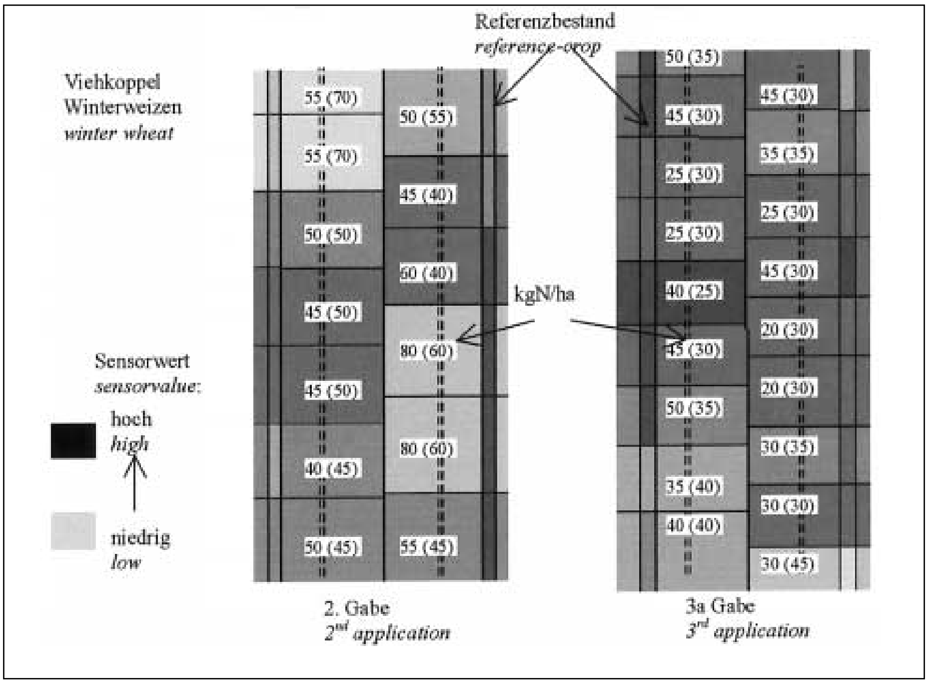

Fig. 2: Global and site-specific calibration. The numbers on the sites are the amount of nitrogenreally applied wich was calculated according to the difference in the sensor values of the reference crop (cf. equation 2). The numbers in brackets show the quantity which would have been applied using global calibration.

$$N_{appl} = \begin{cases} N_{max} - s \cdot SW_{norm} & \text{für } SW_{ref} \geq SW_{norm} \text{ und } N_{max} - s \cdot SW_{norm} > N_{mind} \\ N_{mind} & \text{sonst} \end{cases}$$

$$\text{mit } s = \frac{N_{ref}}{SW_{ref} - SW_{norm}} \qquad (2)$$

and N_{max} or N_{min} for the maximum or minimum quantity specified by the farmer.

The results of this sensor controlled nitrogen fertilisation on the basis of site-specific calibration are shown in figure 2. The recommended values resulting from global field calibration are shown in parentheses. These are based on only one calibration function (s = constant in equation 2) for the entire field. The calculated application quantity N_{appl} was averaged and applied for sites of 12 m length in each case.

During the second application it is possible to see clearly the light areas (light green areas in the crop) which would have received an equally high nitrogen application if the field had been calibrated globally (60 to 70 kg/ha). In this experiment, however, low nitrogen utilisation was apparent for half of these areas (top left) so that a lower quantity was applied there (50 kg/ha), while the other half (right bottom) was able to use the extra nitrogen applied there before (dark reference strips) and thus also received a lot of nitrogen during the second application (80 kg/ha).

Prospects

The transfer of this method to large fields is perfectly conceivable by setting up a strip to which more fertiliser is applied with the aid of a liquid fertiliser spray or pneumatic broadcaster. The amount applied is then increased over a part of the width. By setting partial widths in a complementary manner in the following application, it is possible to correct the cross distribution of the total quantity applied within a tramline.

It remains to be examined how this method will effect the quantity of nitrogen applied and the yield.

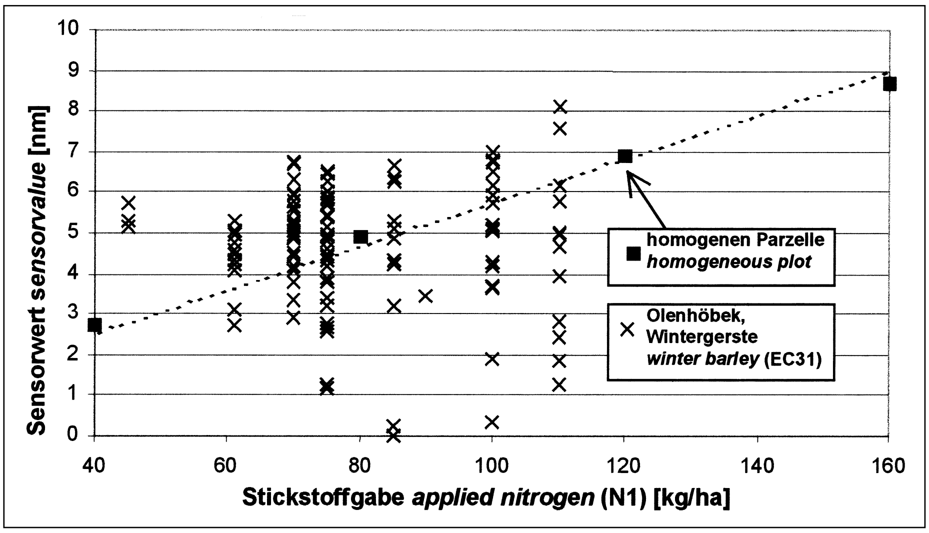

Fig. 1: Sensor values of different sites six weeks after the first nitrogen application. The dotted line is the linear relation taken from a plot test