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Generating Yield Maps from Aerial Images

Due to the stress during harvesting, yield measurement systems in combine harvesters are often not utilised according to the prescribed format. As a result, many yield maps are erroneous. Here a method is presented which makes it possible to evaluate yield maps, based on the similarity of the fully developed crop stand pattern from aerial images, and the pattern on the yield maps. For this process the only requirements are yield data gathered from a few tracks in the field, and an aerial image of the crop stand.

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Keywords

Precision farming, yield maps, aerial images

An increasing number of farmers have placed orders for new combine harvesters, which have been pre-mounted with a yield measuring device. The accuracy of measurement of these devices for the purpose of management decisions is sufficiently accurate [1]. Nevertheless, a relatively high number of created yield maps are erroneous and hence, it is impossible to make a reliable statement regarding the yield distribution. The main cause of this dissatisfactory data is due to the stress of the combine harvester operator during the harvesting season. A consequence of the fact is that during the application, not much attention is paid to the accurate calibration and supervision of the components of the yield measurement system fitted aboard.

Images of crop stands often show a pattern similar to that of a yield map [2]. Aerial photographs taken either from aeroplanes or from satellites are made available upon request from service companies.

In order to reduce the time and effort during the harvesting season; it is proposed to make an estimation of the yield maps. Accordingly, a distribution pattern of a vegetation index calculated on the basis of the aerial image is interpreted as a distribution pattern of the yield. A prerequisite to estimate a yield map is the allocation of yield values to the pattern, asking for the existence of a relationship between the calculated vegetation index and the yield. Approximately 20 data pairs of yield and vegetion index are sufficient to derive such a stochastic relationship, which is generally considered to be linear. Therefore, the yield acquisition in a combine harvester is quite sufficient when the yield is recorded alongside a few tracks of a field.

Materials and methods

A solution to verify this application took place in a field on the outskirts of the "Magdeburger Boerde". The 48 hectare field has an uneven southern-slope with an approximately 30 metre difference in elevation. As background information for this experiment; an aerial image was taken from a sportplane on June 6th, 2003 as well as yield recordings of the winter-barley from the year 2003 harvested by a JD-Combine Harvester and the GreenStar System. The VARI (Visible Atmospherically Resistant Index) = (Green - Red)/(Green + Red - Blue) was calculated as a vegetation index.

Data from three tracks provided a basis for the calculation of the regression function of yield = f(VARI). With the help of the regression function, it was possible to convert the VARI values into yield values. For this intention a 20 m • 20 m grid cell raster of the whole field was used.

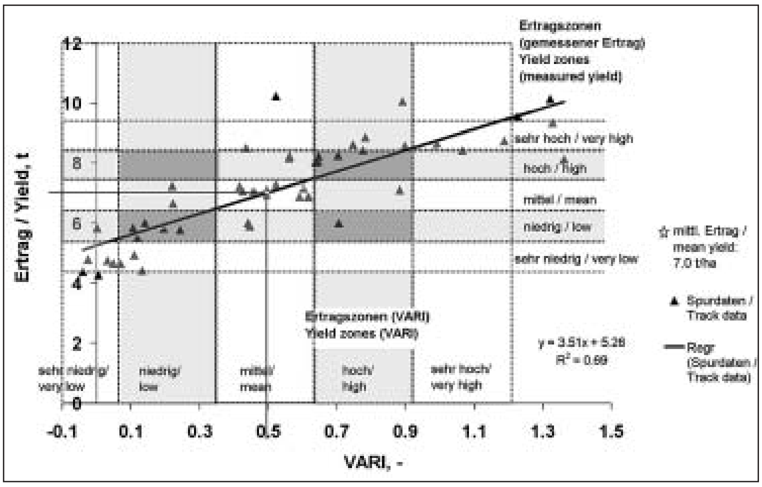

Fig. 1: Creating the yield zones based on the yield data and the VARI data, respectively

The calculation eventually was computed using an extension for the ArcView 3.2/Spatial Analyst, specifically designed for this purpose, comprising among others the following:

- classification of yield values in five classes
- search for all sections within the chosen tracks containing a minimum of seven consecutive yield values of the same yield class
- creation of rectangular sub-units, whose length corresponds to the length of a section and whose width corresponds to that of the utilised cutting-width of the combine header
- determination of the average yield of the discovered sub-units
- calculation of the VARI using the three colour bands of the aerial image in a grid measuring 1 m • 1 m
- determination of the average VARI of the sub-units
- calculation of the VARI for the created 20 m grid cells of the whole field by averaging.

The calculation of the yield values for the 20 m grid cells of the measured yield was carried out using the blockkriging interpolation method. The identification of the data pairs resulted in a regression function, which showed a correlation between the yield and VARI.

Evaluation Method

The accuracy of the estimated yield values cannot be directly evaluated, since error-free measured values are not available. Since the farmer is primarily interested in the displaying of the yield zones, a comparison of the derived yield zones took place on the basis of the VARI values and the measured yield data. Each yield zone of the measured yield was allotted a yield-class (horizontal lines) (*Fig. 1*). The range of the yield classes, which generally cluster symetrically around the average yield of the field, amounted to 1 t. It was assumed that the average yield value arose from the average VARI value. The class boundaries of the measured yield were converted within the VARI boundaries (vertical lines) using the reciprocal form of the regression function (VARI=f(yield)). The accrued VARI classes were likewise used to sub-divide the field into yield zones (Fig. 1).

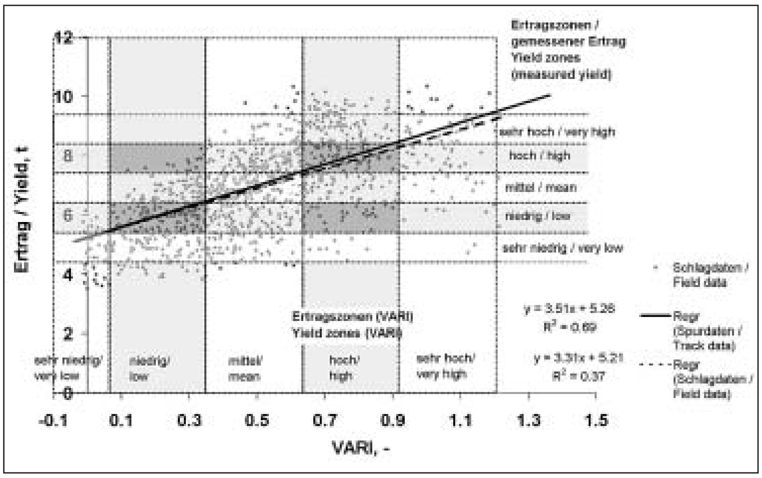

Fig. 2: Segmentation of the grid cells on the yield zones

The incorporation of data of the 20 m grid cells in the graphic (*Fig. 2*) clearly shows a distinctive creation of yield zones when applying the two methods. Depending on whether the scatter-plot gets horizontally sub-divided (yield zones of the measured yield) or vertically sub-divided (yield zones of VARI); various subsets of the grid elements get allocated to the corresponding yield zone. The fraction of the grid cells, irrespective of the process of creation of yield zones, allocated to the same yield zones, is therefore a variable for the assessment of this solution approach.

Results

It confirms the fact that a stochastic relationship between the yield and VARI exists (image 2). The stochastic character is conditionally objective, because a crop parameter, which was measured in June, cannot be directly proportional to the grain yield, which cultured weeks later. It is however conditionally subjective, caused by the errors while recording the two variables.

The relationship of the track data is closer as compared than to the data of the whole field. The coefficient of determination increases from 0.37 for the whole field to 0.69 for just the tracks (*Fig. 2*). This clearly points out additional errors caused by the yield measurement of the whole field, which could be avoided in the area alongside the tracks.

The fraction of the grid elements, which during this procedure are allocated to the same yield zones, fluctuates as against the yield zones between 31% and 79% (*Table 1*). A compilation of the same allocated grid elements over all the yield zones would have resulted in an average value of 38%. These values are not very high. The similarity of both the procedures of the creation of yield zones shows on the contrary, that a relatively higher fraction is recorded at the intersecting point of the same yield zone, as compared to all the grid elements put together. The evaluation must stop while determining the same allotted grid elements. A right or wrong evaluation of allotted grid elements cannot happen.

This estimation procedure is in any case appropriate for the creation of yield zones if, on the assumption that the measured yield values are correct, the means in the VARI yield zones significantly differ. Using a t-test, the differing means could be verified at a probability of error of 5%, except for the means of the very high and high yield classes.

Discussion

The presentation of this procedure for the estimation of yield data has been tested on few fields in the last few years. The limits of extending this application are as a consequence, still to be determined.

The advantages are however indisputable. Any agricultural producer requires just one yield mapping system mounted on a combine harvester. The operator of the combine harvester has the possibility to operate the yield measurement equipment with the help of the manual along the tracks of a field. For the rest of the field yield mapping is not necessary. The acquisition of the required aerial images as well as their evaluation can take place outside of the harvest season.

Yield Zone (Yield)	Yield Zone (VARI) very low	low	average	high	very high
very low	**78.9**	33.0	12.9	5.0	2.3
low	21.1	**38.3**	19.9	9.4	9.3
average	0	24.3	**36.9**	20.5	17.4
high	0	4.3	23.2	**31.2**	29.1
very high	0	0	7.1	33.9	**41.9**

Table 1: Fraction of the 20 m grid cells from the yield zones (yield) in the yield zones (VARI)

Literature

[1] *Noack, P.O., T. Muhr and M. Demmel*: Relative accuracy of different yield mapping systems installed on a single combine harvester. In: Precision Agriculture, Proceedings of the 4th European Conference on Precision Agriculture, edited by J.V. Stafford and A. Werner (Wageningen Academic Publishers, Wageningen, Netherland), 2003, pp. 451-456

[2] *Blackmore, S., and M. Moore*: Remedial correction of yield map data. Precision Agriculture 1 (1999), pp. 53-66