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Recording the spatial correlation of soil parameters for the development of precision tillage

In the context of a joint research project different site specific soil and yield data of an inhomogeneous test field have been recorded over several years. For this purpose modern on- and offline sensor systems have been employed, e. g. a newly developed online capable camera sensor for measuring the percent residue cover. The spatial correlation of soil conductivity, grain yield and residue cover have been determined and could be described by correlation coefficients between 0.52 and 0.65.

Keywords

Residue cover, soil conductivity, yield mapping, site specific

Abstract

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In the context of a joint research project a precision tillage system has been developed which automatically adjusts the tillage depth depending on different soil parameters and the percent residue cover. The objective was a site specific tillage which is optimized with regard to erosion control, field emergence and energy consumption [1]. For the determination of percent residue cover an online capable camera sensor has been developed. By linking the camera sensor to a GPS-receiver residue cover maps could be recorded during field trials. Since the further input data (see below) were collected via mapping approach they were GPS referenced as well. Thus an additional outcome of the project was the possibility to compare the different site specific data sets of the same test field. In the following this will be demonstrated exemplarily for the residue cover, the soil/ground conductivity (EM38) and the grain yield of a test field of the University of Kiel. The project partners were the Department of Agricultural Engineering of the University of Kassel/Witzenhausen (camera sensor), the Department of Agricultural Engineering of the University of Kiel (soil data, experimental machinery for site specific tillage), the University of Applied Sciences Kiel and the farm machinery manufacturer Amazone. The project has been supported financially by Deutsche Bundesstiftung Umwelt.

Material and Methods

On the experimental field "Tiergarten" trials concerning site specific tillage have been conducted in the years 2008–2010. The notedly inhomogeneous soil conditions ranged from sand to sandy loams with measures of productivity between 23 and 53. For the field trial in 2009 (winter wheat) which will be discussed below a subarea of about 30 ha was used.

The residue cover has been determined with a new optical system [2]. A Black-and-White CCD camera (1/2'' sensor, 768 × 576 pixels, max. 50 frames/second) with a 4.8 mm/F1.8-lens was employed. A photographic infrared filter was attached to the lens providing light in the near infrared between it's cut-on wavelength of 800 nm and the sensitivity limit of the CCD sensor (about 1 100 nm). In this spectral range the contrast between soil and straw usually reaches a first maximum. Optionally the camera's field of view could be protected from direct sunlight by a diffusor-box with a transparent milky roof. The camera could be controlled directly from the employed image analysis software via an USB interface. The algorithm for image classification into soil/residue was based on edge detection and automatic thresholding, the processing time amounted to approximately one second and thus enabling online capability. For the field trials the camera sensor was mounted onto an ATV serving as carrier vehicle, the height of the lens above the soil surface was about 1 meter. The image data were recorded after shallow stubble breaking with a disk tiller. On defined tracks with a perpendicular distance of 10 m between each other the ATV travelled over the field at a speed of 5–8 km/h. About every third second an image of the field surface was recorded what resulted in a grid pattern of the sampling points of about 5 × 10 m. Since the diffusor-box has been used only partially the images were analysed subsequently in order to test different algorithms for balancing the varying illumination constraints.

The site specific ground conductivity has been mapped with help of the EM38 conductivity meter from Geonics Ltd., Canada. For this purpose the device has been placed into a plastic sled and pulled with a SUV over the field following tracks with a perpendicular distance of 24 m. The sampling frequency was one measurement reading per second. In this approach the ground conductivity is integrated up to a depth of 1.5 m and correlates to a high extent with relevant site specific parameters like soil texture [3] and soil moisture [4].

The wheat grain yield was measured GPS referenced during harvesting with a Lexion 600 combine from Claas with an effective width of the cutting unit of 10.44 m. The yield quantification based on a volume measurement via a photo sensor in the grain elevator. The moisture content was measured inductively in a bypass of the elevator and allowed for a correction of the grain yield to a moisture content of 15 %.

Results

In **Figure 1** maps of the ground conductivity, percent residue cover and grain yield are shown which have been interpolated from the underlying data point grids, the headland regions have been excluded. The interpolation was done with the geographical information system ArcGIS using the "Ordinary Kriging" method. The range of values was devided into 10 equidistant steps for each map.

Already visual checking shows a quite good spatial accordance of the three parameters. To enable the calculation of correlations spatial joins of all data grids were created with ArcGIS: To each point of the residue cover grid the means of ground conductivity and grain yield respectively within a radius of 15 m were allocated. Residue cover points with a higher minimum distance to the other grids were excluded. The new residue cover/EM38-grid consisted of 1 167 data points, the Pearson correlation between cover and ground conductivity amounted to 0.52** (** level of significance p ≤0.01). The residue cover/grain yield-grid included 1156 data points, the Pearson correlation was 0.47**. To gain a simplified illustration the residue cover values were clustered to classes formed by the integers without decimal places ("rounded" values). These classes showed a Spearman correlation of 0.54** with the related conductivity values and 0.52** with the related yield values. In **Figure 2** the mean ground conductivities and the mean grain yields respectively are plotted against the related residue cover classes.

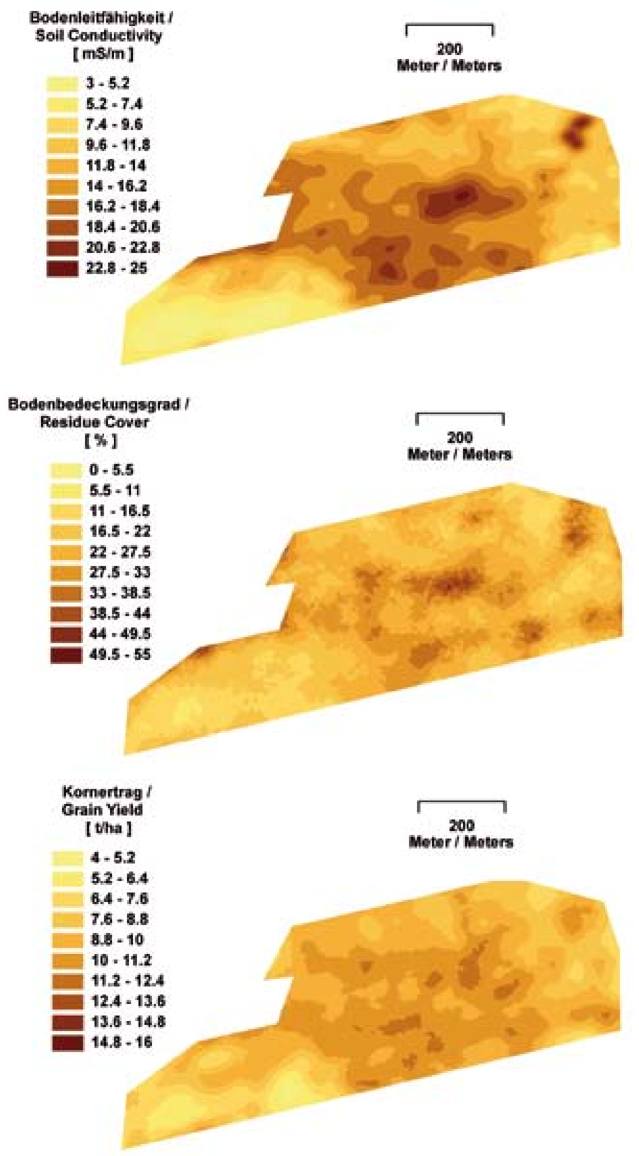
In **Figure 3** the relation between ground conductivity and grain yield is shown. Again mean values on the y-axis (yield) have been allocated to integer classes on the x-axis (conductivity). The Spearman correlation was 0.65**.

Conclusions

The spatial correlations of the investigated parameters showed a more or less expected behaviour. At sites with high ground conductivity according to EM38 it is more likely to find productive soil types and vice versa. Hence the ground conductivity can be expected to show a positive correlation with grain yield and residue cover respectively. To a certain extent also the grain yield and the mass of straw show a positive dependency what again explains the found correlation in this case. With increasing percent residue cover the ground conductivity and yield curves in **Figure 2** seem to reach a saturation range, however, in this range the curves show by far the highest variation. One reason for this increasing variation is that the number of data points drastically decreased for residue covers above about 35 %. Further the local appearance of high residue covers might be caused by a varying driving speed of the combine or the transport of straw during stubble breaking.

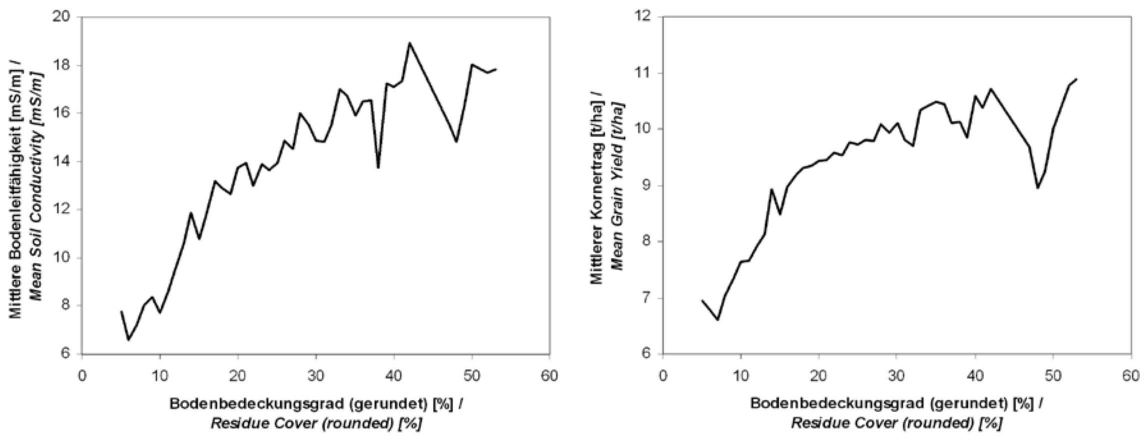
However, in the case of a sufficient number of readings the found correlations seem to be good enough to derive the approximate spatial distribution of one parameter from the georeferenced measurement of another one. This could be interesting if not all of the measurement methods are available or applicable under the given conditions and a rough estimation of the not directly accessible parameters is acceptable.

Fig. 1



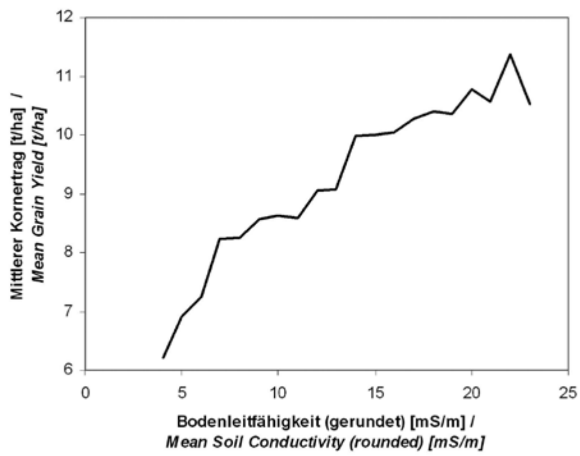
Maps interpolated by "Kriging" from the underlying data grids of the EM 38 soil conductivity (top), percent residue cover after stubble breaking (center) and wheat yield (bottom) of the test field "Tiergarten" in the year 2009

Fig. 2



Relations between the mean EM 38 soil conductivity (left) and the wheat yield (right) and the classes formed by the integers of percent residue cover ("Tiergarten", 2009)

Fig. 3



Relation between the mean wheat yield and the EM 38 soil conductivity ("Tiergarten, 2009)

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