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Soil Electrical Conductivity and Soil Nutrient Sampling

Investigations in an Older Moraine Area

*In a 500 ha area in Saxony-Anhalt the relationship between soil electrical conductivity (EC) and base nutrient contents was investigated. A significant correlation exists between the EC and the pH-value, the K- and Mg-content. In a simulation from samples taken every 4 ha, a uniform mean per plot for nutrient content was formed and with regard to EC distribution the nutrient contents for 100*100 m screens were estimated. The estimate on nutrient contents was only slightly better, when using the EC as the mean of several plots.*

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The investigations were conducted within the framework of the research Project "Development of a low input solution for precision farming on a farm scale" being promoted by the BMVEL.

Keywords

Soil electrical conductivity, base nutrient fertilisation, soil sampling strategy

Society expects farmers to carry out precision fertilising with base nutrients as a contribution to environmental protection and conservation of natural resources. However, precise measuring of nutrients presupposes a dense sampling grid and iterations, which increases the costs of sampling and analysis. The possibilities of cost saving resulting from reduced nutrient quantities and enhancement of profits by increasing the yield are restricted. Consequently the willingness of farmers to increase sampling density voluntarily beyond the statutory stipulations is limited.

In order to obtain correct statements about the distribution of nutrients with a reduced number of sampling operations a targeted sampling strategy is recommended instead of the customary grid sampling strategy. Auxiliary information is used for targeted sampling that can be surveyed more easily and which is expected to provide a connection with the nutrient distribution. Various additional information (aerial photography patterns, soil organic matter, soil map units, terrain attributes or yield maps) have been suggested as auxiliary information [1].

Soil electrical conductivity is recommended as a further item of auxiliary information that can be determined at comparatively low cost in a tight grid (50 - 100 points / ha) [2]. On a farm south of the Fläming region in Saxony-Anhalt it was to be investigated whether a more precise forecast of the nutrient distribution is possible by considering the soil electrical conductivity.

Material and methods

The land of the selected farm is largely located on a ground moraine from boulder clay, and in some parts on sandy glacial sediments. Thirteen fields covering altogether 500 hectares were selected as the area for the study. The soil electrical conductivity was measured on these fields using the EM38 device from Geonics [3] in the vertical dipole mode at a height of 20 cm above ground level. The measures were conducted at field capacity in spring 2001 and 2002 and the results were corrected to a ground temperature of 25 °C (EC25).

The sampling of the fields to test the base nutrient levels was carried out on a 100 • 100 m grid by Agri Con GmbH in spring and autumn 2001. A composite soil sample was formed from about 10 individual samples drawn on a circular line with a diameter of ~ 20 m. The samples were analysed by LUFA Saxony-Anhalt. The testing covered the pH-value and the magnesium content (both with the $CaCl_2$ method), the phosphorus and potassium content (both with the DL method) and the fine soil proportion (clay and fine silt), as well as the humus content. The farm received the LUFA data from Agri Con GmbH as geo-coded data, in other words supplemented with the positions of the centre points of the sampling circles.

To compare the nutrient levels with the EC25 values it was necessary to refer both attributes to certain sub-units. The nutrient levels can be assumed to be exact for an area tightly surrounding the sampling points. They were related to a circular area with a diameter of 25 m. The existing EC25 values were averaged for this circular area too. Consequently the data sets to be analysed contained the centre position of these circular areas, the name of the field , the nutrient levels, the fine soil proportion, the humus content, and the average EC25.

The following data evaluation was carried out:

• Descriptive statistics for the entire area, the imaginary summary of the 13 fields.

• Calculation of the correlation according to Spearman-Rho between EC25 and the nutrient levels, the fine soil proportion and the humus content for the total area.

• The following example was simulated in order to be able to assess the effect of considering soil electrical conductivity data for correct nutrient measuring. A 200 • 200 m grid (4-hectare grid) that is customary in practice was generated from the 100 • 100 m grid (1-hectare grid) that is customary for precision farming. The nutrient levels of the 4-hectare grid were used to estimate the nutrient levels of the 1-hectare grid. This was done on the basis of two approaches:

1) The mean values of the nutrient levels were calculated for each field and appended to the data-sets in the 1-hectare grid (uniform fertilising for each field).
2) The mean values of the nutrient levels were calculated for each EC25 cluster within a field and appended to the data-sets of the 1-hectare grid of the relevant field and the EC25 Cluster (EC25-dependent precision fertilising).

Despite the grid-shaped sampling in approach 2 as well, this was considered to be targeted sampling, since it was subsequently evaluated as a function of the EC25 clusters. The mean difference between the estimated and measured nutrient levels per field is a dimension for the estimation error. The comparison of the estimation errors of both approaches is a measure for the effect that can be achieved by using EC25 data in the way shown in this example.

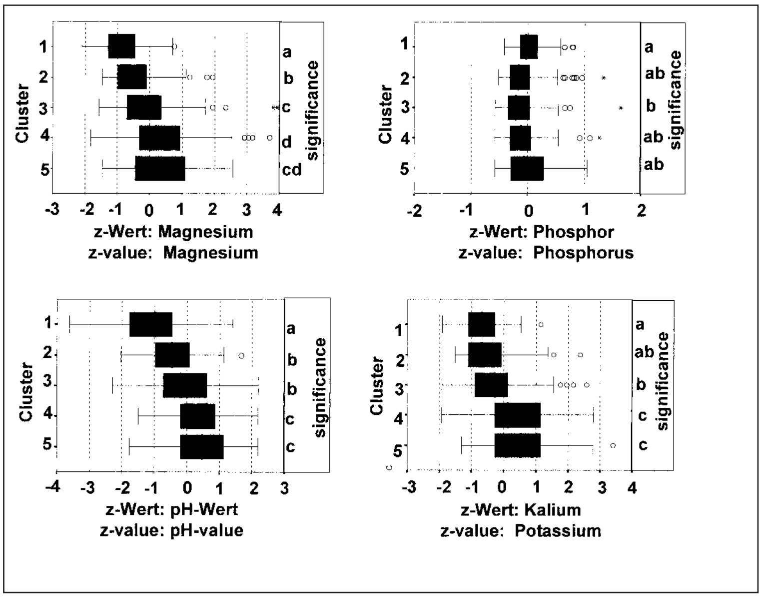

Fig. 1: Box plots of the z-values of the nutrients for the EC25-cluster of the total area

Results

The data

The variation coefficient of five of the attributes listed is relatively uniform and varies between 22 % and 30 % (*Table 1*). The variation in the pH-value is well below this, since the lime supply of the soils is altogether high. The very high variation in the phosphorous content is due to a few outliers and is thus not typical.

Correlation

With an error probability of 1% for the overall area, there is a significant positive correlation between the soil electrical conductivity EC25 and the pH-value, as well as between the potassium and the magnesium content, with a value above 0.4. There is no such connection for the phosphorous content.

The correlation could be connected with the high correlation coefficients of over 0.6 between the EC25 and the fine soil proportion and the humus content. Considering the soil electrical conductivity simply as a substitute parameter for these two soil attributes is not enough, however, since the correlation between these attributes and the nutrients is lower (below 0.4), even though it is also significant. However, the connection between potassium and humus is high (>0.5). Phosphorous also shows no correlation regarding the fine soil proportion, but a weak correlation with the humus level.

This correlation that applies for the entire area cannot be generally demonstrated for the individual fields, however. Alongside positive correlation even above 0.6, for example for the pH-value and the magnesium level, negative correlation occurs too for the potassium and magnesium levels.

Estimation of the effect

The model use of soil electrical conductivity for estimating nutrient levels in a tighter grid essentially confirms the preceding results. If the estimation error is set at 100 % without considering the EC25 cluster, the estimation error taking the EC25 cluster into account for the entire area is 89 % for the magnesium level, 88 % for the pH-value, and 86 % for the potassium level. The estimation error is thus reduced by more than 10 %. In agreement with the preceding results estimating the phosphorous content cannot be improved by taking the EC25 clusters into account.

However, the estimation errors vary considerably when individual fields are considered. Reduced estimation errors for individual nutrients in individual fields can be set against equal or even elevated estimation errors in other fields. Thus no distinct trend is evident.

Discussion and conclusion

The significant correlation between the soil electrical conductivity on the one hand and the pH-value, potassium and magnesium levels on the other hand for a relatively large area, in this case the entire area studied, shows that such a connection exists objectively in the ground moraines and sandy glacial sediment area studied. However this interrelation is superimposed on individual fields by different interference parameters (locally varying nutrient uptake via the harvested material or vertical/lateral material transport, locally varying nutrient inputs by varying nutrient levels in the fertilisers, and due to faults in fertiliser spreading) and is thus concealed. Consequently the effect of practical use of this interrelation for individual fields - since this alone is interesting for a farm - cannot be appraised in advance. However, this means that so far mapping of the soil electrical conductivity cannot yet contribute to reducing costs in base fertilising operations. Studies in other soil landscapes or with modified solution approaches can lead to a different result.

Criterion	Mean value	Standard deviation	Coefficient of variation %
P content, mg/100 g soil	7,7	7,0	91,0
pH-Wert	6,1	0,4	6,6
K content, mg/100 g soil	16,4	4,9	29,9
Mg content, mg/100 g soil	5,9	1,7	28,8
Pan, %	11,0	2,7	24,5
Humus, %	1,8	0,4	22,2
EC25, mS/m	26,8	7,9	29,5

Table 1: Descriptive statistic of the features

Literature

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