Werner, A., Jarfe A. (eds): Programme book of the joint conference of ECPA-ECPLF. Wageningen Academic Publishers, ECPA Berlin, 15.-19.6.03, S. 812-814

Precise site assessment by data of German soil ratings, geoelectric conductivity, terrain modelling and digital farm soil mapping[4]

extended summary of the respective subprojects of preagro, dealing with methods for site characterizations

J. Lamp, R. Herbst, G. Reimer, F. Schmidt, E.W. Reiche, U. Schmidhalter and J. Bobert

Knowledge about soil and relief heterogeneity within fields is a prerequisite for Precision Agriculture (PA) and a key factor to site specific variable rate technology (VRT) of various applications from tillage to sowing and fertilising. In water limited regions, available soil water capacity (AWC) of the rooting zone determines mainly the yield, whereas in more humid areas complex interactions of soil, weather and relief become more important. With increasing depth soil surveys require higher expenditures, but a data amelioration by all static site features will be profitable on a longer run. In preagro several subprojects aim for alternatives and a most efficient site inventory by using simplified support information either of existing or new spatial data sources.

Inventories on preagro pilot fields: On 64 fields of pilot farms (in total 1.262ha), covering main soil(land)scapes of Germany, site assessments by various approaches were performed. Initially, the old German soil rating data ("Reichsbodenschätzung") were digitised and used mainly for VRT maps of the first trial year. In addition, ECa maps by an electric conductivity sensor (EM38) and digital terrain models (DTM) either from State Geodetic Agencies (LVA) or by very precise Global Positioning Systems (RTKGPS) covered increasingly all fields. From the second trial year, an AWCoptimized version of digital Farm Soil Maps was used instead which tries to integrate all support information and soil boring data of ground truth surveys. On selected project fields special investigations were performed about quality (calibration, validation) and functional aspects (relations to plant and yield parameter) as well as on statistical measures of heterogeneity.

Geostatistical Results: Measures of local variabilities of soil and nutrient attributes are important prerequisites for assessing the profitability of PA and for planning efficient surveys. From random grid surveys on selected fields, spread statistics of sum frequency and variogram curves were evaluated for soil and available nutrient attributes. In few cases of the fields and attributes (ca. 1015%) the geostatistical measures enhanced non applicability or non profitability of PA by extrem narrow or very wide autocorrelations, respectively. Some fields show a very distinct separation of field management zones and a high attribute concordance which can be used for method testing and demonstration purposes of PA. But in most cases soil correlations tend to be mediumlow. The semivariances approach the critical interpolation sills at ca. 70m. Therefore, site mapping by interpolating data from dense raster samples (sample density > 2/ha) will often not be acceptable by farmers from an economic point of view. But which areal support information can be used instead?

Old German soil ratings: These data source, based on a standard 50m grid survey all over the farmer German territories, was made available from local fiscal offices. Rating class maps (1:2000) and soil pit field descriptions designating the polygons were digitised, georeferenced and translated into a modern nomenclature. For PA purposes, the spatial density of pits is rather low with one sampling point per 24 ha and the quality of the data assessment was not uniform. Soil texture data seem to be most reliable, though silt fractions have not been classified. But the old geology and pedogenetical diagnostics, either due to soil and land use changes or to scientific progression, often need careful checks and validations.

[4] Reprint from: Werner, Jarfe (2002): Precision Agriculture – Herausforderung an Integrative Forschung, Entwicklung und Anwendung in der Praxis, KTBL Sonderveröffentlichung 038, Darmstadt, pages 30 - 33

Soil electrical conductivity (ECa): Diffusely induced by the EM38 probe into soil depths of about 2m, the electrical current is mainly influenced by the soil texture or clay content as well as by the amount and the salt content of the soil moisture. A high survey performance of up to and more than 100 ha per day is achievable and EC maps can be generated with often very low costs per ha. EC maps from different instruments or sampling times reproduce relative soil texture patterns rather stable, especially for sandy soils and dry regions. But loamy to clayey soils and humid conditions may show time and location dependant moisture effects more strongly which overlay and cover the texture information. These complex interactions and an increased depth resolution need further research emphasis.
Proximal spectral sensing of soil surfaces: A hyperspectral scanner (Tec5Zeiss) and a Trimble dGPS, both mounted on the "SoilRover" and connected to a laptop data logger, were used to capture spectral signatures. These were interpolated to remission maps (Rl). The spectral signatures were analysed by bi and multivariate methods to determine the optimal wave length and a best combination of spectral and soil field parameters for estimating the humus content (Corg) of topsoils, both under laboratory and field conditions. Colour images from many observation points along the tramlines of fields were also taken by a digital camera (Kodak DC290). A semiquantitative visual evaluation of the images, assisted by a picture database, helped to code and eliminate interferences by varying coverages of plants, residues and stones or by soil structures. But these factors, as mapped by interpolation, are of high interest for plant management, too.
Digital Terrain Modelling (DTM): Instead of data from the geodetic surveys, very precise elevations were measured by the Real Time Kinematic GPS-technology and used in the preagro project. By GIS interpolation techniques detailed elevation data on raster basis were generated which can be used to compute slope, exposition and relief parameters for assessing local climate conditions. Especially, near surface water flow patterns have been computed and mapped by means of the Topographic Wetness Index (TWI, a transformed ratio of the local catchment and the slope for each raster element). The results show the potential wetness at convergent zones, stream lines at slope rills or potentially dry zones at concave areas. These morphometric zones can be used with profit by several modules of management algorithms constructing application maps. A data resolution of 25m in grid size and ± 10cm in elevation is sufficient to produce high quality results of the water fluxes and moisture predictions. For this purposes the quality of data from the geodetic surveys often proved to be unsufficient. An ArcView extension is being developed which predicts by lowpassfiltering and a modified TWI more applicable soil moisture potentials. Optionally, the overlay with ECa maps will be integrated in order to allow the production of moisture maps by two sensor data sources from one tramline drive only.
Soil water storage: The project aimes to assess the variability in time and space of the water regime of plants and soils by an optimal combination of capacity and gravimetric as well as geoelectrical methods. In 2001 the calibration of the capacitive sensors the year was enforced which predict the relative soil moisture and thus the dynamics very well, but which have an offset of ca. +30% in the absolute measurement of volumetric water contents (WCv). In order to calibrate the sensors for the soil conditions of the Wulfen pilot farm, six representative soil samples (from sand to silty loam) were analyzed in the laboratory. Calibration functions of "scaled frequencies" of the sensors were established with respect to the moisture status, the texture class, mineralogy and humus contents of the soils (r^2 =0.86, without humus rich samples: r^2=0.91). The water contents were measured on two fields at 16 sites of the farm with the Diviner system and at four sites with the system EnviroScan. Soil densities were assessed from texture data acc. to Saxton (1986). The transferability was proved by applying the method on another field of Wulfen (for a depth of 0130cm r^2 is now 0.67). Texture specific calibration functions for single soil profile depthes shall increase the estimations.

Combination of terrain and moisture regime models: By example of field 641 of the Wulfen farm the concordance of TWI based moisture predictions and soil water measurements have been investigated and the transferability of the approach been studied. The results show high correlations (r^2 up to 0.81) between predictions and measurements for specific, agronomic relevant seasons and soil depthes. Seasonal dynamics have to be considered: with the dryness r^2 increases at the topsoils in spring time, too, and after progressed soil evaporation until sommer higher correlations can be expected at greater depthes, only. The areal moistures of wet or very dry soils are better predictable by texture than by relief indicators. The assessments of clay contents by geoelectrical (EC) signals could be enhanced by taking the TWI values in account, too. Therefore, the combination of both approaches is rational for improving the predictions of the moisture regimes on heterogeneous fields. High EC values correspond usually with high clay and humus contents, but occur also in depressions and waterways which show relations to high TWI values and in normal years with higher yields. Sandy to gravelic hilltops show contraversal indicator patterns. But if TWI and EC values do not correspond, a local study soil is neccessary. The transferability of the complex relationships is critical. In the rolling landscapes of young moraines of the Kassow farm, high TWI values at erosion valleys correspond with low EC signals and low humus amounts, but at lower hillfoot positions both signals have a high level.

Indicator quality, efficient boring technique and soil inventory: The geostatistical results show on one side that soil mapping by interpolating raster survey data are not acceptable by farmers due to cost reasons. On the other side, quality assessments of the areal support information like German soil ratings, geoelectrical and proximal (or remote) spectral sensoring and of terrain modelling remind repeatedly not to forget the ground truth checks by direct soil borings, especially if modells have to be transferred to different soilscapes. This demand is higly supported by the summary evaluation of existing preinformations while performing on all 65 pilot fields of preagro soil inventories based on totally 1680 soil borings. The indicator quality, as assessed by criteria of data availability, transferability and prediction power for single target parameter, varies by landscapes and conditions very much. This hinders the setup of generic prediction models. Therefore, emphasis was laid on the development of an efficient soil boring technology by the "SoilRover": by a dGPS and GISaided drive along all tramlines of the fields, geoelectrical and spectral signals as well as colour images are being collected, georeferenced and interpolated afterwards. Together with other important support informations (German soil ratings and multiannual yield maps) conceptual soil maps are constructed as basis for an optimal sampling design. Soil profile data from a Concord hydraulic borer help to identify correlating map zones, delineate the borders and to setup an additional boring survey if discrepancies occur or models have to be extended.

PESWoptimized and special farm soil maps: On all pilot fields a total of 798 soil polygons were delineated and characterised in a corresponding GIS table by several soil attributes (soil and substrate type, humus and stones in topsoils). Following the main agronomic target, prediction of yield potentials, and predominantly by help of EC values the soil polygons were constructed with respect to include similar AWC values. But for practical reasons, too intricate patterns and too small units were avoided. From the second year, these management units with fixed and sharp boundaries have become the basis for all targetyield dependant application maps of the preagro - experiments. But many application algorithms which are being developed by preagro also demand special soil parameters, especially from topsoil's (eg. for VRT tillage depths, seeding and base fertiliser rates). Therefore, a set of special soil maps (esp. humus and soil texture/clay content in Ap) has to be generated, each based on the best possible prediction model and data sources. This approach will be followed also by 3Dfuzzyset methods.