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5.2 Yield Potentials of Sub-units within Fields as a Key Input for Crop Management in Precision Agriculture

extended summary of the respective subprojects of *pre agro*, dealing with "yield potential"

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Introduction: Spatial distributions in the conditions of plant variables or spatial differences in crop yield within fields are caused by (i) small scale site effects (soil, relief, lateral impacts, depth of water table etc.) or (ii) by anthropogenic impacts (historic land use, previous management, variance of crop management techniques, mishaps in technical measures etc.). The total result of all these impacts and effects is a heterogeneous crop with spatial differences in plant density, canopy structure, biomass, yields and qualities of the harvestable products. The *crop management technology of precision agriculture* tries to regard such differences and controls the cropping measures[6] accordingly. There are several ways, on what terms such a control of the cropping measures is planned and can be operated. These different approaches relate either the degree of the measure to (I) an average or specific previous site conditions of the sub-unit (mapping approach), to (II) actual conditions of the crop and/or that of the site of the sub-unit (online approach) or (III) both (online approach with map overlay). Especially the third possibility promises to be the main approach in the future of precision agriculture.

A process of planning the measures of precision agriculture is only possible when the average site conditions (approach I) or average site conditions plus the actual conditions of crop and/or site (approach III) are known in advance. From such information the feasible cropping measures can be derived within several crop management strategies. In most of these cases the cropping measures are related to the goals of the very crop production. The absolute levels of these goals[7] or at least their range are an input in the decision making process when selecting the quantity or quality for a cropping measure or for a set of cropping measures. Knowing the goal that should and could be reached, is a general prerequisite when planning or steering a crop stand with cropping measures. Therefore it is necessary to have an understanding of the possible development of the crop stand in its future. At least it is necessary to have an estimate of the final condition of the crop stand, the height of the yield.

The yield levels or the absolute values of expectable yields are necessary inputs for crop driven decision support systems in precision agriculture. In the practical application of such decision support systems for precision agriculture, the farmers will be able to select from a set of different methods to estimate the yield characteristics of its sub-units of the field. The choice for a specific method will depend on available data necessary for the method, the reliability and robustness of the method and its support by the developer over time.

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[6] Important cropping measures are: soil tillage, seedbed preparation, sowing, Nitrogen-fertilisation (N), weed control, crop protection and fertilisation of Phosphorous (P) and Potassium (K).

[7] Yield in level and stability, concentration of specific compounds in the harvested products etc..

Several methods to determine the possible yield and its characteristics for a single subpart of fields are scientifically developed and compared in this book.

Terms: *Yield potentials* are defined as long term averages of yields for a specific site, a selected crop species and a range of similar varieties growing under a predefined type of homologous management strategies. Such yield potentials are necessary input information within crop management planning to look ahead into a still unknown future. The exact future cannot be determined in advance. But it is obvious, that the pattern of crop development, crop growth and yield formation of a (f. e. not yet sown) crop will most likely be very similar to one of those that can be estimated by experience or will be derived from available data or their appropriate inter- and extrapolations. Thus yield potentials are theoretical values for sub-units of heterogeneous fields for a general situation. The yield potentials can be absolute values as averages with their distribution, caused by the weather-variance of that site. Yield potentials can also be classified values as levels of yield height[8].

Yield expectations are defined as values or levels of yields that can be achieved with a specific crop, a specific variety, a specific history of crop management and with average or distributed weather conditions. In most cases of operative decision making for cropping measures, it is necessary to look into the future of a crop from a time-point within the crop development. From that point on the crop development and the yield are determined by the previous growth conditions, the applied cropping measures and the pattern of possible weather conditions. These can be characterized by the long-term weather data for that site. The crop stand itself has only a restricted number of possibilities for its future development. This number is higher before sowing[9] and reduces gradually until the end of the growing season. Thus yield expectations are theoretical values for sub-units of heterogeneous fields for a specific situation. The yield expectations can be absolute values as averages with their distribution, caused by the weather-variance of that site. Yield expectations can also be classified values[10].

Methods: A simple but pragmatic approach (Roth, 1995) was applied in the joint research project *prea-gro* to determine the yield potentials of sub-units when preparing the site specific sowing rates and nitrogen-dressing. By using a table function, empirically developed from measured yield data and expert knowledge, the site specific yield of small grains (winter wheat as a reference) is derived in dependence of the German soil classification number and annual average precipitation. The model works on most sites relevant for precision agriculture in Germany. The estimated yields correspond well with the experiences of the farmers working in the joint research project *preagro*. These site-specific yield estimations are supplied as options in the *preagro* modules for supporting the decision-making in the management of sub-units with precision agriculture. The farmers still can override these estimations with their own experiences (chapter 6.2). The estimated values correspond well with simulations.

8 Yield classes: high, medium, low etc.; and adding an absolute reference value for reason of comparability.

9 Yield potential and yield expectation of a sub-unit can be equal at the evaluation point of pre sowing, but because yield potential is derived for a set of varieties and yield expectations can derived for a specific variety, there can be differences at that specific point.

10 Yield classes: high, medium, low etc.; and adding an absolute reference value for reason of comparability.

In many regions of Central Europe the yield patterns within fields are caused by differences in local water supply of the very site of a sub-unit. In most cases this will be a lack of water, not fulfilling the demands of the crop for a high yield. In other, fewer cases this might be a too high water supply caused by shallow groundwater tables, collected water in depressions or water accumulation due to impermeable layers in the soil. Because of this, it is reasonable to develop methods for determining yield potentials and yield expectation of sub-units with respect to the water supply of the very sites.

With a combined approach of remote sensing and soil surveying, a regression-based method is developed that allows estimating the *site potentials* and *yield potentials* (chapter 3.5). Based on the reflection characteristics of crop canopies in the thermal and the near infrared-range of light, the water status of the crop-plant complex is determined. Relating the different values of biomass and yield to the water status of sub-parts in the field the method estimates the water holding capacity of the soil profile. From that maps of potentially plant available water of a field can be derived. These data can be a base for yield estimations with models.

When looking for very detailed aspects of *yield potentials* or *yield expectations*, then methods are necessary, which evaluate the appropriate yield values for the interactions of *species* x *variety* x *site* x *management* for all sub-parts within an arable field. A feasible method is the application of validated crop growth models. It is described, that with the use of such models (CERES-family), the yield potentials can be estimated without long-term data sampling (chapter 5.3). Only data are used that are available for farm fields on an overall base. With additional calibration experiments the data input for soil information, evaluated with the soil water balance are determined (chapter 2.4 and 5.4). The yield potentials are determined as averages of multi-year simulations, using long term weather records of the very site. The first results show a good fit of the estimated yields compared to those being measured on the fields, especially when delineating the observed zones in the fields with remote sensing.

Management Units: When determining the yield potentials of sub-parts of fields, it is important to know, how far in distance these values are valid. The spatial range of the yield potentials or yield expectations is a crucial point for managing the sub-parts. Areas, that show homologous characteristics of yield or of crop stand variables can be delineated as management zones or management units. Methods to determine such units are described in the book.

Discussion: *Yield potentials* or *yield expectations* are theoretical values. It is therefore obvious, that it will not be possible to determine exact values of yield potentials by yield mapping or through correlations from soil and relief related site information.

Yield mapping will predominantly represent values of a single or of few years for a specific variety and the specific management of that year or those few. These data hardly can be reliable information for a view onto yields on a long-term base. Only in a few regions and with few fields it will be possible to determine persistent spatial yield patterns with a few years of yield mapping. Changing in varieties, crop rotations and crop management over time will restrict this.

Site information does not properly consider the dynamics of a crop stand over time and the autocorrelation of certain later situations with earlier conditions in crop stand or that of the site.

Literature

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