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Integrated approach to site-specific soil fertility management

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Abstract. *In precision agriculture the lack of affordable methods for mapping relevant soil attributes is a fundamental problem. It restricts the development and application of advanced models and algorithms for decision making. The project "I4S - Integrated System for Site-Specific Soil Fertility Management" combines new sensing technologies with dynamic soil-crop models and decision support systems. Using sensors with different measurement principles improves the estimation of soil fertility parameters such as plant available K, P, Mg, humus and soil texture. However, involving many sensors can cause technical difficulties and is expensive. Choosing the appropriate set of sensors will become an important aspect of decision making in precision agriculture.*

Keywords. *Proximal soil sensing, fusion of soil sensors, soil-crop models, decision support systems,*

site-specific soil management.

Introduction

Due to natural and manmade in-field heterogeneity improvement of soil fertility by fertilization and other measures requires informed decision making based on detailed assessment of soil properties and deep understanding of soil processes. It is well known that conventional uniform management of fields creates loss of yield due to too low input on some parts of the fields while other parts receive too much input which leads to waste of resources. Despite the fact that implements for adaptive fertilization, tillage, and spraying are available adoption and success rate of precision agriculture is low. We have to state that the fundamental problem of site-specific management is the lack of affordable methods for mapping soil attributes. The high cost for soil sampling and laboratory analysis not only prevent a higher spatio-temporal resolution of soil monitoring but also caused the use of rather simple recommendation algorithms based on a very few soil properties as inputs. The demand for a multitude of input variables is one of the main reasons why research results on soil nutrient dynamics (e.g., process based soil models) were not adopted in practice. For example, existing knowledge on processes in the subsoil are not regarded. Additionally, scientific models of soil processes are difficult to handle for practitioners. Thus, these models need to be embedded into an accessible decision making framework which regards agronomic and socio-economics aspects, including user-friendly interfaces, before they will be accepted by farmers.

Materials & Methods

To address these issues the project "I4S - Integrated System for Site-Specific Soil Fertility Management" has been launched. I4S is part of the German "Year of Soil" initiative "BonaRes" which will be funded over 8 years. The aim of I4S is to develop an integrated system for soil fertility management designed for agricultural service providers, famers and other end users who will provide recommendations on adaptive fertilization and other measures to improve soil functions and reduce environmental impacts. The system will address the within-field management of N, P, other macro- and micro nutrients, pH, SOM and water. It will also derive soil functions such as filtering, erodibility and water storage as a basis for policy making.

Besides the development of novel soil sensors, soil process models and decision support system the tight coupling of these three components and will be the main achievement. The integrated approach should guarantee that (a) sensors will be designed as to serve the models as good as possible; (b) models will make most of the sensor readings, which may require modification of sensors; (c) decision support system (DSS) will interpret model outcomes in terms of agronomic and external socio-economic conditions.

The work includes sensor design, testing and calibration, a stepwise integration of sensors into the mobile sensor platforms, the evaluation and modification of soil process models regarding the needs of decision making in practice, and the integration of models into algorithms of a user-friendly decision support system. The models will allow do derive soil functions. They will also form the core of the DSS. At the same time, the DSS will integrate agronomic and socio-economic requirements and restrictions such as exiting crop rotation and farm machinery, costs and legal issues.

Results & Conclusions

The current focus is on basic research and development research related to chemical sensors and models of soil nutrient dynamics. Sensors include are: multi-depth galvanic coupled resistivity meter, potentiometric sensors for pH, nitrate, potassium, and spectrometers for Vis-NIR, MIR, Raman, UV, fluorescence, laser induced breakdown (LIBS), Tera-Hertz (THz), gamma, and X-ray fluorescence

(XRF).

A sensor platform for continuous mapping of the rooting zone is under development which is able to integrate different sensors without interference. Electronics and software for sensor management has to allow maximum flexibility.

Preliminary results indicate the potentials and limitations/challenges of the sensors. At the same time, the possibilities of these sensors impose new challenges to modelers. They have to open up their models to include new input variables such as total nutrient content (from XRF and LIBS) of different humus fractions (MIR and Raman). Furthermore, process based (causal) models are challenged by statistical / machine learning approaches which are capable to handle the plethora of data and my find hidden/neglected relationships between soil properties as observed by sensors and crop yield. However, sensors data are not for free. Some of the sensors are quite expensive, some are difficult or even dangerous to operate, and some sensors are more accurate than others. With the increasing availability of new sensors the decision on which sensors to use will become an important aspect which has to be integrated into DSS.

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