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HAL Authorization



Sowing modulation from air seed drill embedded data

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INTRODUCTION & OBJECTIVES

Successful sowing depends on two main factors: initial soil conditions and the proper configuration of seed drill settings, as these influence seed placement, seed-soil contact, and the microenvironment for germination. However, high spatial and temporal variability in soil properties makes achieving optimal conditions challenging.

Current systems lack the capacity to adapt dynamically during sowing. To address this question, this PHD project adopts an interdisciplinary approach that combines principles of soil science, hybrid modeling (Mathematical and AI), and agricultural engineering. The main objective is to develop a model to support real-time adjustments of a precision seed drill, based on spatially explicit soil diagnostics. The scientific objectives are described below:

Identify and estimate in real time the soil factors influencing plant emergence

Estimate critical soil properties; such as water availability in the seed zone, soil mechanical resistance, temperature and seedbed structure; using indirect measurements from embedded sensors on precision air seed drill. Pedotransfer functions (PTFs) will be conceived to translate sensor data into agronomically meaningful indicators, considering intra-field spatial variability.

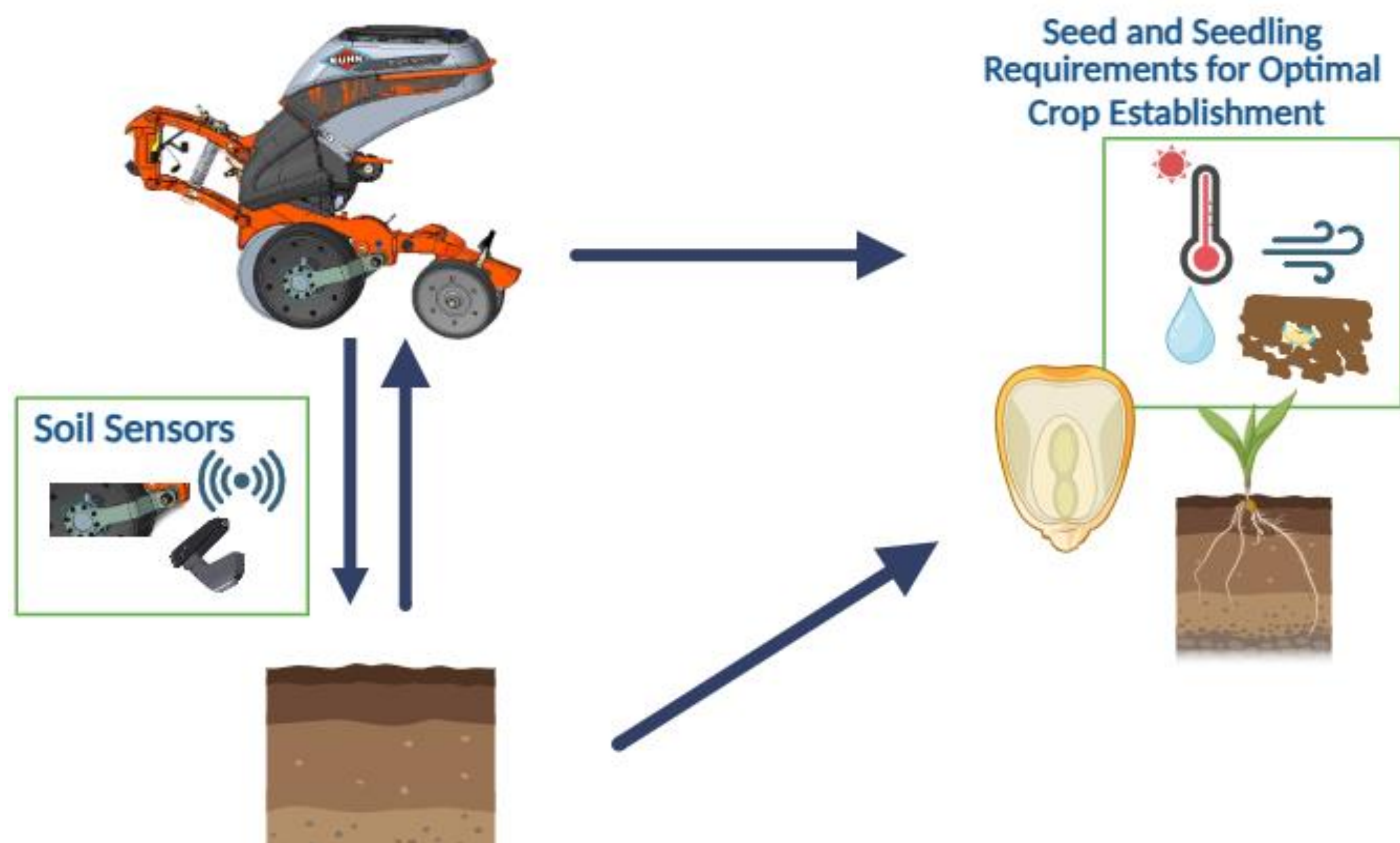
Optimize precision seed drill settings in real time based on diagnosed soil conditions, with the aim of improving seedling emergence.

Design of a theoretical model to determine optimal air seed drill settings (e.g., sowing depth, coulter pressure and closing discs) based on real-time soil diagnostics. The model integrates agronomic criteria, machine responsiveness, and soil variability, formalizing the interaction between soil, plant, and machinery to support intelligent, site-specific sowing.

Evaluate and enhance the robustness of the model across diverse soil and environmental Scenarios

A key challenge is understanding the conditions under which the model remains relevant and reliable. To extend the model's conceptual scope a diverse soil, climate, and management contexts will be tested, contributing to its future applicability in precision agriculture.

VISUAL CONCEPTUAL FRAMEWORK



As illustrated in the Figure 1, the implementation of embedded soil sensors technology enables real-time monitoring and adaptive management of the micro-environment surrounding seed and after seedling. This system facilitates:

- Continuous assessment of soil temperature, moisture and structure
- Data-driven adjustments to seeding depth, coulter and closing discs pressure
- Enhanced alignment with seed and seedling physiological requirements

This approach supports the development of the conceptual model proposed in this thesis and its future application.

Figure 1. This framework formalizes the soil-plant-machine interaction and supports adaptive sowing considering soil heterogeneity

SENSOR VALIDATION & FIELD CHARACTERIZATION

The first stage of this project was the sensors selection. It was based on scientific criteria and commercial feasibility to monitor key soil properties: texture, moisture, temperature, organic matter... Chosen sensors were tested in lab and field conditions to assess performance and reliability. During the field trials, the experimental site was also characterized to ensure accurate interpretation of sensor data.

Field Characterization

- Gamma sensors used as proxies for soil texture.
- Commercial sensors (moisture, temperature, reflectance, EC) and load cells on gauge wheels were mounted on the seed drill.
- **Data Processing & Zoning**
 - Data points per variable were interpolated using ordinary kriging of Smart-Map plugin on QGIS
 - C-means clustering segmented the field into three soil zones.
- **Validation & Integration**
 - Sensor data validated against lab analyses. Of 50 manual samples analyzed for texture, organic matter, mechanical resistance (compression and penetration resistance), moisture and bulk density
 - Validated sensors integrated into the air seed drill for spring 2025 sowing trials on the three soil zones (Figure 2)



Figure 2. Three zones represent spatial variability in soil properties identified through sensor data and clustering analysis