Research for the Future of Agriculture

Food, feed, fiber, and fuel: Crop farming plays an essential role for the future of humanity and our planet. The environmental footprint of agriculture needs to be reduced: less input of chemicals like herbicides and fertilizer and other limited resources like water or energy. Simultaneously, the decline in arable land and the progression of climate change pose additional constraints like drought, heat, and other extreme weather events.

Our research approach focuses on improving the fundamental understanding of all relevant parameters like plant growth, soil, biodiversity, or atmosphere. PhenoRob, the only Cluster of Excellence in agriculture in Germany, aims to address these issues: Change crop production by optimizing breeding and farming management with the help of new technologies.
**NEW FIELD ARRANGEMENTS**

Crop mixtures offer multiple advantages over sole crops. Newly developed advanced data acquisition and data analysis tools enable new insights into interactions and mechanisms in crop mixtures. This leads to an established set of well-characterized, compatible crop partners. Furthermore, the new tools allow optimized allocation of plants to field patches. This then results in ideal field sizes, shapes, and neighborhood with regard to the ecosystem, biodiversity, resource use, and resource efficiency.

**TECHNOLOGY ADOPTION AND IMPACT**

This project analyses the potential impact of robotics and phenotyping technologies on agricultural development, welfare, and the environment and landscape but also on the farm level. Therefore, a simulation model for PhenoRob technology diffusion and impacts will be developed. Furthermore, the project assesses regional feasibility and ecological-economic impact in Germany and on a global scale by analyzing economic barriers and opportunities for the market launch of the inventions.

**THE SOIL-ROOT ZONE**

This project measures the soil-root zones of crops with minimally or non-invasive bespoke sensors and robotics concentrating on sensing and predicting root performance in the field. New technologies like 3D imaging methods are used to gather information on the spatial organization of subsurface soil at the field scale. The aim is to assemble the tools to collect and apply soil-root zone data to crop yield predictions and optimize resource inputs on farms in real time.

**4D CROP RECONSTRUCTION**

Different sensor platforms, i.e., ground and aerial vehicles, operate autonomously, providing precisely georeferenced and phenotypic data from single plants over the experimental plot to the field scale. 3D structural models of the same plant will be registered over time for a 4D reconstruction. This leads to the development of a new generation of mapping systems and a better understanding of the spatio-temporal dynamics of structural and functional plant traits. The goal is to reconstruct several hundred individual plants per day in an experimental field design.

**RELEVANCE DETECTION OF CROP FEATURES**

Based on aboveground data acquired in the field that display crop development, the project identifies unknown correlations among input features. The focus is on the link between different growth phases and stress influence like plant disease, nutrient deficiencies, or drought stress on yield development. Key features will be identified using machine learning techniques and validated through experimental design approaches. This leads to new insights into the interpretation of sensor data, as well as support for decision making in practical agriculture or plant breeding.

**AUTONOMOUS IN-FIELD INTERVENTION**

Precise robotic weeding aims to intervene in a minimally invasive manner reducing the amount of inputs like herbicides. The project develops an autonomous field robot which detects and identifies individual plants and creates a weed map of the field to treat individual plants with the most appropriate intervention method. Furthermore, the robot can precisely apply nitrogen fertilizer enabled by digital avatars that predict the plant nutrient demand and probable losses in the field.