Visualizing the economics of sustainable farming practices

Use case analysis of a complex, diversified plant production system

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Abstract: Landscape changes receive better acceptance when communicated visually to stakeholders in the planning process. Examples in agriculture include changing field structures, such as applying strip-intercropping management to increase biodiversity, impacting the landscape as well as farm economics. To visualize environmental and economic impacts of strip intercropping, the cloud-based software GeoPard, developed for precision agriculture applications, was adapted to the structure of the Future Crop Farming research project. Parametrized with data from the first year of the trial, the software was able to visualize basic differences in inputs and yield output per crop and thus the differences in management systems applied in the research project. More complex calculations for economic evaluations as well as use of the system as a digital twin are conceivable.

Keywords: strip intercropping; regenerative agriculture; living lab; software; digital twin; GIS

1 Introduction

The reduction of synthetic inputs and the increase of biodiversity are two important goals in agriculture. Strip-intercropping as a spatially diversified production system may contribute to both of them and is defined as growing multiple crops in the same field in parallel strips [Va89]. While the ecological potential of strip-intercropping systems has been well researched, aspects of mechanization and labor economics, particularly under consideration of autonomous equipment remain to be evaluated. Conversations with farmers at a strip-intercropping field lab [Fu23] unveiled skepticism, pointing to communication as yet another important step towards the acceptance of strip-intercropping.

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Landscape changes may spark hesitancy and require comprehensive upfront information. Digital tools can help communicate anticipated effects. Swiss farmers, for instance, appreciate a combination of realistic and abstract visualization to understand planned changes and are concerned about both landscape structure and farm economy [Sc11]. Visualizations may also serve farmer-community communication and generate both acceptance and appreciation for ecologically beneficial landscape transformation [WV14]. Described at the farm level and from a farmer's perspective as being aimed at "perspective customers" and "local citizens" ([WV14], p. 438), the concept also applies to communication between farmers and researchers or advisors. For example, [La23] used virtual reality (VR) goggles to visualize suitable areas for afforestation on New Zealand farms and found the technology helpful for farm-scale planning processes affecting "farm profitability, landscape aesthetics and […] rural communities" (p. 12). Such visualizations may increase farmers' understanding of and interest in implementing possible landscape changes [Sc20], although implementation also depends on farmers' self-confidence [NBD16].

Given the economic concerns related to landscape changes (cf. [Sc11]), we aim to visualize the economics of strip-intercropping as an advanced management practice. Based on the research project Future Crop Farming at the Bavarian State Research Center for Agriculture [Fu23], we demonstrate the use of the software GeoPard [Fl23], specialized in documenting precision agriculture applications, for a complex and highly diversified plant production system. First results present the visualization of herbicide and nitrogen input as well as yield output, but more complex calculations are planned.

Adapting software for diverse cropping practices presents challenges such as handling data heterogeneity, integrating information from multiple sources, addressing spatial variability, ensuring scalability with larger datasets, designing a user-friendly interface for different crops, and modifying algorithms for scenario analysis. Maintaining an outcome-per-field perspective adds complexities in terms of analytical consistency, ensuring interpretability of results, and developing a unified framework that aligns with different value ranges for different plant species (e.g., magnitude of yield values). Overcoming these challenges is crucial for the software's effectiveness across a range of crops and real-world cropping scenarios. Finally, the aim is to produce an analytical tool suitable for farm advisors to communicate visually the economic effects of ecologically beneficial landscape changes.

2 Material and Methods

For the present approach, the cloud-based program GeoPard [Fl23] is adopted to analyze a strip intercropping production system from multiple perspectives. Equations in GeoPard are parametrized with empirical data from the Future Crop Farming project [Fu23]. The system integrates various data sources such as yield and applied-input datasets and price information for crops and plant protection (provided by the user) as well as satellite imagery (Sentinel-2, Landsat, Planet), topography data, and zone maps of historical data available in GeoPard. Core methodologies encompass spatial analysis and efficient spatial data manipulation on the matrix level using the NumPy framework [Ha20].

Data sources included both .xlsx and .shp files. Notably, the shape file lacked details about individual strips, necessitating the integration of diverse data formats. GeoPard allowed for a spatial arrangement of data to associate strip-specific details with their corresponding geographical locations in the field.

3 Results

The integrated dataset displaying the strips laid the foundation for subsequent descriptive trial analysis in GeoPard. Adding information on herbicide and nitrogen input specific to each crop strip permitted the visualization of spatial patterns corresponding to the different management methods applied in the Future Crop Farming project (Figure 1).

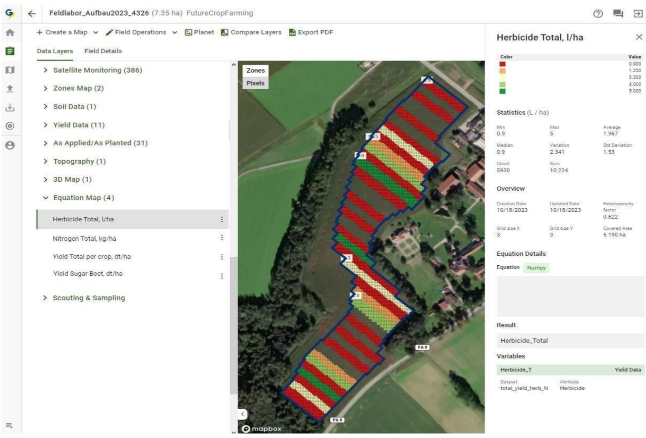

Fig. 1: Herbicide application map displaying a pattern of areas of lower vs. higher input, corresponding to the two management systems being compared in the field lab

While the research project does not study variable-rate application of inputs, the resolution of GeoPard's mapping permits displaying detailed information on the pixel-level (pixel size: 3x3 m; Figure 2), providing opportunity for another layer of complexity. This may prove particularly useful for future applications when combining multiple layers or more spatially variable information such as 'yield profiles' based on small-scale yield data collected by plot combines in the research project.

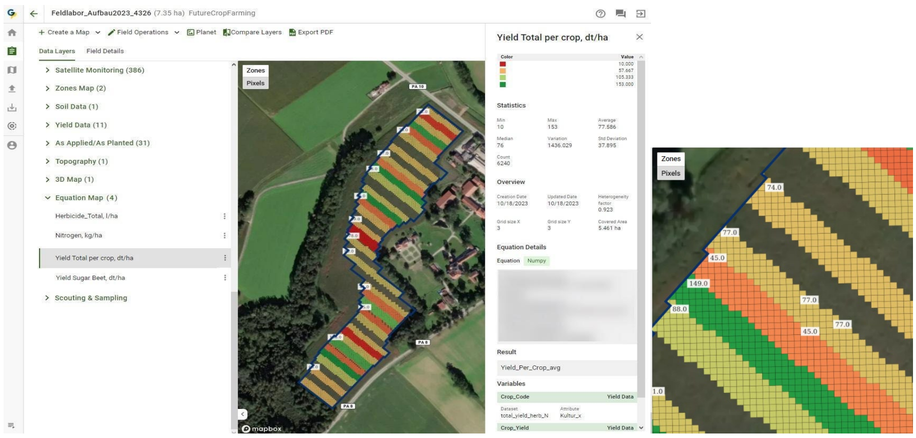

Fig. 2: Yield-per-crop map in full view and zoomed-in to show pixel-level details

4 Discussion and Conclusion

Providing foresight through digital technologies can increase farmer willingness to implement landscape-level measures for sustainability (cf. [La23]). The presently evaluated and adapted tool has shown the potential to analyze complex strip-intercropping economics. Learning to manipulate the tool may be too time-intensive for farmers, though. Instead, agricultural consultants and extension agents could be a suitable target group. Indeed, the application of the tool on an individual farm may not need to be continuous but could rather be used *ex-ante* to inform about the ecological and economic effects of adopting a strip-intercropping approach.

The presented use case of GeoPard software has only made use of its descriptive functions, but more complex visualizations are possible. Given the availability of sub strip-level yield data obtained from a plot combine as well as price information on all inputs and outputs, a profit map visualizing edge effects between neighboring crop strips may be generated. Labor economic data could be added as an additional layer to visualize the impact of reducing economies of scale to achieve more biodiversity. Such data would also lend itself to modeling scenarios, varying in crop rotations, strip widths, or type of mechanization used, enabling users to explore diverse cropping practices while maintaining a focus on outcomes per field, contributing to improved agricultural management and decision-making. Paired with a direct input of data from the machines and sensors employed on the field, the set-up could thus be used as a digital twin. Real-time data transfer to GeoPard is already possible from some commercial technologies as well as satellite data. However, since farmers are wary of lacking compatibility between technologies [GGS21], integration of additional data sources should be considered.

Using the case study of an existing strip-intercropping field lab, possible adaptations of a precision-agriculture tool were explored. GeoPard allows displaying the specific field structure and combining the available data. Despite the fact that certain details on the software interface should be adapted for practical relevance, the user can display existing data and provide variable-rate application recommendations in GeoPard.

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