Advanced web-based decision support tools for climate-smart Agriculture*

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Abstract

This work presences developing an advanced web-based decision support platform to enhance climate-smart agriculture practices. This platform developed within the STARGATE project, integrates various tools to aid farmers and agricultural consultants in tactical and strategic decision-making regarding farm cultivation, seasonal climate risk management, and long-term adaptation to climate change. It leverages data from satellite imagery, weather forecasts, soil analyses, and machine learning algorithms to provide real-time insights for optimizing farming operations, such as tillage, irrigation, fertilization, and harvesting. Key features include a Tillage Scheduler that evaluates soil moisture levels for optimal tillage timing, an Irrigation Scheduler that offers recommendations based on soil and weather conditions, and a Harvesting Scheduler that uses weather data to estimate crop maturity. By providing easy access to personalized reports and customizable dashboards, the platform facilitates more efficient resource use, risk management, and compliance with environmental regulations, promoting sustainability and resilience in agriculture.

Keywords

Precision agriculture, decision support tools, climate smart agriculture, sustainable farming

1. Introduction

In modern agriculture, web platforms with state-of-the-art services are transforming the way farming operations are conducted [1]. These advanced platforms are designed to provide precise data and actionable insights, enabling farmers and agricultural consultants to optimize their field activities and improve overall efficiency [2]. These platforms offer real-time monitoring and predictive analytics, using satellite imagery, meteorological data, soil data, and machine learning algorithms. This allows for precise crop management, including optimal planting times, irrigation scheduling, pest and disease control, and yield forecasting. By integrating various data sources, these platforms help users make informed decisions, ultimately enhancing productivity and sustainability [3]. Furthermore, these web platforms often include user-friendly interfaces and customizable dashboards, making complex data accessible to a wide range of stakeholders. Features such as automated reporting, alerts for adverse weather conditions, and tools for compliance with environmental regulations streamline the operational workflow. Additionally, advanced decision support systems (DSS) embedded within these platforms provide strategic insights into long-term planning and risk management. For instance, by analyzing historical climate data and forecasting

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future trends, the platforms can suggest crop rotations and diversification strategies that mitigate the impacts of climate change.

This work presents a new web-based platform that includes climate-smart decision-making tools. In more detail this platform was developed within the framework of the STARGATE project to provide the stakeholders with a suite of decision support tools in order to facilitate tactical and strategic decision-making related to farm cultivation activities, seasonal weather/climate risk management, long-term adaptation to climate change, landscape design, and policymaking. In order to achieve this goal different decision tools are used to help them make decisions about agricultural production based on site-specific climate data, weather forecasts and future outlooks. These tools use state-of-the-art precision farming methodologies combining machine-learning techniques with earth observations and weather forecasts to support scheduling decisions about tillage, planting - seeding, fertilizing, spraying, irrigation and harvesting. Farmers and agricultural consultants have access to the system through a web-based application with basic GIS functionalities or through a reporting system that will send personalized reports.

2. STARGATE Functions

The STARGATE platform comprises eight interconnected functions, accessible within specific fields. These functions provide tools for agricultural management. One of the main functions is the Clima Function, which integrates various climatic data sources, from meteorological data to field-installed sensor networks, for detailed weather analysis.

2.1. Clima function

The Clima function integrates available climatic data ranging from open meteorological data to dedicated sensors networks installed in the field. This function exploits interoperable data to suggest sensor array configurations tailored to user needs. In brief, via this module the user can:

- Establish field-specific and targeted sensor networks, based on cultivation zones,
- Monitor all available climatic parameters in one place,
- Get accurate forecasts from reliable sources,
- Receive live meteorological data, based on local micro-climatic conditions,
- Highlight hotspots with georeferenced visualized data,
- Stay informed with customized alerts.

One of the main tabs of the Clima function providing a group of STARGATE functions, namely "Task Scheduling". Navigating to this tab, users can choose between three sub-menus, as shown in Figure 1 to access crop-related management tools provided below:

- Tillage Scheduler,
- Irrigation Scheduler,
- Harvesting Scheduler.

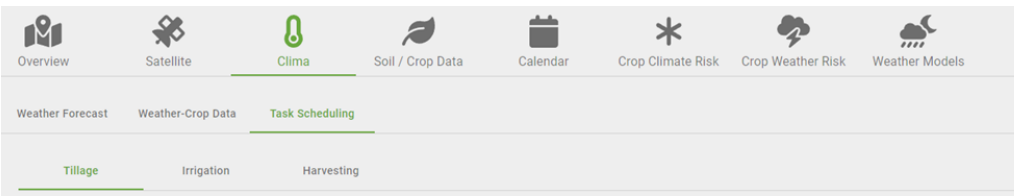

Figure 1: Three sub-menus enabled with Task Scheduling option.

2.1.1. Tillage Scheduler

The Tillage Scheduler tool provides a field-specific evaluation of the soil conditions in terms of its appropriateness for executing or not tillage operations (soil workability).

As a first step, based on the specific soil properties, the tool estimates the optimum soil moisture content for a tillage operation, as well as the upper and the lower limits of the soil moisture to which a tillage operation should take place. Then, the Tillage Scheduler tool reads the value of the soil moisture content from the soil moisture sensors which are established in the field, and based on the soil texture of the field and the forecasted weather conditions provides the current and expected values of the soil moisture content (for the next four days).

Overall, this tool assists users in making informed decisions about tillage operations by considering various factors, such as optimal soil moisture levels, both lower and upper thresholds, as well as the current and projected soil moisture for upcoming days. By integrating this data, users can determine the most suitable timing for tillage activities with greater confidence. The calculation results are shown in Figure 2. Each graph corresponds to a soil moisture sensor. If only one sensor has been installed, then only one graph will appear, and so forth. The lower and higher straight lines represent the lower and higher limits of the allowed soil moisture content for a tillage operation, respectively, while the central straight line corresponds to the optimum moisture content for a tillage operation at the depth of the watermark. Moreover, the blue dots represent the current soil moisture content and the estimated soil moisture content for the next four days.

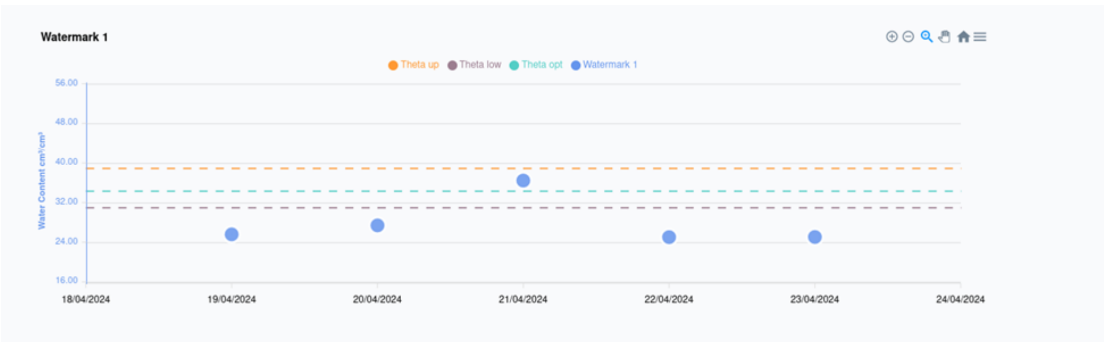

Figure 2: Soil moisture content (current and estimated) along with lower, higher, and optimum ones.

2.1.2. Irrigation Scheduler

Navigating to this tab, users are able to derive suggested irrigation bar charts, so as to manage their actions on their field, according to the results.

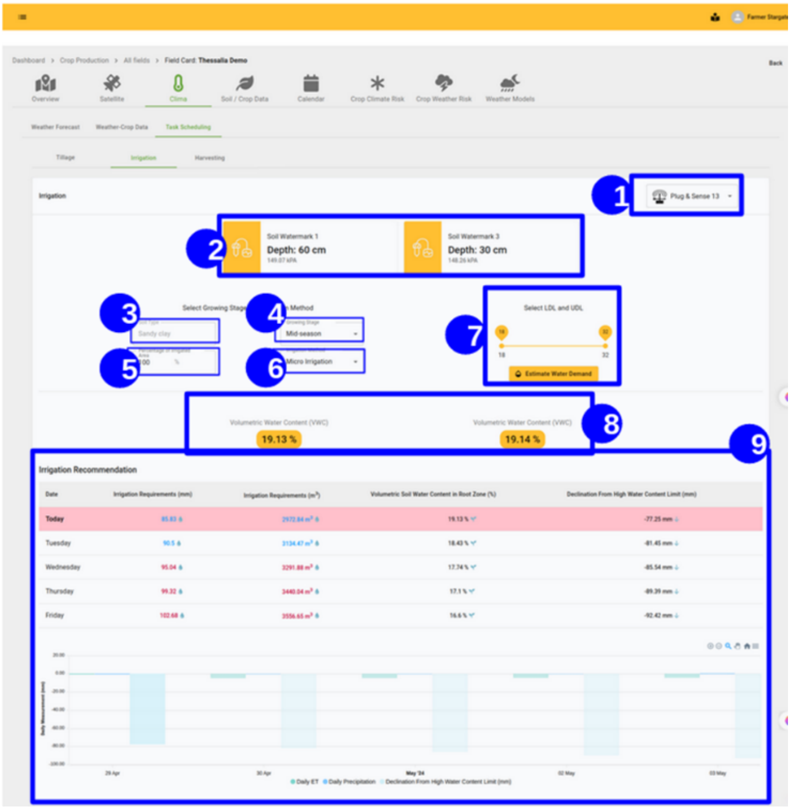

Figure 3: Lay out of Irrigation Scheduler tool.

In particular, as can be seen in Figure 3, the following actions are provided:

1. Select from the available stations for the field,
2. Soil moisture sensor(s) readings,
3. Select soil type or get one that the system provides automatically from a registered soil texture analysis,
4. Select the cropping stage or let the system provide it automatically from the GDD,
5. Select the percentage of the irrigated area as a fraction of the total field area,
6. Select an irrigation system or let the system provide it automatically from the latest irrigation event,
7. Select low and high content limit (%),
8. Define zone preferences regarding volumetric water content,
9. Receive recommendations concerning the water requirements of the field for the current day and the following four days, including the required millimeters of water, cubic meters of water, and the volumetric soil water content in the root zone for both periods.

2.1.3. Harvesting Scheduler

Using this tool, the user is able to see the current maturity stage of the crop from seeding up to period when the crop is ready for harvesting. The tool implements weather historical data for the estimation of the GDD, model-based weather forecasting, as well as correction factors from satellite data and field's history. Harvesting scheduler is provided for six crops, including cotton, corn, wheat (durum), oil seeds-soybean, oil seeds-sunflower, and other cereals-barley. Indicative information about the growth stages of Corn crop are provided in the following graph (Figure 4).

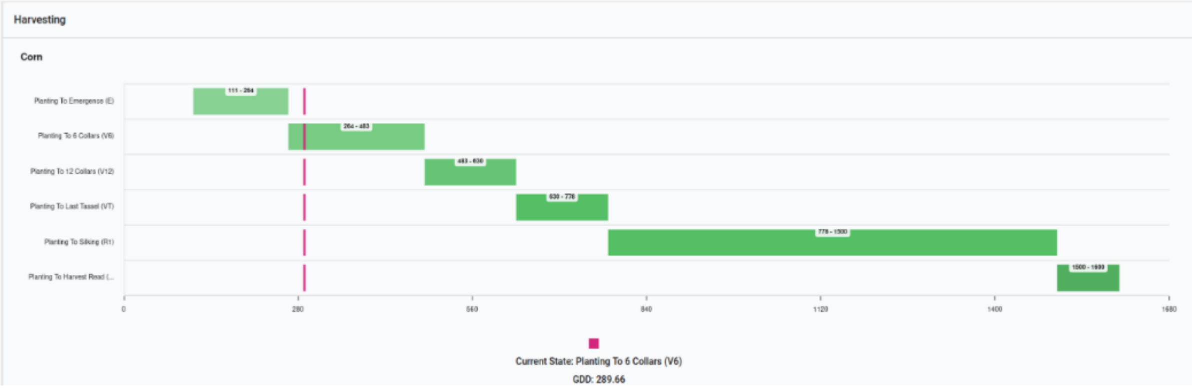

Figure 4: Information about the growth stages of corn.

3. Weather Models Function

The Crop weather risk function of the STARGATE platform provides farmers with meticulous monitoring tools that visualize critical information for managing agricultural operations that include a) sowing, b) spraying, and c) soil trafficability (Figure 5). These functions are based on the meteoblue Weather API [4].

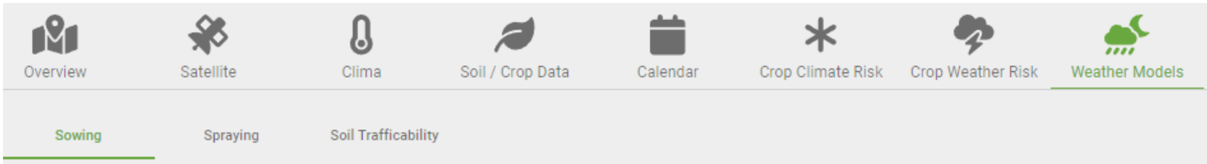

Figure 5: Additional options offered by selecting the Weather Models Risk function, namely sowing, spraying and soil trafficability.

3.1. Sowing

Figure 6 presents a combined visualization of key weather variables, which help determine the suitability of weather conditions for sowing various crops.

Figure 6: Graph integrating key weather variables to determine the appropriateness of weather conditions for sowing different crops.

This concise representation provides immediate insights into the weather, facilitating decision-making for agricultural activities. The top section of the graph shows precipitation in blue bars and soil temperature as a red line, with the respective units displayed on the left and right axes in matching colors. Below, six diagrams are shown, each corresponding to a specific crop: maize/sunflower, wheat, barley, rapeseed, potato, and sugar beets. The sowing suitability is color-coded—red for unsuitable, yellow for less suitable, and green for suitable conditions.

3.2. Spraying

The graph depicted in Figure 7 indicates the most suitable times for spraying the crops. The user can see the time values per day, as well as the anticipated temperature, precipitation, and wind data. In particular, the topmost section of this graph displays the suitability of crop spraying on a particular day, and in 6h intervals within each day. Moreover, red colour indicates unsuitable conditions, yellow stands for less suitable, and green means suitable. The middle section of the graph illustrates wind conditions. The light blue line represents wind speed, while the dark green line indicates wind gust speed. The units for these measurements are displayed on both sides of the graph. Wind vectors at the top show the direction of the wind. Finally, the bottom section presents the precipitation forecast in blue bars, with units on the left, and the air temperature, depicted by a red line, with units shown on the right side.

Figure 7: Graph integrating key weather variables to determine the appropriateness of weather conditions for spraying different crops.

3.3. Soil Trafficability

The graph concerning soil trafficability depicted in Figure 8 is essential for obtaining precise data on soil trafficability across various soil types, including sand, silty loam, silt, and clay. In this graph: Red denotes no trafficability, yellow implies restricted trafficability, green means good trafficability and black curve indicates how the conditions are going to develop over time.

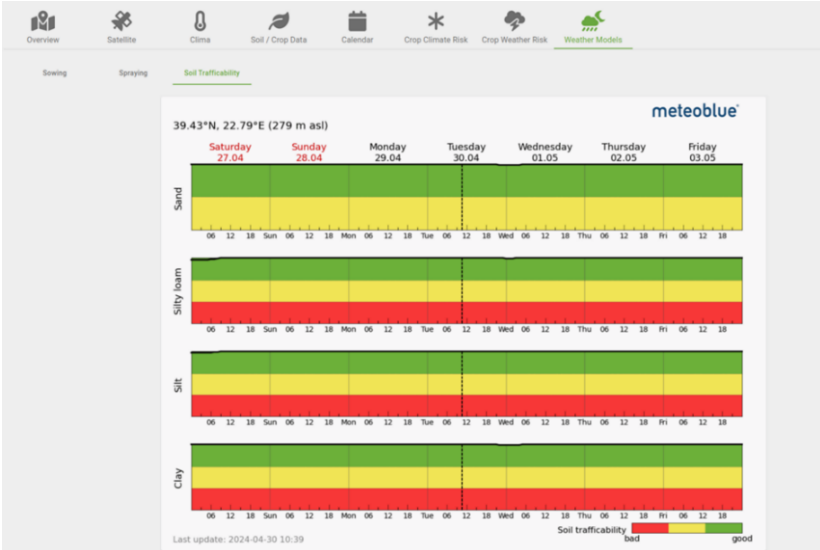

Figure 8: Graph showing soil trafficability.

4. Conclusions

In conclusion, the medium-range weather forecasts provided by the STARGATE platform are valuable for predicting weather conditions over the next seven to ten days. These forecasts support various agricultural activities (tactical decisions), such as planting, fertilizer application, and spraying. They also assist farmers in adapting to increasing rainfall variability by allowing them to adjust planting schedules on short notice. On the other hand, short-range weather forecasts, which cover one to three days, aid in immediate decisions like chemical spraying, fertilizer application, and frost protection. Prompt responses are crucial, as delays may reduce the effectiveness of these operations, especially when specific weather conditions are expected within the next few hours. The development of these decision-making tools is considered vital for improving the resilience of agricultural systems to climate variability and promoting sustainable farming practices.

Acknowledgements

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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