

Crop Growth Simulation and Analysis Integrating Sensor Based Data

Subject: Molecular Biology and Basic cellular physiology (24AIM112)
Ethics, Innovative research, business and IPR (24AIM115)

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Introduction

This project focuses on simulating crop growth using real-time environmental data to predict and visualize plant development. By analyzing factors such as soil moisture, temperature, and chlorophyll content, the simulation generates growth patterns and trends. The output of the project is a dynamic graphical representation of crop health, allowing for informed decision-making and optimized crop management.

Problem Statement

- Farmers often struggle to monitor crop health and predict growth accurately.
- Traditional methods lack real-time data integration, leading to inefficient resource use and lower yields.
- This project aims to simulate crop growth using sensor data and MATLAB, providing visual insights for better decision-making.

Computational Aspects

1. **Data Collection:** Gather real-time environmental data using sensors such as: - TCS3200 for chlorophyll content , Soil moisture sensors, DHT 11 for temperature and humidity.
2. **Data Integration:** Integrate collected data into MATLAB for preprocessing and analysis.
3. **Model Development:** We will simulate growth patterns, calculate plant stress indicators, and optimize resource use.
4. **Visualization:** Generate dynamic graphs and visual representations of crop health trends for informed decision-making.

Project Overview

Our project focuses on simulating and analyzing crop growth using real-time sensor data integrated with MATLAB to support data-driven agricultural decision-making. By utilizing sensors like the TCS3200 for chlorophyll measurement, soil moisture sensors, and the DHT11 for temperature and humidity monitoring, we collect vital environmental parameters that influence plant health and growth. This data is processed to visualize growth trends, detect early signs of plant stress, and calculate key indicators such as stomatal regulation, water-use efficiency, and vapor pressure deficit (VPD). MATLAB is used to model these factors, providing graphical insights into crop development and helping optimize resource management, such as water and nutrient usage. Ultimately, the project aims to improve crop productivity and sustainability by offering real-time monitoring and predictive insights to assist farmers in making informed decisions.

Cellular Aspects

1. Stomatal Regulation and Gas Exchange

Stomatal opening and closing, controlled by guard cells, regulate CO₂ uptake for photosynthesis and water loss through transpiration. Our sensor data simulate how environmental factors like moisture and humidity influence these cellular processes.

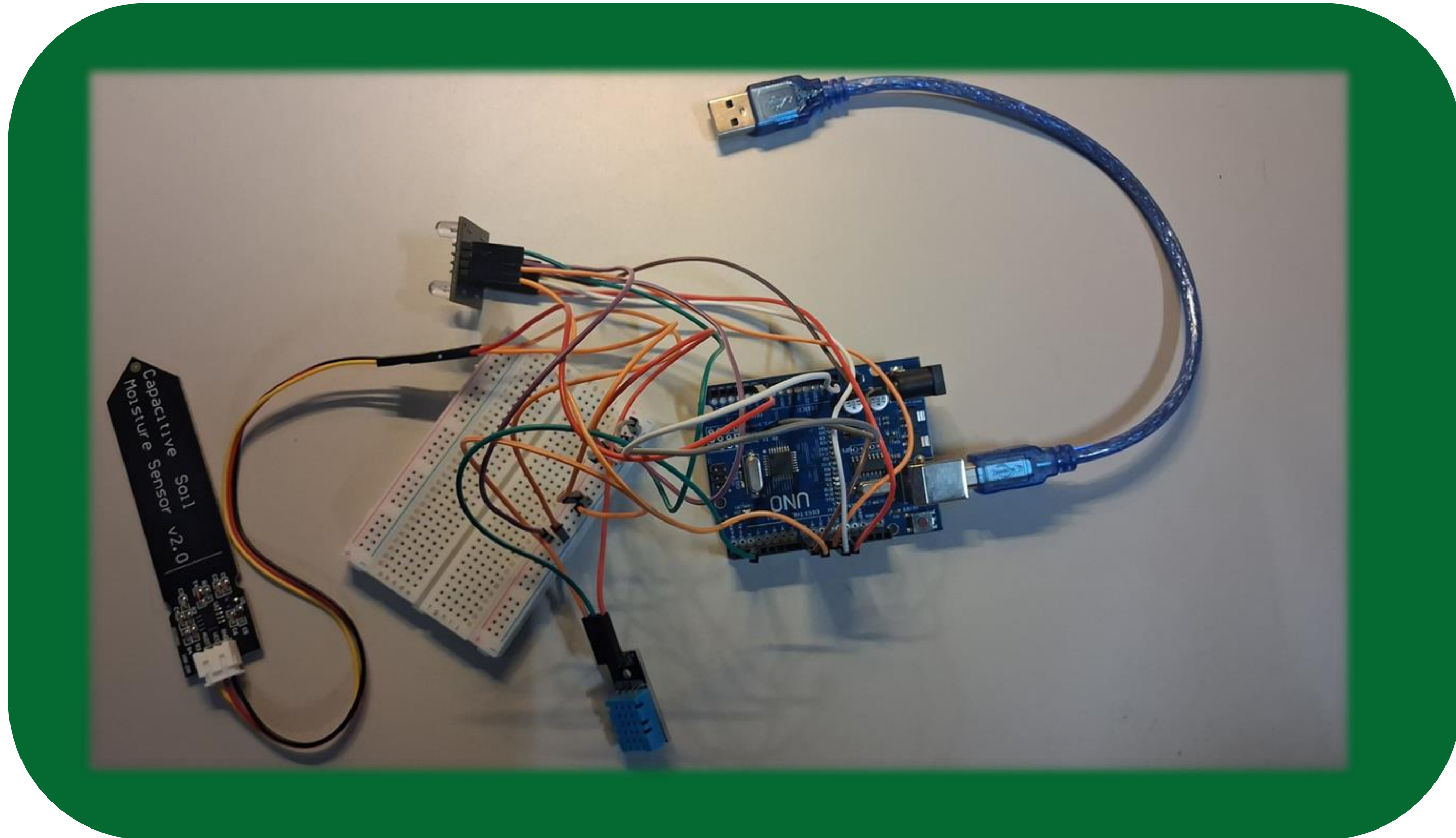
2. Water Transport and Cellular Turgor

Soil moisture affects water potential and turgor pressure in plant cells, impacting cell expansion and growth. Our simulations model how changes in soil moisture influence these physiological responses.

3. Photosynthesis and Chlorophyll Content

Chlorophyll, measured by the TCS3200, reflects photosynthetic capacity driven by light absorption and energy conversion in cells. Our project simulates how chlorophyll variations affect crop growth at the cellular level.

Hardware

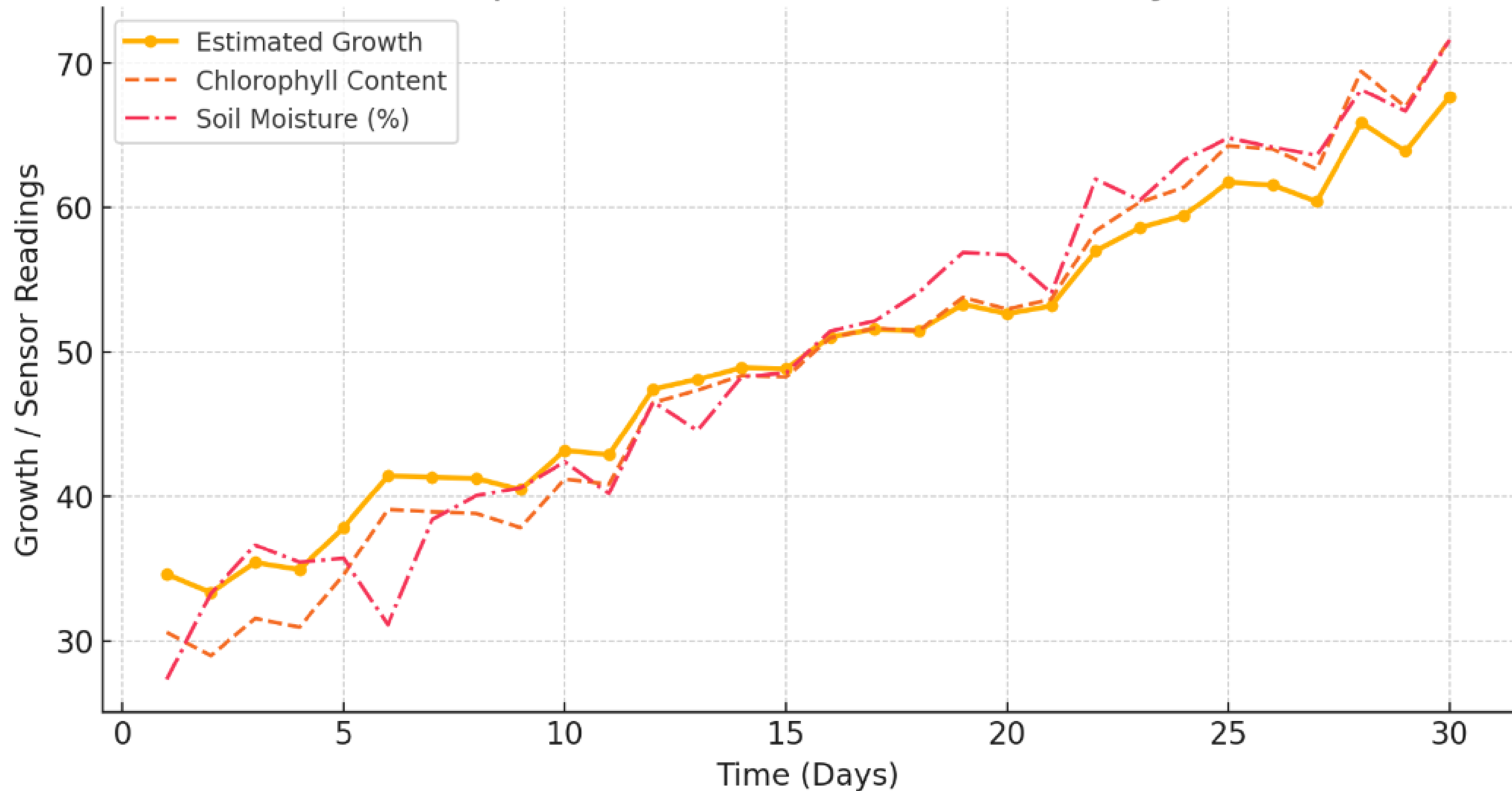


Plant growth



Example Simulation

Crop Growth Simulation Over 30 Days



Progress so far

- Hardware Implementation Completed
- Dataset Acquired & Preprocessed
- MATLAB-Based Crop Growth Simulation Developed
- Initial Testing Conducted
- Ethical Guidelines Drafted

Objectives for the Final Review

- Green Gram Crop Growth Status
- Complete full data collection once leaves are mature.

Ethical Guidelines



Transparency – Clearly state model assumptions and sensor data sources while acknowledging limitations in real world factors.



Environmental Responsibility – Model predictions should promote eco-friendly techniques based on environmental factors.



Farmer Inclusivity & Accessibility – Outputs should be clear and visual for non-technical users, with considerations for offline or mobile access in remote areas.



Data Privacy & Security – Sensor data and farm information must be securely stored, with encryption and informed consent.



Over-Reliance on Simulation Validity - Without validating sensor data with real world measurements leads to uncertainty in growth predictions, affecting accuracy.

Paper 1 : Challenges and opportunities in crop simulation modelling under seasonal and projected climate change scenarios for crop production in South Africa

In South Africa, there is a notable lack of legislation that obliges public access to private owned data, a lack of sustainable funding mechanisms for long-term collection and curation of important classes of data, and technical difficulties in managing and sharing data. A study by Koopman and De Jager [96] carried out at the University of Cape Town (UCT) showed that even though past research had generated digital data in many different formats, these data are being reused and shared within a controlled group of collaborating researchers.

These snippets highlight the importance of **Transparency in model limitations & Data security**.

Accordingly, their study indicates that very few researchers were willing to allow free use of data sets under their control. Hence, data ownership was found to be a significant limiting factor for data sharing. Data ownership var-

just beginning to gain traction [3]. According to Alter and Vardigan [3], most authors acknowledge the potential for the exploitation of the local population and other forms of harm that might affect research participants, including loss of privacy, and issues around informed consent, including questions about the rights of research subjects and potential benefits to the local community. Other bar-

Paper 2 : Simulation and visualization of plant growth using a functional–structural model

Belesky, 2015; 2018). The validity of the use of such simulation tools by landscape architects has been discussed by Ervin and Raxworthy (Ervin 2001, Raxworthy 2018). Criticisms include the challenges in accurately simulating highly complex systems, and an over-reliance on their assumed validity. Kullman also discussed the challenges associated with the use of

This snippet highlights the **Over-Reliance on Simulation Validity** guideline

Paper 3 : The role of crop simulation modeling in assessing potential climate change impacts

agriculture is still highly dependent on weather conditions for sufficient plant production to meet the world's growing needs. The global scale climate, which is defined by the long-term changes in weather, has been relatively stable for millennia and this stability contributed to the development of agriculture (Joan & Alexander, 2018). However, this longterm stability is being threatened. Due to industrialization and an increase in agricultural activities, atmospheric CO₂ and other greenhouse gases (GHGs) have been increasing, and there is widespread consensus that this is driving longterm changes in weather, notably temperature increases, more flooding, and longer drought periods (van der Wiel & Bintanja, 2021). The Intergovernmental Panel on

Intergovernmental Panel on Climate Change (IPCC) in 1990, crop simulation models have been actively used for climate change impact assessment in conjunction with evolving GCMs. The initial works focused on the responses of major staple crop yields (rice, wheat, maize, and soybean) to increasing CO₂ and climate change scenarios (Curry et al., 1990; Rosenzweig & Iglesias, 1994; Rosenzweig & Parry, 1994). Since then, the scope of crop model applications has expanded to broader geographic areas, diverse climatic variables,

These snippets highlight the importance of **Environmental Responsibility & Climate change**

become more severe in the future. Furthermore, limitations in resources such as water, arable land, and fertilizers can reduce the potential for food and fiber production. Driving factors behind these limitations include increased urban and industrial land use, competition for energy sources, depletion of groundwater resources, more frequent extreme weather events, and global warming.

Paper 4 : Data-driven crop growth simulation on time-varying generated images using multi-conditional generative adversarial networks

the output of a processbased model. The minimum MAE/ME is not reached at 100:100, mainly due to the slight dataset bias towards SW and the resulting under-prediction of FB plants in the images, as already discussed. Assuming an unbiased image generation model, this type of analysis can serve to improve the calibration of the process-based model and bring it closer to image-based field observations: If the minimum MAE deviates from the

This snippet infers to the Fair and Equitable Access to Agricultural Technology which comes under **Farmer Inclusivity & Accessibility** guideline.

IPR Patents involved

Yield Estimation in Agricultural Harvesters : [US10295703B2](#)

This patent describes a system that estimates crop yield in real-time by analyzing power variations across harvester head components. Sensors detect these variations to determine crop quantity distribution, improving harvesting efficiency.

Intelligent Irrigation Decision Support System [WO2022190124A1](#)

This patent describes an intelligent irrigation system that analyzes soil moisture, weather forecasts, and crop water needs to provide data-driven irrigation recommendations. This helps optimize water usage, reduce waste, and improve crop growth efficiency.

Chlorophyll and Turbidity Sensor System [EP2389447A1](#)

This patent introduces a sensor system designed to simultaneously measure chlorophyll concentration and water turbidity. By integrating optical sensors, it enables real-time monitoring of water quality and plant health in aquatic environments.

Arduino-Based Smart Irrigation System Using IoT [202131057754](#)

This patent describes an Arduino-based smart irrigation system that utilizes Internet of Things (IoT) technology to monitor soil moisture levels and automate watering schedules. This system aims to optimize water usage and enhance crop health by providing precise irrigation based on real-time data.

Recent innovations in crop growth methods and monitoring

1. IoT Based Smart Farming

- Sensors measure soil moisture, temperature, nutrient levels to optimize irrigation and fertilization.

2. Remote Sensing and Satellite Imaging

- NDVI (Normalized Difference Vegetation Index) and hyperspectral imaging helps monitor crop stress and growth from space.

3. Digital Twin Technology in Agriculture

- Virtual simulations of real crop conditions help predict plant behavior under various environmental conditions.

4. Precision Agriculture with Robotics

- Robots assist in weed detection, harvesting, and soil analysis, reducing labor dependency.

References

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