End-to-End Crop Analysis and Management using Satellite (CAMS)

Ramana Heggadal Math, Saransh Agrawal, Phanender Chalasani, Ashutosh Tiwari, Jose Landivar Scott, Benjamin Ghansah, Lei Zhao, Juan Landivar, Mahendra Bhandari

Texas A&M Institute of Data Science, Texas A&M University
Texas A&M AgriLife Research and Extension Center at Corpus Christi

Abstract

Crop Analysis and Management using Satellite (CAMS) leverages high-resolution PlanetScope satellite imagery, captured at a 3-meter by 3-meter resolution in RGB and NIR bands, to enhance crop yield prediction. Targeting specific Areas of Interest (AOIs), CAMS automates data retrieval and includes AOI-based cloud cover checks to ensure only relevant imagery is processed. Using historical data (2019–2024), the system computes vegetation indices (VIs) like NDVI and GCI, which serve as indicators of crop health. These indices are integrated with time-series canopy data to train Machine Learning models, including Artificial Neural Networks (ANN), Support Vector Regression (SVR), and Random Forest Regression, for in-season yield forecasts.

The CAMS platform's micro-service architecture ensures secure, flexible deployment on cloud systems. Through a user-friendly web portal, farmers can draw field boundaries, view crop health, and access yield forecasts, helping them make informed decisions. Seasonal trends in VIs show consistent growth patterns, offering insights into vegetation health and yield potential.

Key words: Satellite Imagery, Vegetation Indices (VIs), Yield Prediction

Introduction

- The Satellite-based Crop Monitoring System (CAMS) is an end-to-end solution that automates the entire process of crop monitoring and management using high-resolution satellite imagery.

CAMS - System Design

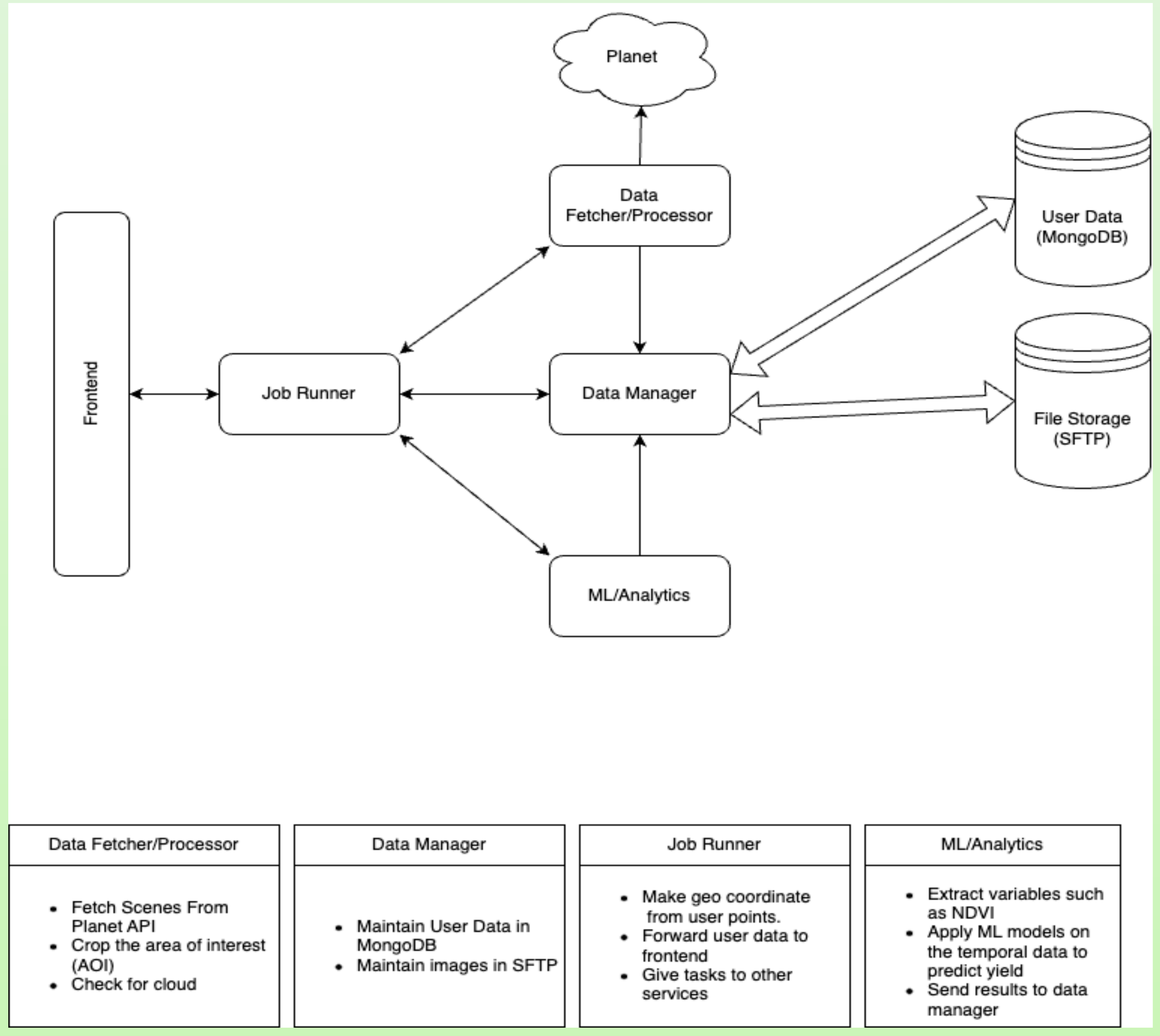


Figure 1. Architecture of the Satellite-based Crop Monitoring System (CAMS) components and their interactions.

Key modules include:
1) Data Fetcher/Processor, which collects satellite imagery from the Planet API, crops images to the specified Area of Interest (AOI), and performs cloud checks;

2) Data Manager, responsible for maintaining user data in MongoDB and managing images in SFTP storage;

3) Job Runner, which processes user inputs, generates geo-coordinates, forwards data to the frontend, and coordinates tasks among services; and

4) ML/Analytics, which extracts key variables like NDVI, applies machine learning models for yield prediction, and returns results to the Data Manager. Together, these modules enable streamlined, automated crop monitoring and prediction accessible through the frontend interface.

Overall Workflow of CAMS

- Define the Area of Interest.
- Satellite images scenes are retrieved and fetched into the system.
- The images are cropped to each AOI, checked for cloud cover, and prepared for analysis.
- CAMS uses MongoDB to store metadata for each image and AOI, enabling rapid querying and optimized data retrieval.
- The Data Manager oversees this storage, maintaining both raw and processed images in a secure SFTP environment, while the Job Runner coordinates tasks across different modules, ensuring a seamless flow from data acquisition to analytics.

CAMS's ML/Analytics module is where raw data transforms into actionable insights. Using vegetation indices (VIs) like NDVI and GCI, it analyzes crop health and integrates these indices with historical data in a time-series format. Advanced machine learning models, such as Artificial Neural Networks (ANN), Support Vector Regression (SVR), and Random Forest Regression, are then applied to predict crop yields based on temporal changes in crop health metrics. The platform's microservices architecture ensures scalability and reliability, allowing each component to function independently yet cohesively.

Goals

1. **Enhance Decision-Making for Crop Management**: Provide real-time crop health insights and yield forecasts, enabling farmers to make data-driven decisions.
2. **Support Predictive Analysis by Integrating Diverse Data Sources**: Enhance yield prediction by integrating weather, economic, and historical data.
3. **Provide Accessible and Scalable Technology for Precision Agriculture**: Improve accessibility to satellite and machine learning tech via a user-friendly dashboard.

Methodology

Area of Interest with Grid Overlay

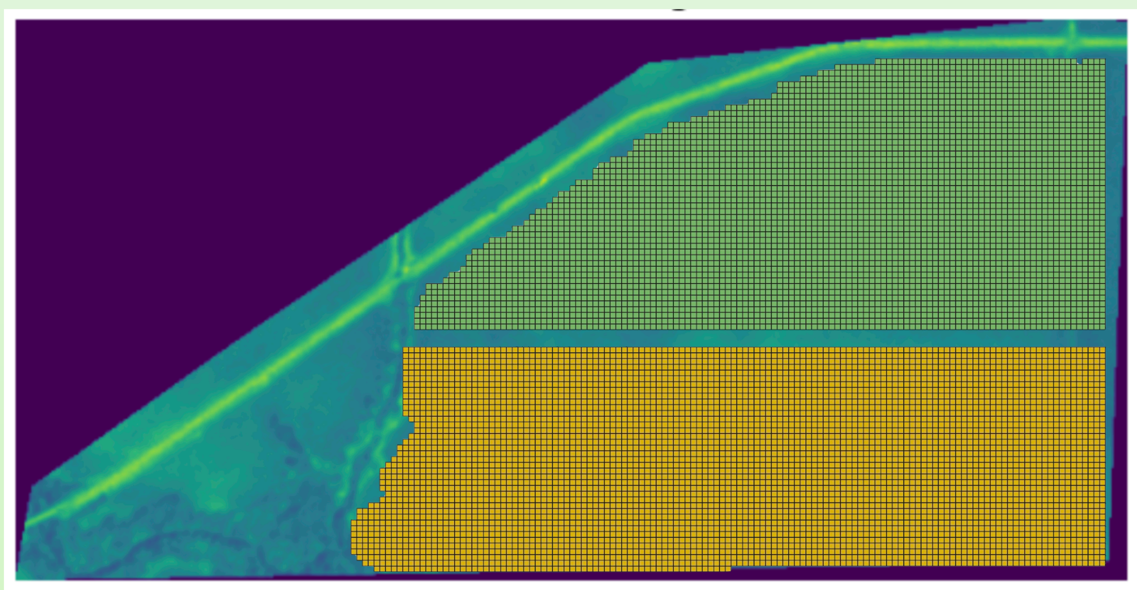


Figure 2: This image displays the area of interest with a grid overlay, dividing the fields into uniform sections to facilitate crop yield calculations. Each grid cell allows us to standardize yield metrics across different image sources, whether from drones, satellites, or other platforms, creating a consistent framework for analysis. The two fields follow a crop rotation schedule: cotton is planted in the bottom field in even years and in the top field in odd years to help maintain soil fertility.

Masked Image of Lower Field Section for 2022 Crop Analysis

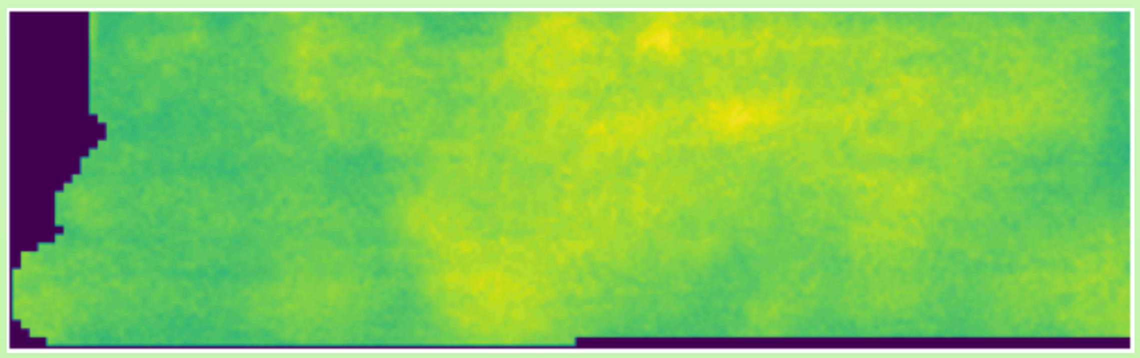
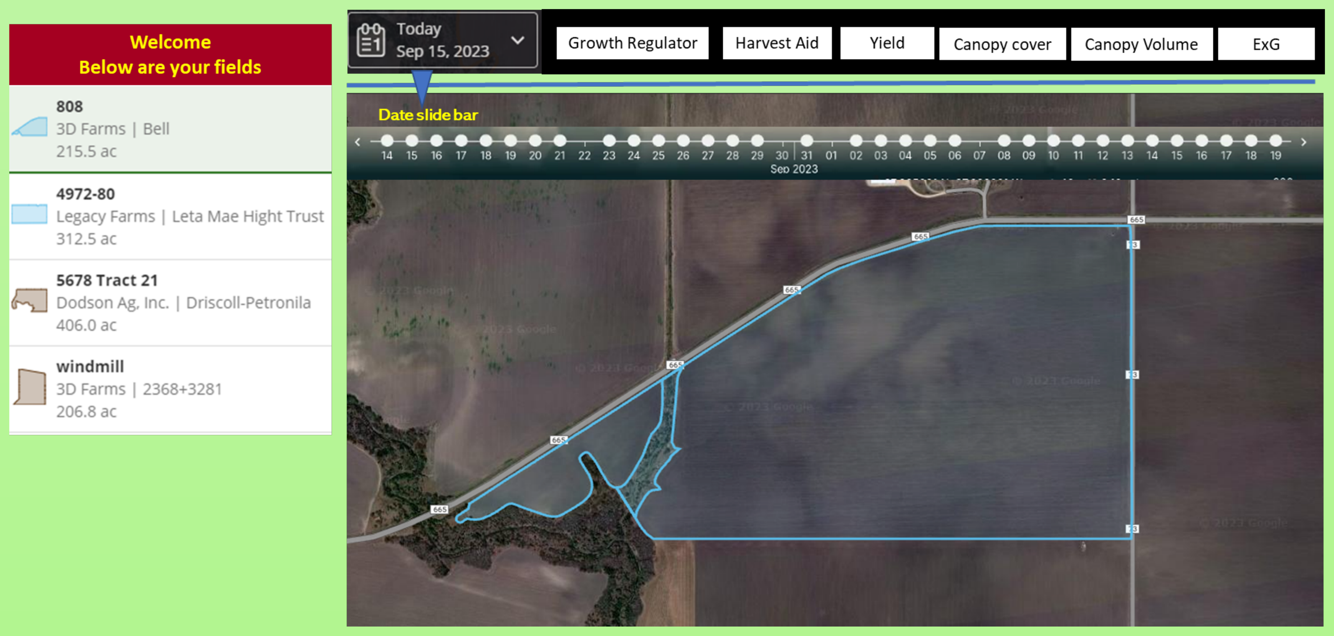


Figure 3: Masked satellite image of the bottom field (cotton) for 2022, serving as the area of interest. This multi-band image includes Blue, Green, Red, and Near Infrared (NIR) bands. NDVI (Normalized Difference Vegetation Index) and GCI (Green Chlorophyll Index) are calculated from these band values. Each grid cell consists of 9 pixels; NDVI and GCI are computed for each pixel, then averaged across the 9 pixels to assign a value to the grid cell.

$$\boxed{NDVI = \frac{NIR - Red}{NIR + Red}} \qquad \boxed{GCI = \frac{NIR}{Green} - 1}$$



GCI and NDVI trends for 2022

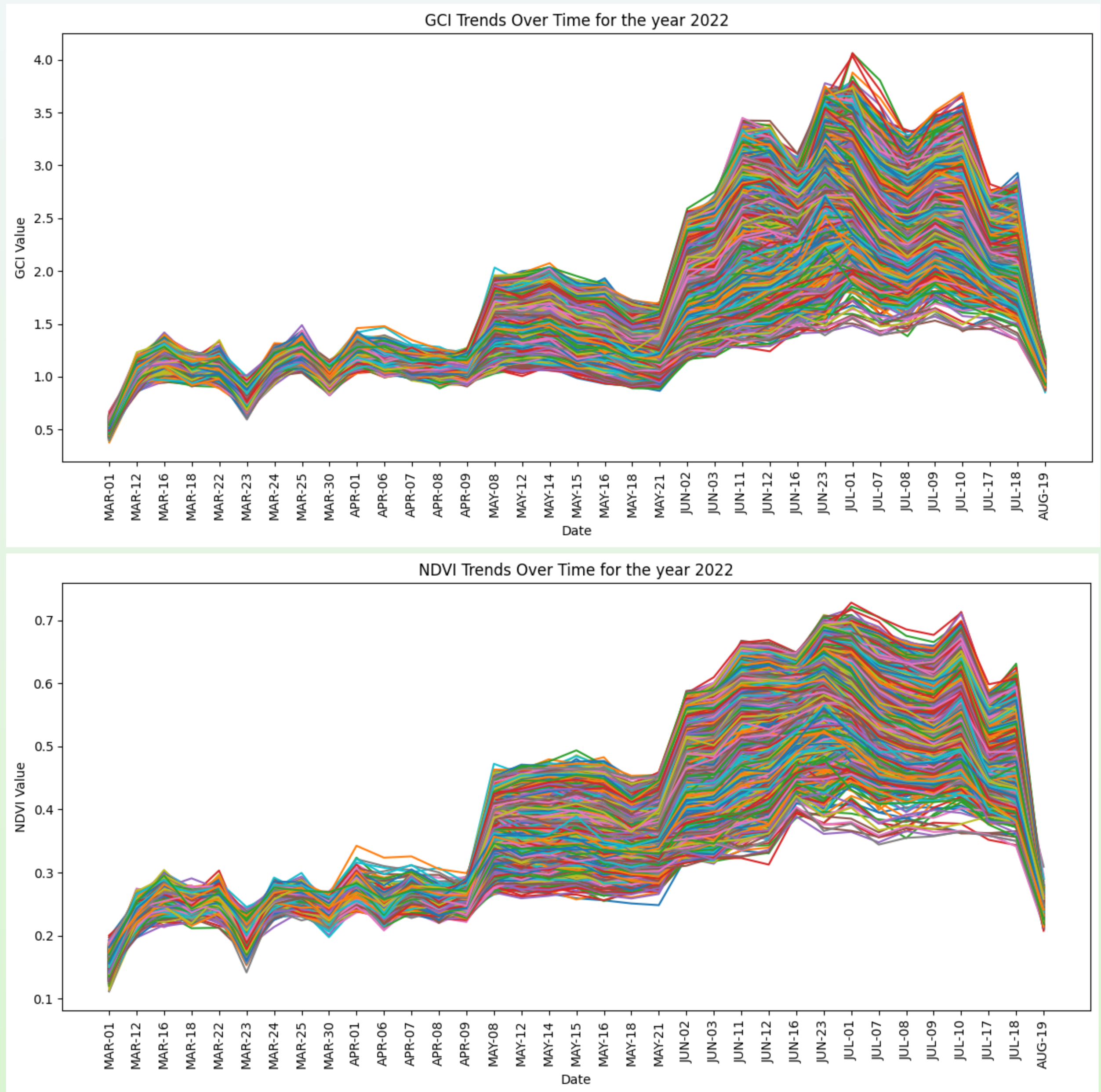


Figure 4: GCI and NDVI trends over time for the year 2022. The graphs show the progression of GCI and NDVI values from seeding day through defoliation day to harvest day. GCI and NDVI values steadily increase from seeding to defoliation, reflecting plant growth and health. After defoliation, both indices display a sharp decline, indicating the end of the growing phase and preparation for harvest.

User Facing Web App (In Development)

Figure 5: User interface of the CAMS application (in development). The interface includes: (1) a login screen for secure access, (2) an AOI (Area of Interest) marking tool allowing users to define project areas on the map, and (3) a dashboard displaying all projects with various metrics for each. Users can select a date range of interest to view detailed analytics and insights specific to that period.

RESEARCH POSTER PRESENTATION DESIGN © 2015
www.PosterPresentations.com