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Satellite Crop Monitoring and Farm Yield Prediction - A Review and Future Prospects

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Abstract: Satellite imaging of crops provides valuable insights into crop health, stress, and yield to optimize production and boost yields. Satellite crop monitoring data is richer and more efficient than traditional manual and ground-based methods. Satellite based farm monitoring and planning has thus been implemented since the 1970s using satellites like Landsat, Sentinel and Resourcesat. This study presents a review of satellite remote sensing technology used in crop monitoring and farm yield prediction. We take an in-depth look at the famous satellites used for this purpose. Satellite based methods offer several advantages over traditional ground based methods. We take a look at these benefits of efficiency, cost effectiveness and scale. Finally, we round up the study with a look at the future trends in satellite-based remote sensing in optimizing farm productions and agriculture.

Keywords: Remote Sensing, Crop Monitoring, Yield Prediction, Satellite Imagery, Hyperspectral Imaging, NDVI, Soil Condition Monitoring, Water Stress Detection, Passive and Active Sensors, Landsat, Sentinel, Resourcesat, Spatial Resolution, Spectral Resolution, AI Integration, Machine Learning Models.

Table of Contents

1. Introduction

Satellite imaging of crops provides valuable insights into crop health, stress, and yield to optimize production and boost yields . Satellite crop monitoring data is richer and more efficient than traditional manual and ground-based methods. Satellite based farm monitoring and planning has thus been implemented since the 1970s using satellites like Landsat, Sentinel and Resourcesat. Crop monitoring and yield prediction satellites are typically low earth orbit (LEO) fitted with remote sensing sensors. They use active and passive sensors to monitor crops with microwave, optical and radar radiations. Thus, they provide information about crop health, water and nutrient content, chlorophyll levels, soil health, air quality and yield predictions.

2. Satellite Based Remote Sensing For Crop Monitoring and Yield Prediction

Numerous studies have detailed the application of remote sensing earth observation satellites for crop monitoring and farm yield prediction. (Karmarkar et al, 2024) summarise the various applications of satellite remote sensing such as yield estimation, crop monitoring and classification, land cover mapping and flood and drought detection. (Omia et al, 2023) describe the various sensor systems and the different electromagnetic spectra involved in crop imaging for agriculture management and optimisation. (Gnanasekaran et al , 2023) describe the working principle of satellite remote sensing for crop monitoring. (Inoue Y. , 2020) describes the recent advances in this domain including hyperspectral imaging. The present study aims to summarise and review the

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developments in satellite remote sensing for agriculture and also enlist the key future trends that will shape the field in the coming years.

3. Principle Of Operation Of Agriculture Remote Sensing Satellites

- Earth Observation Remote Sensing Satellites measure reflected or emitted electromagnetic radiation from earth's biomass to track, map, monitor, measure or collect data about crops and plants.
- Utilize Hyperspectral Imaging of plants through both active (reflected incident radiation) and passive (emitted natural radiation) to collect a rich haul of data about plants.
- Use advanced charged coupled devices (CCD) as high precision sensitive sensors
- The combination of reflected, absorbed, transmitted and emitted electromagnetic energy from plant species creates a unique plant spectral signature.
- Remote sensing satellites compare and contrast real time spectral data from plants with standard plant spectral signatures to assess health, stress, yield, and composition levels.
- Estimates are made, stress areas are identified, prophylactic steps taken and marketing, planning and business decisions made based on data and solid insights. (Figure-1)

4. Sensors

Remote Sensing Agriculture satellites use two types of sensors

Passive Sensors

Passive sensors measure and analyse the natural emitted electromagnetic energy or electromagnetic energy reflected off natural sources like sunlight. Common passive sensing payloads include:

- ***Radiometer:*** To measure intensity of electromagnetic radiation in some band of the spectrum eg. in infrared, visible or near infrared wavelength band
- ***Scanning Radiometer:*** Imager with scanning ability to sweep a two-dimensional image of the area based on the measured electromagnetic intensity. Scanning could be mechanical or electronic.
- ***Spectrometer:*** Device to measure, detect and analyse the spectral content of a signal.
- ***Spectroradiometer:*** Radiometer with ability to measure intensity in different spectra bands for multispectral imaging.

Active Sensors

Optical, radar or microwave radiation are beamed on the target and the reflected, transmitted and absorbed spectra analysed to derive conclusions. Common active sensors include:

- ***Radar:*** Emitter in radar or microwave frequency. A directional antenna and receiver measures the time of travel of reflected or backscattered waves. EM waves travel at the speed of light. So, position, distance, velocity and location of the reflecting object can be calculated. Other parameters can be measured using different properties of the EM frequency.
- ***Scatterometer:*** Radiation to measure specifically backscattered radiation.
- ***Lidar:*** Light detection and ranging, emits a laser pulse and detects and measures the reflected beam for data.
- ***Laser Altimeter:*** Used to measure topography through the height of the recording instrument panel using light and laser.

5. Resolutions of Remote Sensing Satellites

Remote Sensing Satellites have resolutions across several dimensions

Spatial Resolution

Refers to the pixel size of the image - the smallest image element size that is discernible and measurable. Decides the fineness of the imagery. High Resolution can be granular and can capture rich details.

Temporal Resolution

Refers to the frequency of measurements. Depends on the swath width of the satellite. Polar orbital satellites measure once or thrice per day for every meter onboard. Geosynchronous satellites measure every 15 seconds to 30 minutes every day.

Spectral Resolution

Refers to the number of channels in the measurement. Fine Tune wavelength details. Finer Resolution capture finer details of the captured channel Single Spectral meter captures moderate spectral resolution Hyperspectral meters capture higher spectral resolution

Radiometric Resolution

Refers to the intensity levels that the detector can measure. It is a measure of the sensitivity of the detector. Number of bits as powers of 2 captures available intensity levels. The higher the number of levels, the sharper the image captured. High radiometric resolution gives more detailed information and is more granular Eg. Landsat-7 TM has 2 to the power of 8 , 255 levels. Landsat-7 TSS has 2 to the power of 6, 64 levels.

6. Different Measurements in Agriculture Remote Sensing Satellites

Different wavelength bands and sensors capture different information about crops and soil.

- ***Optical Radiance And Surface Reflectance:*** measuring water content, chlorophyll content and biomass composition.
- ***Active Microwave Radar:*** measures soil moisture, crop patterns and soil nutrients and composition.
- ***Thermal Radiation:*** measures water content, precipitation, surface temperature, crop nutrient health, crop water and nutrient stress
- ***Passive Microwave:*** measures precipitation water resources and crop stress in terms of water and nutrients

7. Application Of Remote Sensing Satellites in Crop Monitoring and Yield Prediction

Earth Observation remote sensing satellites find numerous applications in agriculture to improve productivity, outcomes and boost ROI.

Crop Monitoring And Observation

Remote sensing satellites are used for crop monitoring and observation using visible, infrared and near infrared wavelengths using multispectral imaging. Normalised Difference Vegetation Index NDVI : NDVI is the most commonly used index to measure crop health and condition using remote sensing satellites. It is based on the difference in red light spectrum (absorbed by crops) and near infrared spectrum (reflected by crops).

Crop Health is assessed and monitored, and corrective actions are taken.

Remote sensing helps

- To estimate chlorophyll content
- To estimate biomass density
- To predict crop yield
- Satellite based crop monitoring is cost effective and more efficient than traditional manual and ground based methods.
- It also allows early detection of problems and is easily scalable.

Soil Condition Monitoring

Satellite remote sensing can measure and track key soil parameters in real time such as

- Soil Organic Matter (SOM)
- Soil Texture
- PH Content
- Moisture Content

Measuring and tracking soil parameters like moisture help in efficient and sustainable farming. It helps

- Improve Yield
- Conserving Water
- Optimise Irrigation
- Prevent nutrient leaching and over irrigation
- Traditional soil testing needed labs and could be done only in batches
- Satellite based soil monitoring is real time accurate efficient and improves outcomes

Water Condition Observation and Monitoring

- Satellites help monitor, measure and track
- Water Bodies and their water levels and conditions
- Crop and soil water levels, contents and stress
- Irrigated crop land water metrics
- It helps in conservation of water and optimum resource utilisation
- It helps to plan irrigation plans and reduces crop risk and improves yield and output
- It is a boon for sustainable agriculture

Crop Yield Prediction

Using the various measurements and data from remote sensing satellites and making the necessary calculations, we can predict crop yields to a high level of accuracy. This is beneficial and helps in:

- Harvest Planning
- Farm Management
- Ensuring profitability
- Robust financial health of the farm
- Providing the farmer with crucial bargaining power in the markets
- Marketing optimisation
- Managing storage and reducing wastage
- Optimise harvest timing and synchronizing it with sales
- Optimal inventory management
- Satellite based crop yield prediction is grounded in rich data, is accurate, timely, and efficient for better results.

8. Famous Remote Sensing Satellites Used in Crop Monitoring and Agriculture

The following earth observation satellites have been used to optimise agriculture since around the 1970s.

Landsat

Landsat satellites have been the workhorse of earth observation and remote sensing in the USA for a long time. The newest LANDSAT 8 and LANDSAT 9 carry on the good work and are used in agriculture and crop monitoring to boost productivity and reduce losses.

Landsat 8 And Landsat 9 Specifications

- Altitude : 705 kms
- Inclination : 98.2 degrees
- Sun synchronous orbit
- LANDSAT satellites observe the same point on earth every 16 days.
- If used in pairs, LANDSATs can be used to monitor a point on the earth every 8 days.
- Optical Land Image Sensor OLI : It has 9 spectral bands with resolutions of 15m and 30m
- Thermal Infrared Sensor TIRS: It has 2 thermal bands with 100 m resolution
- Radiometric resolution has a dynamic range of 12-bits and 14-bits

Sentinel-2

Sentinel-2 is part of the European Union's Copernicus Program Satellites

SENTINEL-2 has been used extensively in agriculture across countries boosting performance. SENTINEL-2 specifications:

- Altitude: 786 kms sun synchronous low-earth orbit
- Revisit Time: 5 days at Equator and 2-3 days at mid-latitudes
- Swath-width: 290 kms Sensor:
- Multi Spectral Imager MSI with 13 spectral bands and high resolution wide swath
- Multispectral bands cover visible, near infrared, shortwave infrared
- 4 bands with a resolution of 10m, 6 bands with 20m, 3 bands with 60m

Resourcesat-2 And Resourcesat-2a

India's remote sensing satellites RESOURCESAT-2 and RESOURCESAT-2A have been used in crop monitoring, yield prediction to improve and streamline agriculture.

ResourceSat-2 and ResourceSat-2A specifications:

- Altitude: 822 km low earth orbit remote sensing
- Revisit Time: 5 days Sensors:

LISS 4 Linear Imaging Self Scanning 4

- High resolution
- Multi spectral
- 3 bands
- Resolution of 5.8m
- Swath width of 70 kms

LISS 3 Linear Imaging Self Scanning 3

Medium Resolution

- 3 Visible Near Infrared Bands
- 1 Short wave Infrared Band
- Spatial Resolution of 23.5 metres
- Swath Width of 140km

Advanced Wide Field Sensor (AWiFS)

- Coarse resolution
- 3 visible near infrared bands, 1 short wave infrared band
- Resolution of 56 metres
- Swath Width of 740 km.

9. Results and Discussion

Satellite Remote Sensing has helped improve productivity and optimised agriculture in the last few decades. Using multispectral high resolution imaging, satellite methods have helped track key crop metrics to boost ROI and enable sustainable agriculture.

10. Future Trends In Satellite Based Crop Monitoring and Yield Prediction

Going forward, satellite remote sensing for agriculture would use higher resolution imagery and integration with advanced AI and ML models for better performance and outcomes.

Some of the future trends to watch out for:

Higher Resolution Imagery: The technology is going to advance even more and higher resolution multispectral imaging make satellite remote sensing more precise and sharper. It will enable individual plant level monitoring and management. In addition, this will enable highly localised and precise application of fertilisers, pesticides and other materials.

Integration With Advanced Artificial Intelligence And Machine

Learning: Satellite data will be integrated with advanced AI and ML models to automate management with improved accuracy and efficiency. Early detection and prediction of risks and disease will be streamlined, leading to reduction in wastage and better productivity. Yield prediction will become robust leading to better business ROIs.

Commercialisation And Adoption: Satellite remote sensing based agriculture will proliferate leading to increased adoption and commercialisation.

Innovation In Imaging, Signal Processing And Indices: Innovation will drive novel methods of imaging to extract richer data, and improved processing techniques will derive better insights and outcomes. Modelling will lead to robust indices and metrics to better manage plant health and improve agriculture outcomes.

11. Conclusion

Satellite based remote sensing has revolutionised agriculture leading to improved productivity, efficiency, outcomes and reduced wastage and disease. Satellite based methods are more efficient and effective than traditional ground based ones. Hyperspectral imaging with improving resolutions will take the field forward and lead to interesting innovations. Sustainable agriculture is key to feeding the world population for a long time and satellite remote sensing based crop monitoring and yield prediction is helping achieve that goal.

12. References

[1] Karmarkar P., & Teng S.W., & Murshed M., & Pang S., & Li Y.,& Lin H. (2024). Crop Review By Multi Modal Remote Sensing: A Review. Remote Sensing Applications:Society and Environment, 33, Article 101093

[2] Omia E., & Bae H., & Park E.,& Kim M. S., & Baek I., & Kabenge I., & Cho B.K. (2023).Remote Sensing in Field Crop Monitoring: A Comprehensive Review of Sensor Systems, Data Analyses and Recent Advances. Remote Sensing, 15(2),354

[3] Gnanasekeran M.,& Dhayalan D., & Pazhanivelan S.,& Yasin J.K. (2023).Remote Sensing and GIS in Crop Monitoring and Management for SMART Agriculture. Agronomy Compendium: Diverse Perspectives on Crop Science,210-242

[4] Inoue Y. (2020). Satellite- and drone-based remote sensing of crops and soils for smart farming – a review.Soil Science and Plant Nutrition,66, 798-810

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