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Revolutionizing Farming: The Role of Remote Sensing based Vegetation Indices in Smart and Precision Agriculture

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Imagine a world where farmers can check the health of their crops from their smartphones, adjust watering schedules based on real-time data, and apply fertilizers only where needed, all from the comfort of their homes. Welcome to the era of precision agriculture, where cutting-edge technology meets traditional farming, transforming it into a high-tech operation. Precision Agriculture (PA) is a farming management concept that uses technology to observe, measure, and respond to variability in crops. It aims to optimize field-level management regarding crop farming by using detailed, site-specific information (Tripathi *et al.*, 2012; Maurya *et al.*, 2024). This approach not only increases efficiency and yields but also reduces waste and environmental impact (Stein, 2024). Geospatial technology (i.e., Remotes Sensing & GIS) is one of the critical technologies driving PA. It involves collecting data about crops and fields from a distance, primarily using satellites, drones, or aircraft. These sensors capture images in different wavelengths of light, including those invisible to the human eye, to gather detailed information about the crops (Sangeetha, 2024). The availability of high resolution (spatial, spectral and temporal) satellite images has promoted the use of remote sensing & GIS in many PA applications, including crop monitoring, soil condition assessment, irrigation management, nutrient application, disease and pest management, and yield prediction (Sisodia *et al.*, 2020). Vegetation indices (VIs) are quantitative metrics derived from remote sensing data to assess the health and vigor of crops. This article explores several key vegetation indices and their roles in monitoring crop growth and health, water stress, yield estimation, moisture content, and determining the optimal time for harvesting.

Enhancing Precision Agriculture: The Role of Remote Sensing-Based VIs

VIs is calculated using the reflectance values from different parts of the electromagnetic spectrum, particularly the visible and near-infrared (NIR) regions. The use of VIs is a crucial aspect of remote sensing, as it monitors the changes in spectral reflectance values throughout the different growth stages of crops. A diverse range of VIs can be employed to classify crops and assess their condition and health (Vidican *et al.*, 2023; Kumawat *et al.*, 2023). Normalized Difference Vegetation Index (NDVI) is The Normalized Difference Vegetation

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Index (NDVI) is widely accepted index to quantify vegetation health by measuring the greenness of plants. NDVI has become a staple for monitoring crop growth and green cover (Jena *et al.*, 2019). However, more sophisticated VIs like the Soil Adjusted Vegetation Index (SAVI), Enhanced Vegetation Index (EVI), Normalized Difference Moisture Index (NDMI) and the Green Chlorophyll Index (GCI) have been developed to account for Chlorophyll content, Water stress, soil background effects and provide more specific information about plant health.

The most used vegetation indices in precision agriculture include:

Normalized Difference Vegetation Index (NDVI): NDVI is a widely used vegetation index that measures plant health based on how plants absorb and reflect light at certain wavelengths (Jena *et al.*, 2019; Alvino *et al.*, 2020). It is calculated using the formula:

$$NDVI = (NIR + Red) / (NIR - Red)$$

Higher NDVI values indicate healthy, dense vegetation, while lower values suggest sparse or stressed vegetation. NDVI is essential for crop health monitoring, growth assessment and yield estimation.

Enhanced Vegetation Index (EVI): EVI improves upon NDVI by reducing the effects of atmospheric conditions and soil background noise (Shammi and Meng, 2020). It is calculated as:

$$G*((NIR - Red) / (NIR + C_1 * Red - C_2 * Blue + L))$$

Where, G, C_1, C_2 & L are coefficients for atmospheric correction and soil adjustment. EVI provides more accurate assessments of vegetation health and productivity, especially in regions with high biomass.

Soil-Adjusted Vegetation Index (SAVI): SAVI minimizes soil brightness influences, making it suitable for areas with sparse vegetation (Farg *et al.*, 2012; Huete, 1988). It is calculated as:

$$SAVI = ((NIR - RED) / (NIR + RED + L)) * (1 + L)$$

Where, L is a soil adjustment factor to the equation of NDVI in order to correct for soil noise effects, i.e., soil color, soil moisture, soil variability across regions, etc. SAVI is beneficial for accurate crop monitoring in arid and semi-arid regions.

Normalized Difference Water Index (NDWI): NDWI is used to monitor water content in vegetation and assess plant water stress (Gao, 1996). It is calculated using green and near-infrared wavelengths:

$$NDWI = (Green-NIR) / (Green+NIR)$$

NDWI is particularly useful for managing irrigation and understanding crop water needs, ensuring efficient water resource management.

Normalized Difference Moisture Index (NDMI): NDMI assesses vegetation moisture content, crucial for drought monitoring and water stress analysis (Gu *et al.*, 2008). It is calculated as:

$$NDMI = (NIR - SWIR) / (NIR + SWIR)$$

Where, SWIR represents shortwave infrared reflectance. NDMI identifies areas experiencing water stress and guides irrigation management practices.

Green Chlorophyll Index (GCI): GCI is used to estimate chlorophyll content in vegetation, directly related to crop health and productivity (Gitelson *et al.*, 2002). It is calculated as:

GCI= (Green/NIR) - 1

GCI is valuable for monitoring crop health, nutrient status, and predicting yields.

Role of Vegetation Indices in Crop Monitoring and Management

Monitoring Crop Growth and Health: Vegetation indices such as NDVI, EVI, and GCI provide real-time data on crop health, allowing farmers to detect early signs of stress, disease, or nutrient deficiencies. This early detection facilitates timely interventions and helps maintain optimal crop growth conditions.

Assessing Water Stress: NDWI and NDMI are crucial for monitoring plant water content and stress. These indices help farmers optimize irrigation schedules by identifying areas that require more or less water, ensuring efficient water usage and preventing over- or under-watering.

Yield Estimation: By analysing vegetation indices throughout the growing season, farmers can estimate crop yields more accurately. This information aids in better planning for harvest, storage, and marketing, ultimately improving profitability.

Moisture Content Monitoring: NDMI and other moisture-related indices provide insights into soil and plant moisture content. This information is essential for managing irrigation and understanding the moisture dynamics of crops, particularly during drought conditions.

Determining Optimal Harvest Time: Vegetation indices help determine the best time for harvesting by monitoring the physiological status of crops. For example, GCI can indicate when crops have reached their peak chlorophyll content, signalling readiness for harvest.

Conclusion

As technology advances, the potential for precision agriculture continues to grow. New satellite systems, drones with advanced sensors, and machine learning algorithms are making data collection more accurate and analysis more sophisticated. The integration of these technologies promises to make farming even more efficient, sustainable, and productive. However, challenges remain. Access to very high-resolution imagery and the expertise to interpret the data can be expensive and technically demanding. Ensuring that small and medium-sized farmers can benefit from these technologies is crucial for the widespread adoption of precision agriculture. Remote sensing-based vegetation indices are indispensable tools in precision agriculture. They provide detailed, actionable insights into crop health, water stress, yield potential, moisture content, and optimal harvest times. As we move forward, embracing these technologies will be essential in meeting the global food demand while preserving our natural resources. The future of farming is here, and it's smarter, greener, and more efficient than ever before.

References

Huete, A. R. (1988). A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment*, 25.

Alvino, F. C. G., Aleman, C. C., Filguerias, R., Althoff, D. and da Cunha, F. F. (2020). Vegetation indices for irrigated corn monitoring. *Engineering Agrícola*, 40: 322-333.

Didan, K. (2015). MODIS Vegetation Index (MOD13) Algorithm Theoretical Basis Document.

Farg, E., Arafat, S. M., Abd El-Wahed, M. S. and El-Gindy, A. M. (2012). Estimation of evapotranspiration ETc and crop coefficient Kc of wheat, in south Nile Delta of Egypt using integrated FAO-56 approach and remote sensing data. Egyptian Journal of Remote Sensing and Space Science, 15: 83-89.

Gaoa and Bo-Cai. (1996). NDWI? A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water from Space. *Remote Sensing of Environment*, 58: 257-266.

Gitelson, A. A., Zur, Y., Chivkunova, O. B. and Merzlyak, M. N. (2002). Assessing Carotenoid Content in Plant Leaves with Reflectance Spectroscopy. *Photochemistry and Photobiology*, 75(3): 272-281.

Gu, Y., Brown, J. F., Verdin, J. P. and Wardlow, B. (2008). A five-year analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States. *Geophysical Research Letters*, 35(18).

Huete, A. R. (2012). A Soil-Adjusted Vegetation Index (SAVI). *Remote Sensing of Environment*, 25(3): 295-309.

Jena, J., Misra, S. R. and Tripathi, K. (2019). Normalized Difference Vegetation Index (NDVI) and Its Role in Agriculture. *Agriculture and Food*, 1: 387-389.

Kumawat, R. K., Tiwari, G., Ramakrishnan, R. S., Bhayal, D., Debnath, S., Thakur, S. and Bhayal, L. (2023). Remote Sensing Related Tools and their Spectral Indices Applications for Crop Management in Precision Agriculture. *International Journal of Environment and Climate Change*, 13(1): 171-88.

Maurya, D. K., Maurya, S. K., Kumar, M., Chaubey, C., Gupta, D., Patel, K. K., Mehta, A. K. and Yadav, R. (2024). A Review on Precision Agriculture: An Evolution and Prospect for the Future. International *Journal of Plant & Soil Science*, 36(5): 363-74.

Sangeetha, C., Moond, V., Rajesh, G. M., Damor, J. S., Pandey, S. K., Kumar, P. and Singh, B. (2024). Remote Sensing and Geographic Information Systems for Precision Agriculture: A Review. *International Journal of Environment and Climate Change*, 14(2): 287-309.

Xu, H. (2006). Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *International Journal of Remote Sensing*, 27(14): 3025-3033.

Son, N. T., Chen, C. F., Chen, C. R., Chang, L. Y. and Minh, V. Q. (2014). Monitoring agricultural drought in the Lower Mekong Basin using MODIS NDVI and land surface temperature data. *International Journal of Applied Earth Observation and Geoinformation*, 27: 102-112.

Stein, J. (2024, February 15). An innovative research project based at Aarhus University aims to reduce the climate footprint of agriculture by using advanced technology and data-driven methods. Novo Nordisk Foundation. https://novonordiskfonden.dk/en/news/precision-agriculture-ambitious-research-project-aims-to-reduce-the-climate-footprint-of-agriculture/.

Tripathi, R., Shahid, M., Nayak, A. K., Raja, R., Panda, B. B., Mohanty, S., Thilgham, K. and Kumar, A. (2012). Precision Agriculture in India: Opportunities and Challenges. Published on Rice Knowledge Management Portal (http://www.rkmp.co.in), Central Rice Research Institute, Cuttack-753006, Odisha, India.

Vidican, R., Mălinaș, A., Ranta, O., Moldovan, C., Marian, O., Ghețe, A., Ghișe, C. R., Popovici, F. and Cătunescu, G.M. (2023). Using Remote Sensing Vegetation Indices for the Discrimination and Monitoring of Agricultural Crops: A Critical Review. *Agronomy*, 13: 3040.

Shammi, S. A. and Meng, Q. (2021). Use time series NDVI and EVI to develop dynamic crop growth metrics for yield modelling. *Ecological Indicators*, 121, Article 107124.