



Vegetation Indices in Agriculture for Crop Health Monitoring

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Vegetation indices (VIs) are single-value metrics calculated from spectral reflectance data to assess crop condition. This article covers the main indices in use — NDVI, NDRE, NDMI, MSI, and EVI — explaining what each measures and where it performs best. It also summarises relevant research findings and outlines the practical limits of applying VIs at the farm scale. Satellite and drone imagery are now standard tools in many agricultural operations; understanding what these indices actually measure, and where they fall short, matters for anyone interpreting their outputs.

Introduction

Monitoring crop health across large areas is a persistent problem in field agriculture. Ground scouting is slow, labour-intensive, and tends to catch problems only after they are visible to the eye. Remote sensing — data collected from satellites, drones, and aircraft — can cover thousands of hectares within hours, which substantially changes what is actually feasible in routine crop monitoring. Vegetation indices are the computational layer that makes remote sensing data interpretable. Derived from reflectance measurements at specific wavelengths, they convert raw spectral data into a single number that can be compared across dates and locations. In precision agriculture, where the goal is to match inputs to actual conditions within a field, this kind of repeatable spatial data has proven practical at the farm scale.

Concept of Vegetation Indices

Healthy green leaves absorb most of the red light they receive — using it for photosynthesis — while reflecting a large proportion of near-infrared (NIR) light. This is a well-established feature of plant physiology and forms the basis of spectral crop monitoring. Under stress, this pattern changes. Chlorophyll breaks down, red light absorption falls, and the ratio between red and NIR reflectance shifts. A stressed plant reflects more red and less NIR than a healthy one of the same species. Vegetation indices exploit this contrast. By comparing reflectance values across wavelength bands — typically through a ratio or normalised difference — they produce a number that tracks vegetation greenness or vigour. Low values indicate sparse, unhealthy, or absent vegetation; higher values indicate dense, actively growing crops. This makes consistent comparison of crop condition across dates and sites possible.

Types of Vegetation Indices

Several vegetation indices are used in agricultural monitoring, each with a specific focus and strength. The most commonly used are described below.

a) Normalized Difference Vegetation Index (NDVI)

NDVI is the most widely used vegetation index in agriculture. It measures the difference between NIR and red reflectance, producing values between -1 and $+1$. Values below 0.2 generally indicate bare soil or stressed crops; values between 0.4 and 0.8 suggest actively growing canopy. NDVI is reliable during vegetative growth stages, when canopy density

differences between healthy and poor-performing areas are clear. It is used routinely to map yield potential zones, track crop establishment, and flag underperforming patches.

b) Normalized Difference Red Edge Index (NDRE)

NDRE uses the red-edge band — a wavelength range between red and NIR — which is more sensitive to chlorophyll concentration than standard red light. This makes it more useful than NDVI at advanced growth stages, when the canopy is dense and NDVI tends to plateau. NDRE continues to detect chlorophyll variation even after full canopy closure, and is particularly useful for identifying early nitrogen deficiency, which reduces chlorophyll before any visible yellowing occurs.

c) Normalized Difference Moisture Index (NDMI) / Normalized Difference Water Index (NDWI)

Both NDMI and NDWI use shortwave infrared (SWIR) alongside NIR to estimate water content in the plant canopy. Higher leaf moisture corresponds to better crop hydration. A drop in NDMI values without a corresponding drop in NDVI often signals moisture stress before wilting or visible symptoms appear — making these indices useful for monitoring irrigation efficiency and locating areas where water needs are not being met.

d) Moisture Stress Index (MSI)

MSI is a direct indicator of water stress. It increases as plant water content decreases, so higher values mark stressed crops. It is typically used alongside NDMI or NDWI to confirm moisture stress signals, and performs well in semi-arid conditions where crop water deficits are common.

e) Enhanced Vegetation Index (EVI)

EVI was developed to address known problems with NDVI — mainly its tendency to saturate in dense canopies and its sensitivity to atmospheric conditions and soil background. EVI incorporates blue band reflectance to correct for aerosol interference, making it more reliable in tropical and high-biomass settings, or wherever NDVI has already reached its upper limit and can no longer detect real differences in crop condition.

Applications in Crop Health Monitoring

VIs are most informative when applied consistently over time rather than as one-off readings. The following applications reflect how they are used in practice.

Monitoring Crop Vigour

NDVI maps show spatial variation in crop vigour that is often invisible during field walks. Fields that look uniform on the ground frequently show clear differences in satellite imagery. These maps guide variable-rate fertiliser application, putting inputs where they are actually needed rather than spreading them uniformly across the field.

Early Detection of Health Decline

NDRE can detect chlorophyll decline two to three weeks before yellowing becomes visible to the eye. That lead time allows for corrective action before yield loss has already occurred.

Identifying Nutrient Deficiency Zones

Nitrogen, potassium, and iron deficiencies all affect chlorophyll content in measurable ways. NDRE and NDVI can map these deficiency zones spatially, so treatment can be targeted to affected areas rather than applied uniformly across the whole field.

Tracking Growth Stages

Weekly or fortnightly VI readings allow agronomists to track whether a crop is progressing through its growth cycle at the expected rate. Departures from typical seasonal curves indicate problems worth investigating in the field.

Temporal Monitoring

Comparing VI values across multiple dates is usually more informative than any single reading. A sharp NDVI drop between two consecutive observations can indicate disease onset, pest damage, or lodging. Time-series analysis separates real change from normal variation.

Spatial Variability Mapping

Within-field VI variation reflects differences in soil type, drainage, compaction, and crop establishment. Mapping this variation is the starting point for site-specific management decisions.

Advantages and Limitations

Advantages

Satellite imagery can assess crop health across entire districts in a single pass — something field surveys cannot match. VI monitoring does not require plant sampling, so observations can be repeated as often as imagery is available. Free satellite sources such as Sentinel-2 and Landsat make VI analysis accessible to researchers and government agencies without expensive fieldwork. Most satellites revisit the same location every few days, making near-continuous seasonal monitoring feasible.

Limitations

Cloud cover blocks satellite sensors and creates data gaps. This is a practical problem during monsoon-season monitoring in South Asia. In dense canopies, NDVI values plateau around 0.8 and stop reflecting real differences in crop condition; EVI or NDRE should be used in these cases. Medium-resolution imagery (10–30 m per pixel) may not capture fine-scale variation within small or fragmented fields. Finally, VI values need contextual interpretation: the same NDVI reading can mean different things depending on the crop, soil, and growth stage. Field data remains necessary.

Review of Literature

Tucker (1979) demonstrated a strong relationship between NDVI and above-ground green biomass, establishing the basis for using spectral reflectance ratios in vegetation monitoring. His work showed that the NIR-to-red ratio reliably tracked vegetation density, which led to widespread adoption of NDVI in crop and rangeland assessment.

Thenkabail et al. (2000) evaluated over 60 vegetation indices for estimating biophysical parameters — leaf area index, biomass, and canopy cover — across six major food crops. NDVI performed adequately for general monitoring, but red-edge indices were more accurate at dense canopy stages. This study made a practical case for using NDRE alongside NDVI in field-scale monitoring programmes.

Haboudane et al. (2004) investigated VIs for detecting nitrogen stress in corn. Red-edge reflectance indices separated nitrogen-deficient plants from healthy ones more reliably than NDVI, particularly under high-biomass conditions. Their findings reinforced the need to select indices based on the specific stress being monitored rather than defaulting to NDVI across all situations.

Gitelson et al. (2005) examined how crop canopy reflectance relates to chlorophyll content. Using field measurements from maize and soybean, they showed that red-edge and NIR bands together gave more accurate chlorophyll estimates than NDVI alone, supporting the use of NDRE for in-season nitrogen management.

Kross et al. (2015) analysed multi-temporal NDVI data from Landsat imagery to estimate corn and soybean yields in Ontario, Canada. NDVI values measured during peak vegetative growth correlated with end-of-season yields, and incorporating time-series data substantially improved prediction accuracy compared to single-date readings.

Conclusion

Vegetation indices give crop monitoring a repeatable, spatial form. NDVI tracks broad canopy greenness; NDRE captures chlorophyll variation at finer resolution; moisture indices detect water stress before symptoms appear. Used together, and interpreted against local crop conditions and growth stage expectations, they provide agronomists with earlier and more specific information than ground scouting can offer at the district or farm scale. Satellite coverage has improved, drone imagery has become affordable at the farm level, and data processing is less specialised than it was a decade ago. The gap between research and

practical farm use has narrowed. What this means on the ground is earlier detection of crop health problems — and enough lead time to act before yield losses accumulate.

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