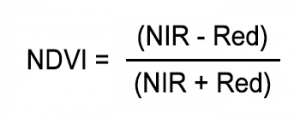
**REMOTE SENSING INDICES**

1. NORMALIZED DIFFERENCE VEGETATION INDEX

It estimates vegetation health by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs) in the electromagnetic spectrum. The NDVI always varies from -1 to +1, although there is no obvious border for each type of land cover The NDVI function's very low values (0.1 or less) correlate to vacant expanses of rocks, sand, or snow. Moderate levels (from 0.2 to 0.3) depict shrubs and meadows, whereas big values (from 0.6 to 0.8) represent temperate and tropical forests. (Yang and Everitt 2011).

NDVI calculated as shown below;



Observing how NIR differs from red light provides a precise indication of the existence of chlorophyll, which correlates with plant health. However, it saturates at a high biomass content of 0.7, making it difficult to distinguish moderately high plant cover from very high plant cover; it tends to magnify atmospheric noise in the NIR and Red bands, making it very sensitive to background disturbance. The NDVI was not designed to estimate density beyond the canopy layer.

1. NORMALIZED DIFFRENCE RED EDGE INDEX

NDRE is a method for determining the quantity of chlorophyll in plants just as NDVI which in turn estimates the health of vegetation. It is represented by a specific value computed from a Near-Infrared (NIR) band and the Red Edge range between visible Red and NIR. The scale goes from bright red at -1 to saturated green at +1. Value -1 to 0.2 denotes bare soil or a developing crop, 0.2 to 0.6 denotes a sickly plant or a crop that is not yet mature, and 0.6 to 1 denotes healthy, mature, ripening crops (IEEE, 2004).

When the crop is mature and ripening, the normalized difference red edge index is most effective. This normally happens near the conclusion of the growing season, as levels less than 0.6 nearly always indicate crop loss. At this moment, NDRE is a far better predictor of crop health than NDVI. The latter will concentrate on the plant canopy's density and the greenness of its upper layer. That is why, at later growth stages, employing an NDRE map for variable-rate fertilization, spraying, irrigation, fertilization, and other field activities will be more successful.

NDRE is calculated as shown below;

NDRE = (NIR — Red Edge)/ (NIR + Red Edge)

1. NORMALIZED DIFFERENCE MOISTURE INDEX

It’s an index that uses NIR and SWIR bands to display moisture in vegetation. The amount of water present in the interior leaf structure has a substantial influence on the spectral reflectance in the SWIR interval of the electromagnetic spectrum. The normalized difference moisture index (NDMI) value ranges from 0.685 to - 0.154. As a result, SWIR reflectance is inversely related to leaf water content (ESRI, 2018). It can be computed as shown below;  
NDMI = (NIR - SWIR1)/(NIR + SWIR1)

1. MODIFIED NORMALIZED DIFFERENCE WATER INDEX

MNDWI is used to distinguish water from dry land and is best suited for water body mapping. In the visible and infrared wavelength ranges, water bodies have minimal radiation and high absorbability. Based on the occurrence, NDWI employs remote sensing images with SWIR and green bands. In most circumstances, it can effectively improve water information. It can improve open water features while effectively suppressing and even eradicating built up land noise, vegetation noise, and soil noise. Because of its benefit in lowering and even deleting built up land noise, it is better ideal for enhancing and extracting water information for a water region with a background dominated by built up land areas (Rundquist *et al.*). The modified normalized difference water index (MNDWI) value ranges from 0.146 to - 0.444. It is calculated as shown;

Sentinel-2 NDMI = (NIR - SWIR) / (NIR+ SWIR)

Landsat 8 NDMI = (NIR – SWIR1) / (NIR + SWIR1)

1. LEAF AREA INDEX

The leaf area index (LAI) measures the quantity of leaf area in an ecosystem and is an important variable in activities like photosynthesis, respiration, and precipitation interception. For a given unit area, the leaf area index (LAI) is the ratio of upper leaf surface area to ground area (for broadleaf canopies) or projected conifer needle surface area to ground area (for coniferous trees). LAI quantifies canopy structure directly and can be used to forecast primary production and crop growth. LAI can be assessed on the ground by extracting leaf tissue and quantifying the leaf surface area, or it can be quantified indirectly using hemispherical photography or optical tools (Plant Canopy Analyzer, DEMON, ceptometer, etc). However, for vast areas, estimating LAI from remotely sensed photos is useful. It takes topographic factors into consideration, and the spectral bands employed in its calculations are corrected for atmospheric effects (Huete, 1988).

1. FRACTION OF PHOTOSYNTHETICALLY ACTIVE RADIATION

The fraction of PAR (fPAR) is a metric used in remote sensing and ecological modeling to represent the percentage of PAR utilised by plants. fPAR is often utilized in ecosystem models because it has a significant impact on energy, water vapor, and carbon dioxide exchanges between the earth's surface and the atmosphere. Precipitation and temperature are two of the most important elements influencing the amount of PAR absorbed by plants. Because plant development is connected to the rate at which radiant energy is absorbed by vegetation, it is an important parameter in assessing biomass output. fPAR can be measured with handheld equipment on the ground or inferred from satellite data at broad regional scales(Huete et al., 2017).

1. RED EDGE CHROLOPHYLL

It’s used to calculate the total quantity of chlorophyll in plants in the red edge band it is sensitive to tiny fluctuations in chlorophyll content and is consistent for most plant varieties. Plants' cellular structures reflect wavelengths in this spectral range, resulting in more light being reflected; hence, the higher the reflection, the greener the area(Ford, E.B. 2005).

1. MODIFIED SOIL ADJUSTED VEGETATION INDEX

This index comes in where NDVI is limited because it has low saturation value of 0.3. It’s usually used when growing crops on the field for the first time or at a different elevation. In addition, it’s used during the seed germination and leaf development stages because of low chrolophyll in the plants therefore detect uneven seed growth and drop in vegetation health which is caused by uneven growth, cold stress and heat stress, abnormal precipitation or elevation difference. It ranges from -1 to 1 where -1 to 0.2 shows bare soil, 0.2 to 0.4 shows germination stage, 0.4 to 0.6 shows leaf development and above 0.6 apply NDVI(Qi et al., 2000).

MSAVI is given as shown below;

MSAVI = ((NIR – RED) / (NIR + RED + L)) \* (1 + L)

L is the soil brightness correction factor.