Crop Monitoring

Vegetation Indices

October 2023

Contents

LIMS Crop Monitoring

LIMS crop monitoring is an online satellite-based precision agriculture platform for field monitoring. This platform incorporates numerous data types i.e., Crop health, crop moisture, crop growth, weather conditions, and other factors.

The platform enables farmers to make better decisions and optimize their practices, such as when to irrigate or apply fertilizer, in order to get the highest yields. It also allows them to track and monitor the health of their crops from anywhere in the world. The platform helps farmers to save time, money, and resources. They can also track the progress of their crops in real-time and detect crop health issues, diseases, pests, weeds and more quickly. This allows the farmers to adjust their farming practices accordingly and make sure that their crops are growing in the most optimal conditions. Early-stage detection enhanced satellite-driven scouting improves field management. Accurate weather forecasts help farmers to optimize the timing of these activities (tillage, planting, spraying, fertilizing, harvesting, and others) and improve the efficiency of their operations. This can lead to higher yields, better crop quality, and reduced water and fertilizer use. Satellite-derived indices, including NDVI, NDMI, SAVI, MSAVI, NDRE and ReCl provide important information about the condition of plants at different stages of growth, allowing farmers to make the most informed and timely decisions.

Zoning

Zoning is an effective tool for carrying out the variable-rate application of seeds, fertilizers, differential irrigation, and differential crop rotation, as well as for determining optimal zones (areas) for precision soil sampling. By providing scouts with **precise geographic locations** corresponding to areas with problems in field, one can potentially save significant time and resources. This system allows farmers, traders, and other users to be up to date with the latest information about the condition of their crops based on data, enabling them to make the best possible decisions.

Figure 1: Zone Distribution across the Field.

Weather Forecast

It provides access to the 14-day weather forecast through which farmers can get real-time data on Wind speed, Rainfall, Humidity, Cloud overage, and Sunshine hours.

Sentinel-2

Sentinel-2 sensor and satellite images are used with no more than 10% cloudiness. Sentinel-2 is a European Space Agency satellite project (ESA). Copernicus mission comprises of two identical spacecraft launched in 2015 and 2017 with a predicted lifespan of 7.25 years. Every single satellite has a multi-spectral sensor and a 5-day return period. At various spatial resolutions, the sensor takes 13 spectral bands 10m, 20m, and 60m (Table 1). The four bands offer a Ground Sampling Distance (GSD) of 10m in blue, green, red, and near Infrared (NIR) sections of the spectrum. Sentinel-2 is meant to record vegetation properties, among other things, with its NIR and SWIR bands. The Level 2A product is a georeferenced 100×100 km^2 tiled set of top-of-atmosphere reflectance measurements in the UTM WGS84 projection.

Table 1: The main specifications on spectral bands of Sentinel-2

Bands	Band Number	Resolution
Coastal Aerosol	1	60 m
Blue	2	10 m
Green	3	10 m
Red	4	10 m
Vegetation Red-edge	5	20 m
Vegetation Red-edge	6	20 m
Vegetation Red-edge	7	20 m
NIR	8	10 m
Vegetation Red Edge	8A	20 m
Water Vapor	9	60 m
SWIR-Cirrus	10	60 m
SWIR	11	20 m
SWIR	12	20 m
Thermal Infrared1	–	–

Indices

Following are the most commonly used vegetation indices in LIMS Crop Monitoring:

1. Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is referred to as **Crop Stress Insects and Diseases** on LIMS Crop Monitoring. NDVI measures the greenness and the density of the vegetation captured in a satellite image. Healthy vegetation has a very characteristic spectral reflectance curve which we can benefit from by calculating the difference between two bands – visible red and near-infrared.

NDVI is frequently used and implemented index, that is computed as normalized ratio between red and near-infrared bands using multispectral data. The NDVI index is a means of determining how green the vegetation is. It detects and quantifies the presence of living green plants using reflected light in visible and near-infrared wavelengths.

It is a measure of the state of plant health based on how the plant reflects light at specific frequencies (some waves are absorbed, and others are reflected). Chlorophyll (a health indicator pigment) strongly absorbs visible light, and the cellular structure of the leaves strongly reflects near-infrared light. When the plant becomes dehydrated, sick, afflicted with disease, etc., the spongy layer deteriorates, and the plant absorbs more of the near-infrared light, rather than reflecting it. Thus, observing how NIR changes compared to red light provides an accurate indication of the presence of chlorophyll, which correlates with plant health.

Normalized Difference Vegetation Index: Change Detection

NDVI of a crop or a plant calculated regularly over periods of time can reveal a lot about the changes in their conditions. In other words, we can use NDVI to estimate plant health remotely.

A sudden drop in the NDVI values may be a symptom of crop health deterioration.

The value drop can also correspond to regular changes, such as the time of harvesting, which is why NDVI should be counter-checked against other available data. Correct NDVI values interpretation can help agronomists raise healthier yields, save money on fertilizers, and take better care of the environment. Among the typical spectral vegetation indices, NDVI is one of the most suitable to track crop development dynamics since it measures photosynthetically active biomass in plants. However, this vegetation index is quite sensitive to soil brightness and atmospheric effects, mitigated in other indices like SAVI.

NDVI formula: NDVI = (NIR – RED) / (NIR + RED)
Where:

NIR – light reflected in the near-infrared spectrum.

RED – light reflected in the red range of the spectrum.

According to this formula, the density of vegetation (NDVI) at a certain point of the image is equal to the difference in the intensities of reflected light in the red and infrared range divided by the sum of these intensities.

Index Range

- NDVI defines values from **-1.0 to 1.0,** where negative values are mainly formed from clouds, water and snow, and values close to zero are primarily formed from rocks and bare soil.
- Very small values (**0.1 or less**) of the NDVI function correspond to empty areas of rocks, sand, or snow.
- Moderate values (from **0.2 to 0.3**) represent shrubs and meadows, while large values (from **0.6 to 0.8**) indicate temperate and tropical forests.

LIMS Monitoring System uses this scale to show farmers which parts of their fields have dense, moderate, or sparse vegetation.

***Key fact*:** NDVI is the most common vegetation index in remote sensing. It can be used throughout the whole crop production season except when vegetation cover is too scarce, so its spectral reflectance is too low.

***When to use*:** NDVI values are the most accurate in the middle of the season at the stage of active crop growth.

Application of NDVI in Agriculture

- Precision agriculture platforms take advantage of NDVI to guide crop scouts to problem areas in the field and improve the precision of fertilizer application and irrigation, among other field treatment activities.
- NDVI is preferable for global vegetation monitoring since it helps to compensate for changes in lighting conditions, surface slope, exposure, and other external factors.

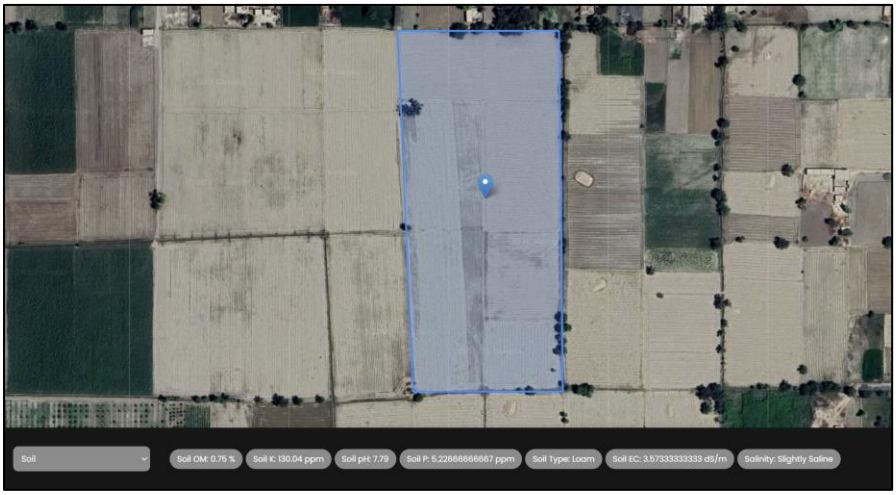

Figure 2: Cotton field in Bahawalpur, Punjab, Pakistan.

NDVI on LIMS Crop Monitoring

For tracking the health of the crops LIMS crop Monitoring is an excellent tool. NDVI is referred to as Crop Stress Insects and Diseases on LIMS Crop Monitoring. It can provide real time data on crop health and help farmers to maximize their yield and minimize losses due to pests and diseases. Based on NDVI measurements another important feature in it is zoning. This index helps to identify how many acres are in good health (dense vegetation), better health (moderate vegetation), and normal health (sparse vegetation) or in bad health across the entire field as measured over a long period of time.

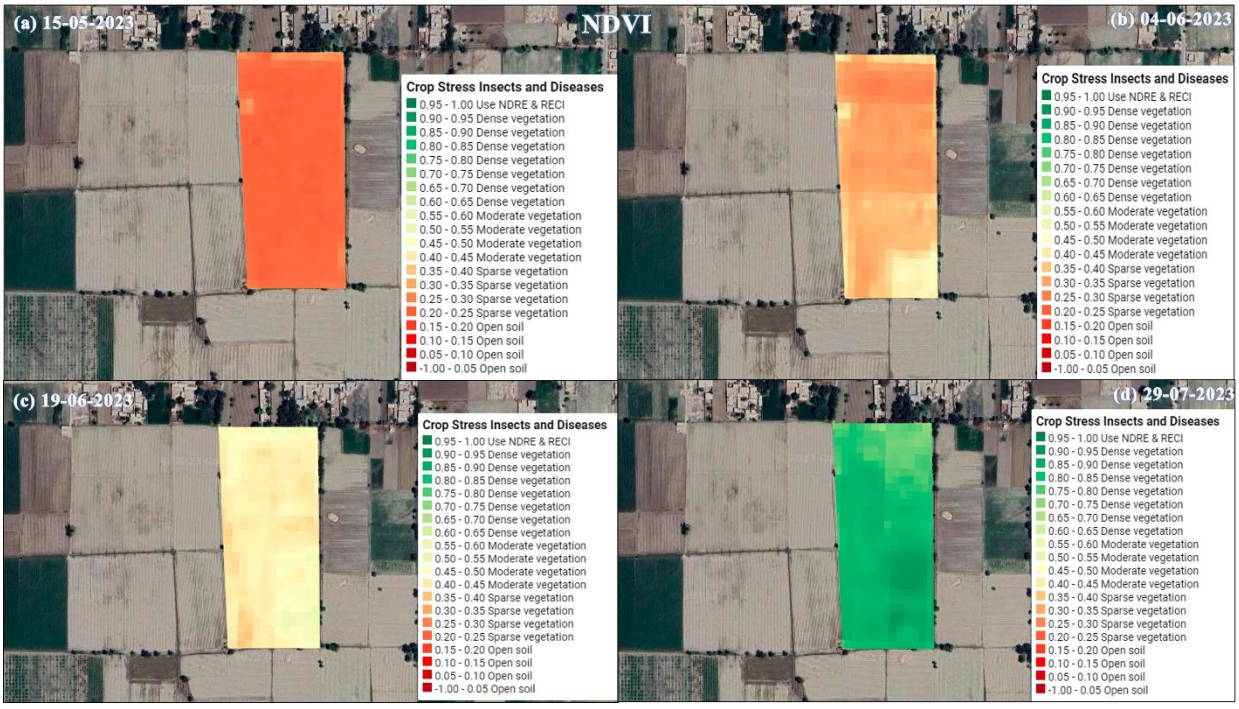

Figure 3: Normalized Difference Vegetation Index (NDVI) of Cotton field from Sentinel-2 for (**a) 15-05-2023, (b) 04-06-2023, (c) 19-06-2023, and (d) 29-07-2023.**

Values and colors

On LIMS Crop Monitoring, values are displayed on the map as different color hues. The NDVI value range spans from the bright red representing -1 to the saturated green standing for 1.

Figure 2 illustrates how NDVI reflects the crop changes over the cotton cycle for the month of (May, June, and July 2023). Areas of field where the NDVI is lowest are those in which the plant is more stressed. In middle of the growing season, during the active period of crop growth, its values are the most accurate.

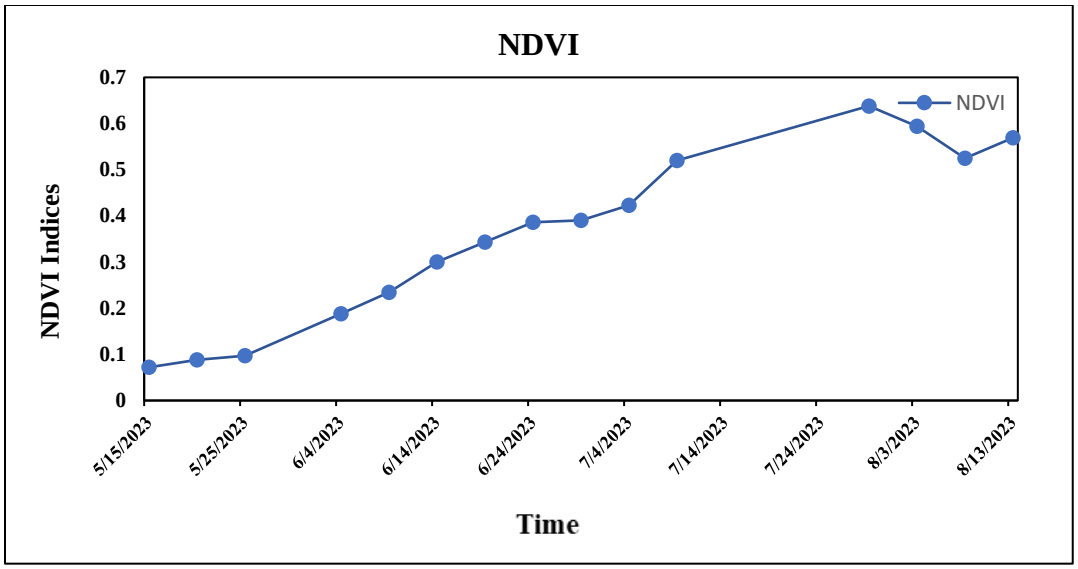

Figure 4: Normalized Difference Vegetation Index (NDVI) Trend from May 2023 to August 2023.

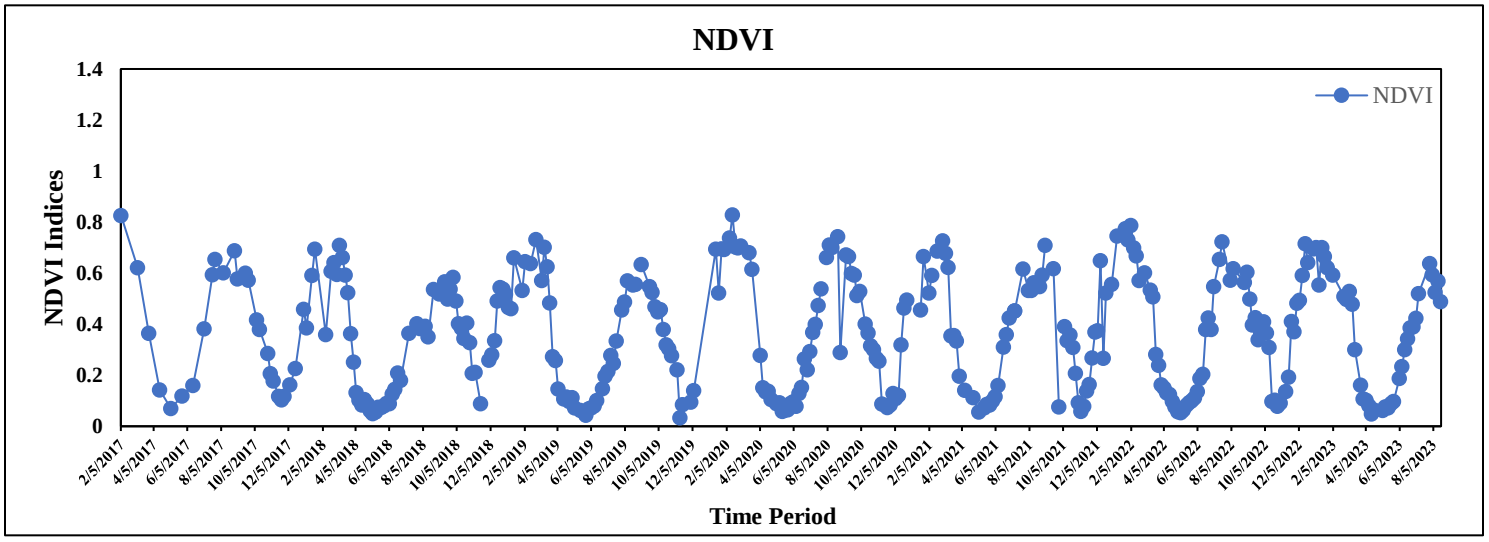

Figure 5*:* Normalized Difference Vegetation Index (NDVI) Long Term Monitoring Trend from May 2017 to August 2023.

2. NDMI (Normalized Difference Moisture Index)

Normalized difference Moisture Index (NDMI) is referred to as **Crop Moisture** on LIMS Crop Monitoring. NDMI detects moisture levels in vegetation using a combination of near-infrared **(NIR)** and short-wave infrared **(SWIR)** spectral bands. It is a reliable indicator of water stress in crops. NDMI can detect water stress at an early stage before the problem has gone out of hand. Further, using NDMI to monitor irrigation, especially in areas where crops require more water than nature can supply, helps to significantly improve crop growth. All of this makes NDMI an excellent farm tool.

NDMI Formula

NDMI is calculated using the near-infrared (NIR) and the short-wave infrared (SWIR) reflectance:

NDMI = (NIR – SWIR) / (NIR + SWIR)

The short-wave infrared spectral channel (SWIR) is sensitive to the vegetation water content and the **mesophyll structure** of leaves. On the other hand, the near-infrared band (NIR) picks up the bright reflectance off the leaf's internal structure and the leaf's dry matter content. When combined, the accuracy of data on the vegetation water content becomes much higher.

It is important to keep in mind that NDMI values vary throughout the growing season because the plants' reflectance is slightly different for every phenological stage. There also exists an interesting correlation between NDMI and NDVI. Water stress indicated by the NDMI values can be confirmed by a significantly lower-than-average NDVI.

When to use:

The Normalized Difference Moisture Index can be used to:

- Regularly monitor water content in crops,
- Determine field/farm zones with water stress,
- Improve tree harvest logistics planning,
- Determine the combustibility levels in fire-prone areas.

Application of NDMI in Agriculture

Helpful in the detection of possible water stress or drought situations.

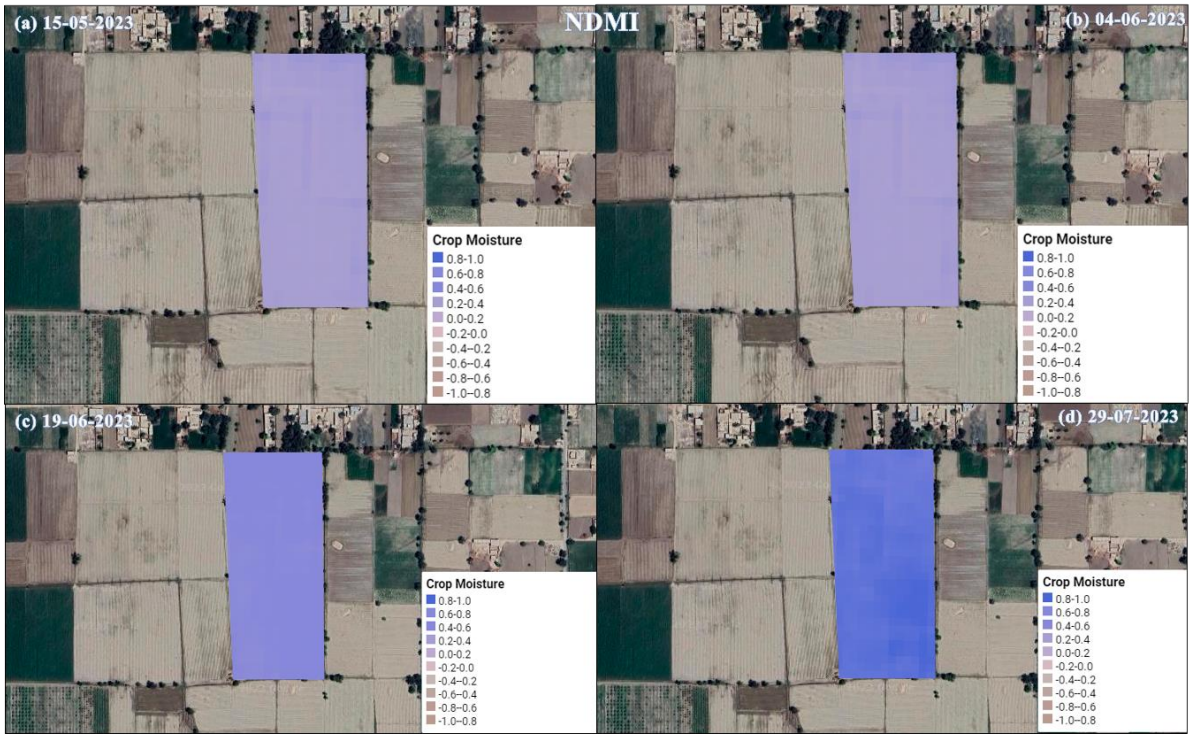

Figure 6: NDMI (Normalized Difference Moisture Index) of Cotton field from Sentinel-2 **(a) 15-05-2023, (b) 04-06-2023, (c) 19-06-2023, and (d) 29-07-2023.**

Values and colors

On LIMS Crop Monitoring, values are displayed on the map as different color hues. The NDMI value range spans from the bright red representing -1 to the saturated green standing for 1.

NDMI gives us a better understanding of plant water content. Changes in the water content and structure of mesophyll can be seen by SWIR reflectance. **Figure 5** shows moisture content in crops because each phenological stage of the plants has a slightly different reflectance, NDMI values change throughout the course of the growing season.

NDMI on LIMS Crop Monitoring

NDMI is referred to as Crop Moisture on LIMS Crop Monitoring. Zoning helps to identify water-stressed areas across the entire field.

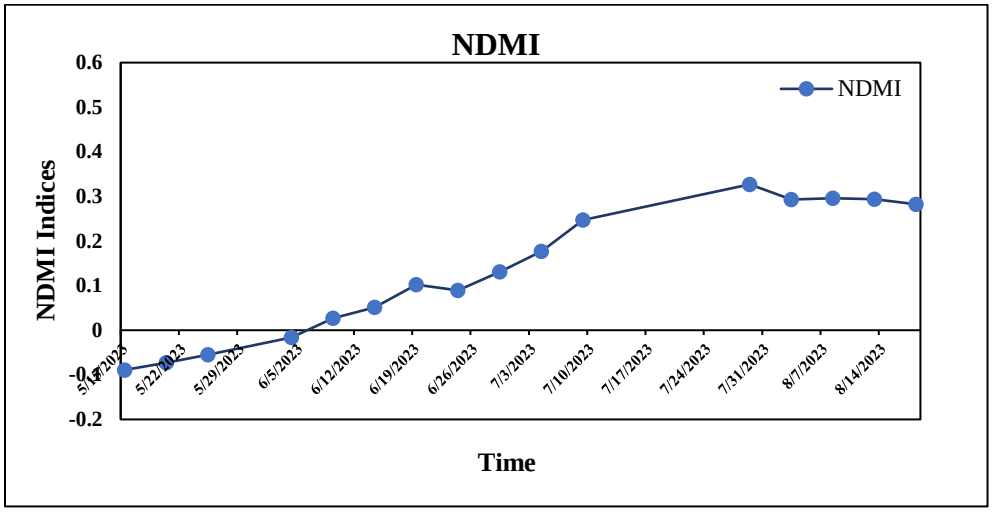

Figure 7: NDMI (Normalized Difference Moisture Index) Trend from May 2023 to August 2023.

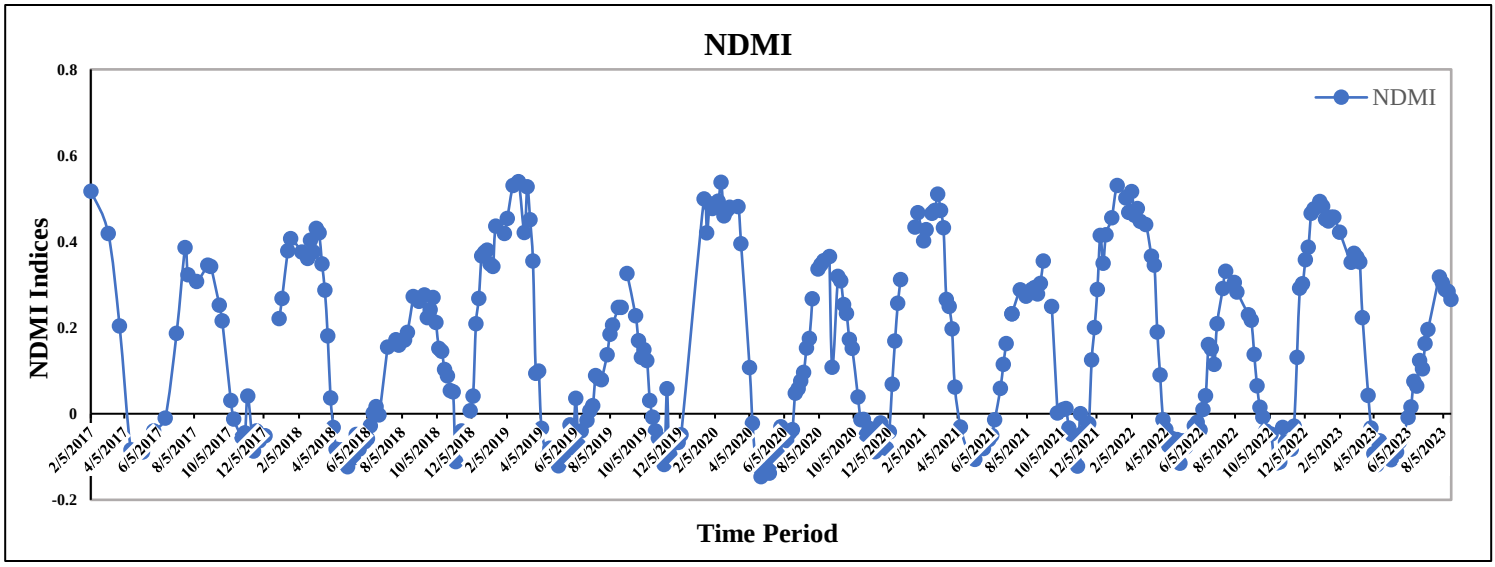

Figure 8: NDMI (Normalized Difference Moisture Index) Long Term Monitoring Trend from May 2017 to August 2023.

3. Soil Adjusted Vegetation Index (SAVI)

Soil Adjusted Vegetation Index (Savi) is referred to as Weeds on LIMS Crop Monitoring. SAVI was introduced to mitigate the impact of soil brightness. Its creator Huete added a soil adjustment factor L to the equation of NDVI to correct for soil noise effects (soil color, soil moisture, soil variability across regions, etc.), which tend to impact the results.

Formula: SAVI = ((NIR – RED) / (NIR + RED + L)) * (1 + L)

Key fact: L varies from **–1 to +1**, depending on the green vegetation density. In areas with high green vegetation L= 0, and in this case, SAVI is the same as NDVI. Conversely, **L = 1** for low green vegetation zones. Most typically, L is set to **0.5** to adjust to most land cover.

When to use: for analysis of young crops; for arid regions with sparse vegetation **(less than 15% of total area)** and exposed soil surfaces.

Application of SAVI in Agriculture

When there is less vegetation or growth of weeds SAVI is a good indicator during the earliest stages of the crop, when plant cover is only partial, and the satellite collects data for both the crop and the soil. The result is impacted by the soil reflectance indices when the plant cover is very low, and this "soil effect" decomposes the NDVI values. This index allows for the only reliance on plant activity while ignoring the soil reflectivity using the soil line as a correction factor (known as the L-factor).

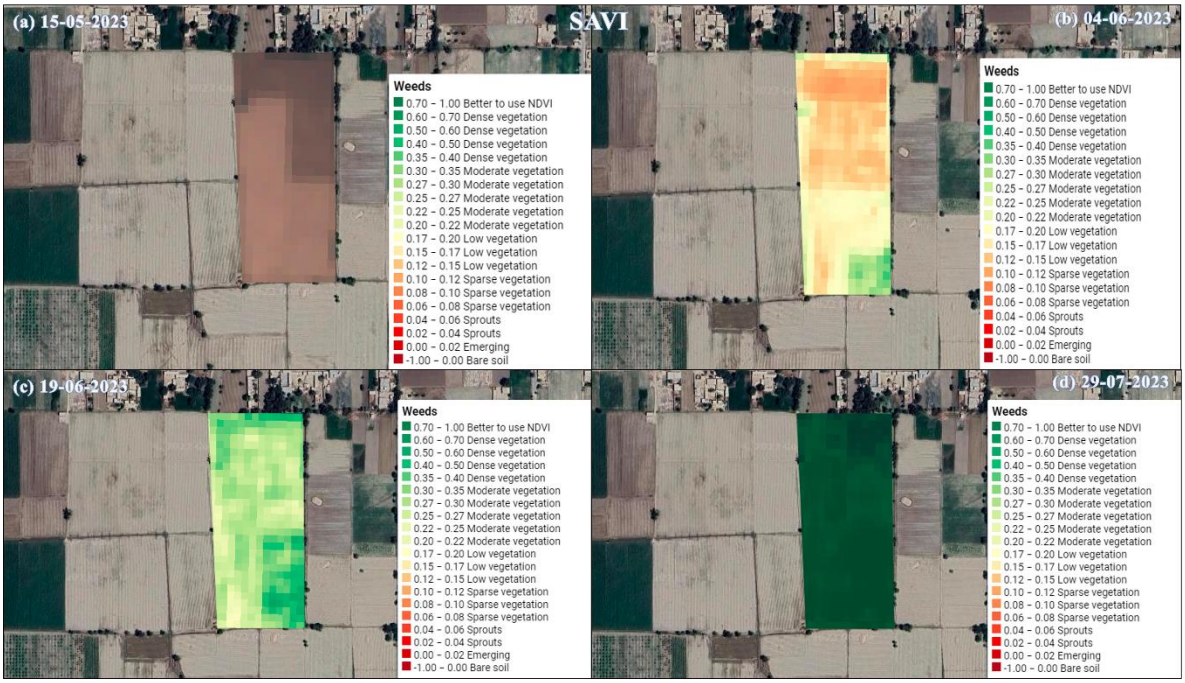

Figure 9: Soil Adjusted Vegetation Index (SAVI) of Cotton field from Sentinel-2 **(a) 15-05-2023, (b) 04-06-2023, (c) 19-06-2023, and (d) 29-07-2023.**

Values and colors

On LIMS Crop Monitoring, values are displayed on the map as different color hues. The SAVI value range spans from the bright red representing -1 to the saturated green standing for 1.

Figure 8 shows the same field on different stages of crop growth, SAVI index is a good indicator in the crop's early stages with little vegetation/young crops or weeds.

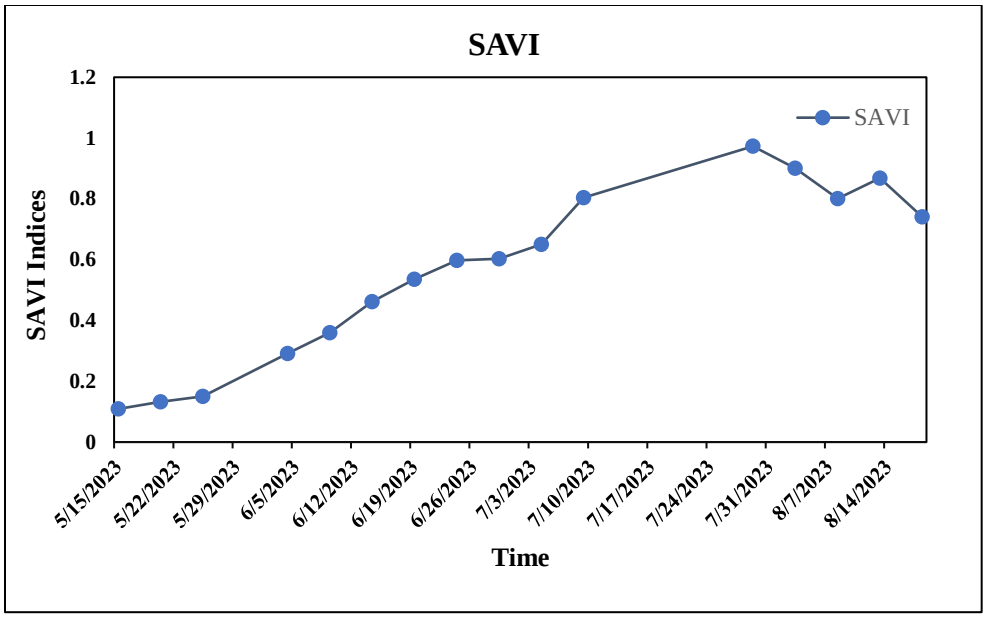

Figure 10: Soil Adjusted Vegetation Index (SAVI) Trend from May 2023 to August 2023.

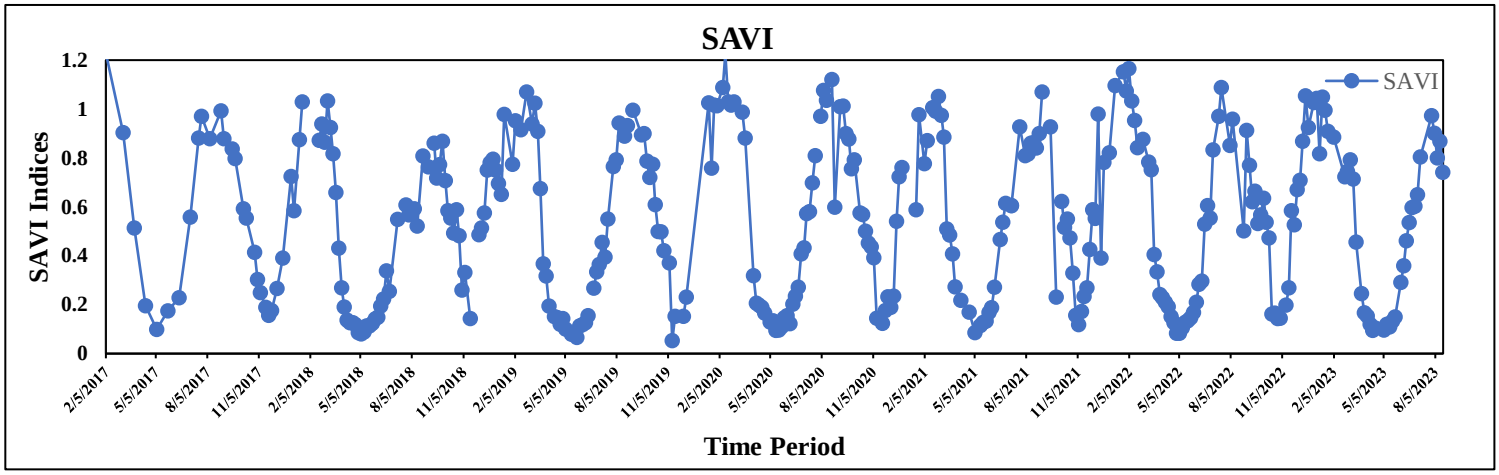

Figure 11: Soil Adjusted Vegetation Index (SAVI) Long Term Monitoring Trend from May 2017 to August 2023.

4. Modified Soil-Adjusted Vegetation Index (MSAVI)

The modified soil-adjusted vegetation index (MSAVI) is referred to as Weeds and Early Fertilizer on LIMS Crop Monitoring. MSAVI is an index designed to substitute NDVI and NDRE where they fail to provide accurate data due to low vegetation or a lack of chlorophyll in the plants. During the stages of germination and leaf development, there is a lot of bare soil between the seedlings. NDVI and NDRE both interpret this as poor vegetation. Here is where MSAVI comes to aid. “SA” stands for “soil-adjusted,” revealing the critical aspect of this vegetation index. It reduces the effect of the soil on the calculation of vegetation density in the field.

Formula: MSAVI = (2 * Band 4 + 1 – sqrt ((2 * Band 4 + 1)2 – 8 * (Band 4 – Band 3))) / 2

Key fact: Since MSAVI is adjusted to soil effects and is sensitive to early vegetation in the field, it works even when the earth is hardly covered with crops.

When to use: MSAVI is useful at the very beginning of crop production season – when seedlings start to establish.

Application of MSAVI in Agriculture

Seeds that have just been sown are vulnerable. They can be eaten by birds and animals. They can rot or get damaged due to unfavorable weather and moisture conditions, among other reasons. Applying MSAVI helps to identify areas within the field where seeds are not germinating. Solution: to resow these problem areas. The sooner it is done, the higher the chance of avoiding the loss of yield.

MSAVI on LIMS Crop Monitoring

MSAVI is referred to as Weeds and Early Fertilizer on LIMS Crop Monitoring.

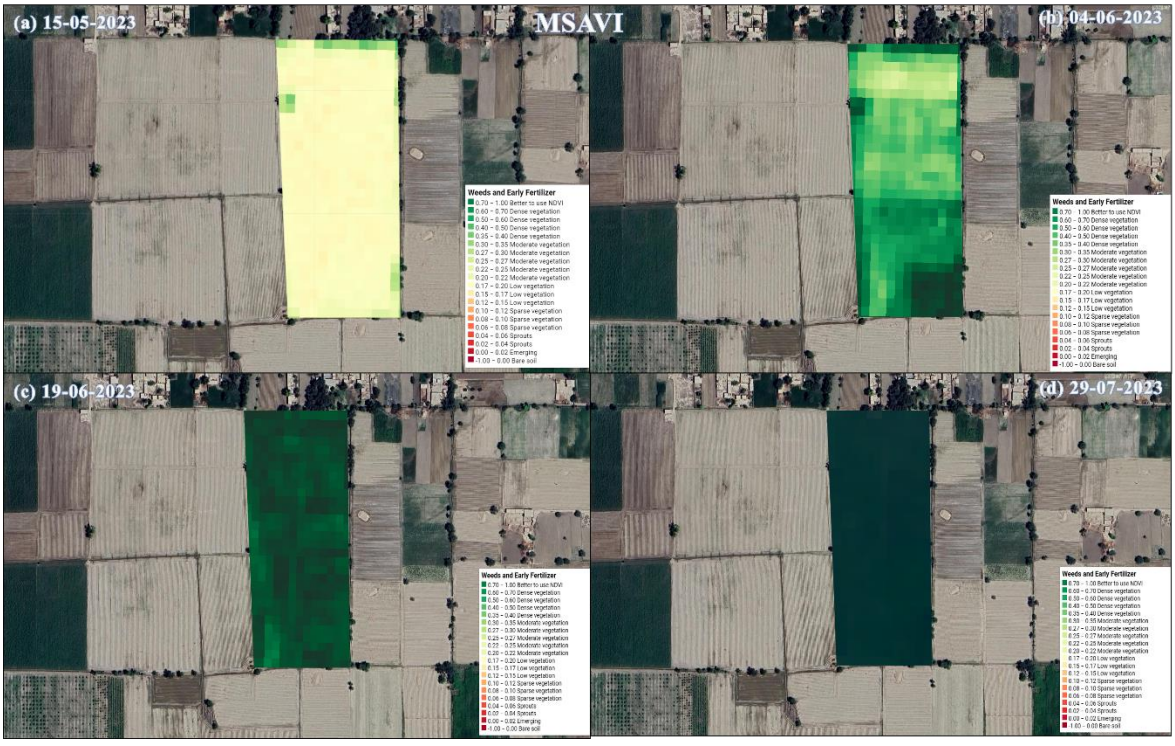

Figure 12: Modified Soil-Adjusted Vegetation Index (MSAVI) of Cotton field from Sentinel-2 for **(a) 15-05-2023, (b) 04-06-2023, (c) 19-06-2023, and (d) 29-07-2023.**

Values and colors

On LIMS Crop Monitoring, values are displayed on the map as different color hues. The MSAVI value range spans from the bright red representing -1 to the saturated green standing for 1.

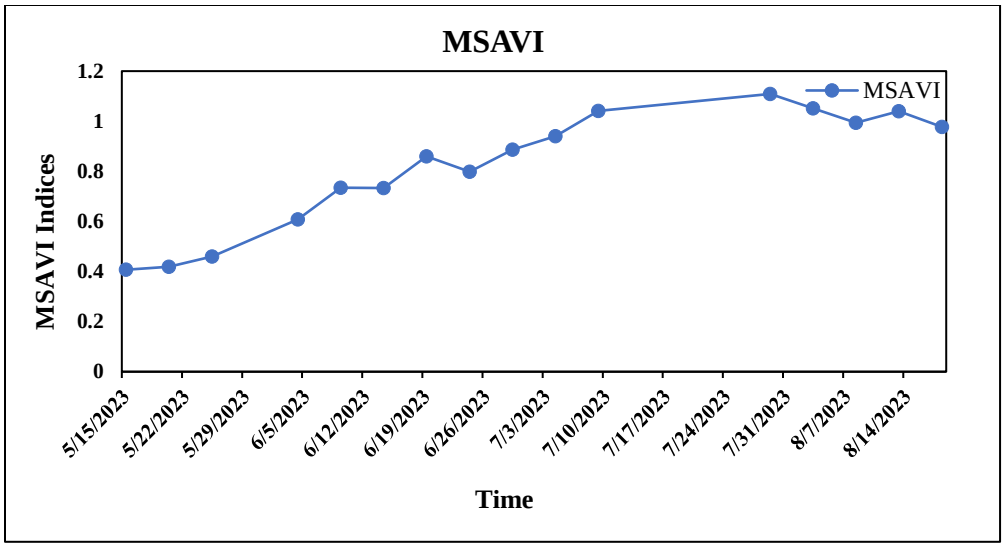

Figure 13: Modified Soil-Adjusted Vegetation Index (MSAVI) Trend from May 2023 to August 2023.

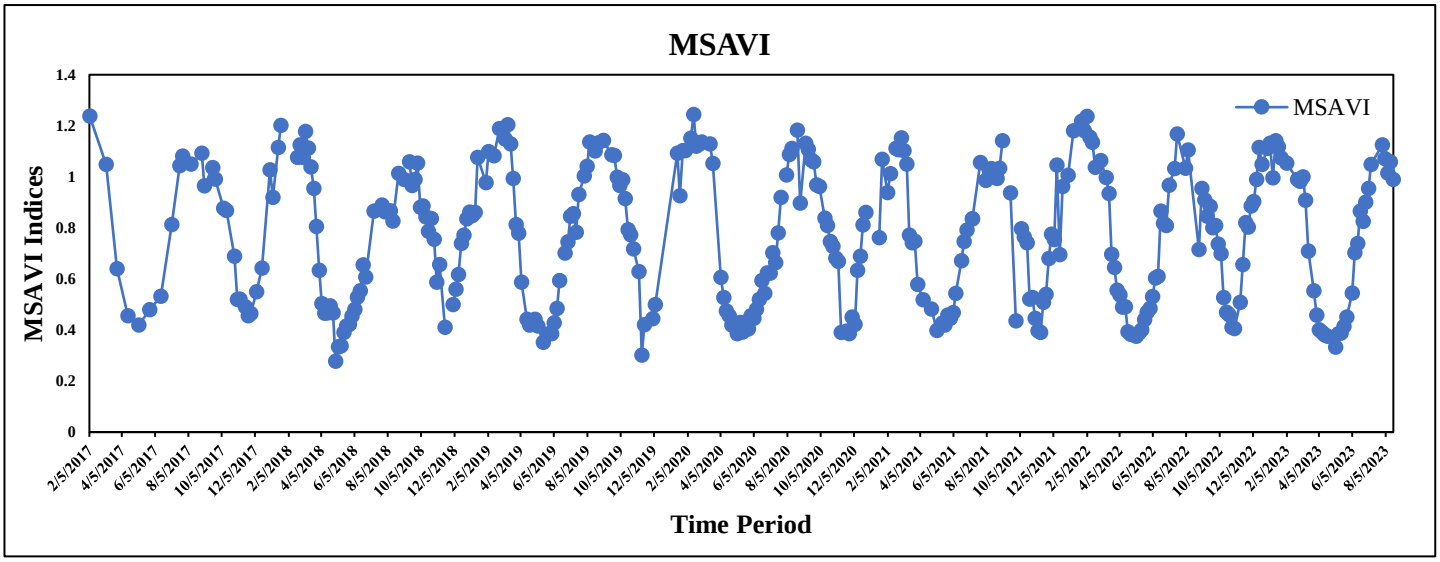

Figure 14: Modified Soil-Adjusted Vegetation Index (MSAVI) Long Term Monitoring Trend from May 2017 to August 2023.

5. Normalized Difference Red Edge Vegetation Index (NDRE)

Normalized Difference Red Edge Vegetation Index (NDRE) is referred to as Nitrogen on LIMS Crop Monitoring. NDRE is a method of measuring the amount of chlorophyll in plants. It is represented by a certain value calculated using a combination of a Near-InfraRed (NIR) band and the Red Edge range between visible Red and NIR.

The NDRE formula is*: *NDRE = (NIR – RedEdge) / (NIR + RedEdge)

Key fact: The given vegetation index applies to high-density canopy cover.

When to use: NDRE is typically used to monitor crops that have reached their maturity stage.

NDRE on LIMS Crop Monitoring

NDRE is referred to as Nitrogen on LIMS Crop Monitoring. Based on NDRE measurements zoning helps to identify acres with sufficient quantity of nitrogen across the entire field as measured over a long period of time.

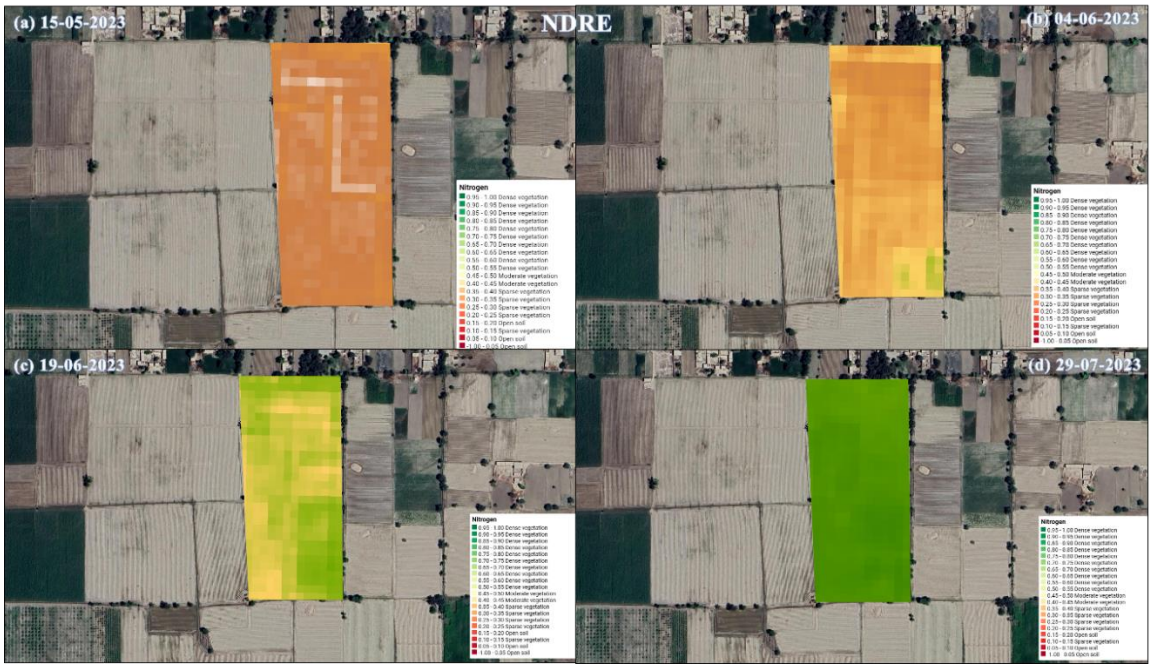

Figure 15*:* Normalized Difference Red Edge Vegetation Index (NDRE) of Cotton field from Sentinel-2 for **(a) 15-05-2023, (b) 04-06-2023, (c) 19-06-2023, and (d) 29-07-2023.**

Values and colors

On LIMS Crop Monitoring, values are displayed on the map as different color hues. The NDRE value range spans from the bright red representing -1 to the saturated green standing for 1.

Above Figure 14 shows the same field on different dates. The NDRE index is a good indicator when a crop is mature and ripening at the end of the growing season.

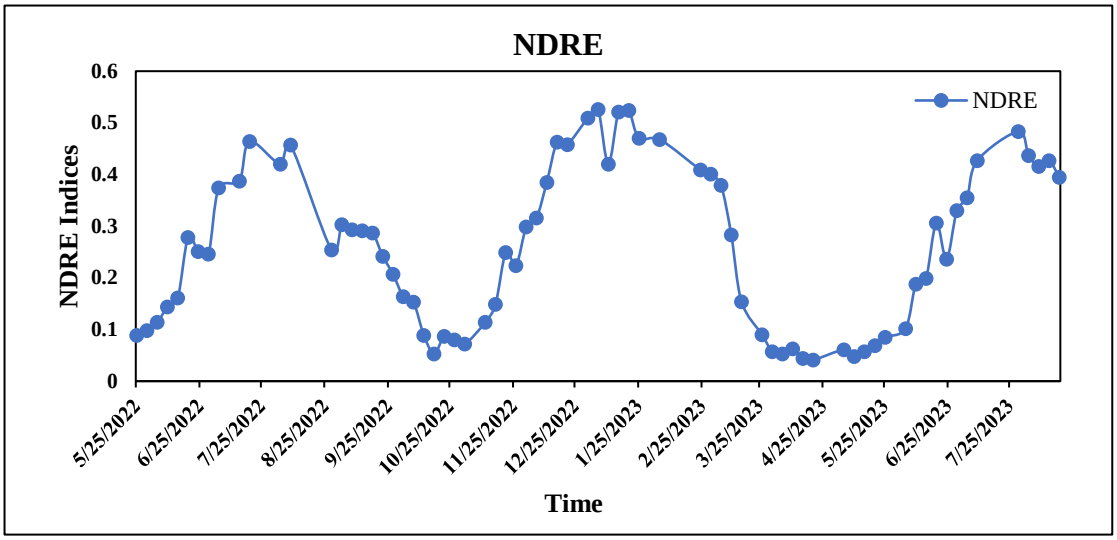

Figure 16*:* Normalized Difference Red Edge Vegetation Index (NDRE) Trend from May 2023 to August 2023.

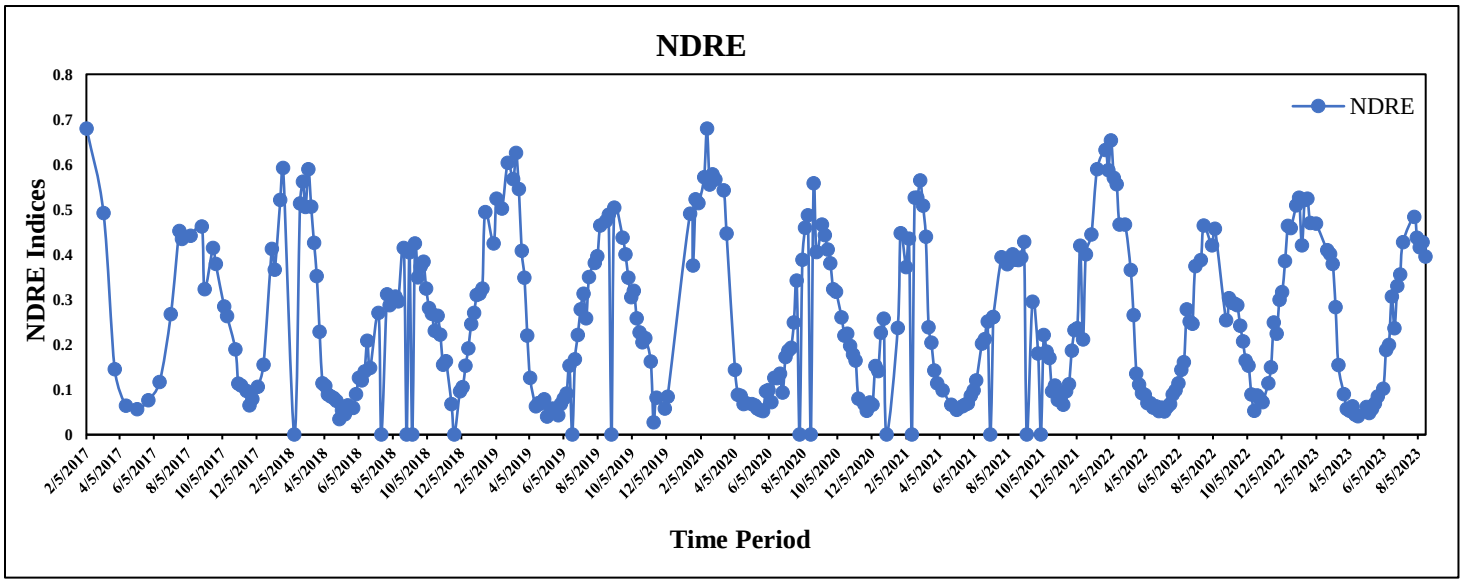

Figure 17: Normalized Difference Red Edge Vegetation Index (NDRE) Long Term Monitoring Trend from May 2017 to August 2023.

6. Red-Edge Chlorophyll Index (CI red-Edge or ReCI)

Red-Edge Chlorophyll Index (Cl red-Edge or ReCl) is referred to as Crop Growth on LIMS Crop Monitoring. The ReCI vegetation index is responsive to chlorophyll content in leaves that is nourished by nitrogen. ReCI shows the photosynthetic activity of the canopy cover.

Formula: ReCI = (NIR / RED) – 1

Key fact: Because chlorophyll content directly depends on nitrogen level in plants, responsible for their "greenness", this vegetation index in remote sensing helps detect areas with yellow or shed foliage.

When to use: ReCI values are most useful at the stage of active vegetation development but are not suitable for the season of harvesting.

CI red-edge takes advantage of a narrow spectral band between the red and the near-infrared (NIR) bands of the plant reflectance range. The red-edge band is highly sensitive to the light reflected off the cellular structure of a plant. Brighter reflectance corresponds to a larger number of plant cells and, by extrapolation, to the greener area. Vegetation maps for variable rate applications built based on the RCI index can be more precise than the NDVI-based maps.

This is due to the high saturation of NDVI data in the images. The saturation occurs because NDVI is used to estimate the density of the biomass, which does not always correlate with crop health. It has been discovered by some growers that the need for swapping the NDVI for the chlorophyll index arises when the canopy closure is around 80% – about the time of the early phases of senescence. During this time, measuring the chlorophyll content in plants is a more reliable way of determining the state of crops.

Application of CI red-Edge in Agriculture

Red-edge analysis can quickly identify changes in chlorophyll functioning. Monitoring these alterations can serve as an early warning system for the onset of biotic and abiotic stress since they occur before the actual decreases in leaf chlorophyll concentrations.

The ReCI vegetation index is responsive to chlorophyll content in leaves nourished by nitrogen. ReCI shows the photosynthetic activity of the canopy cover.

Red-Edge Chlorophyll Index (Cl red-Edge or ReCl) on LIMS Crop Monitoring

Red-Edge Chlorophyll Index (Cl red-Edge or ReCl) is referred to as Crop Growth on LIMS Crop Monitoring. Based on ReCl measurements zoning helps to identify crop growth across the entire field.

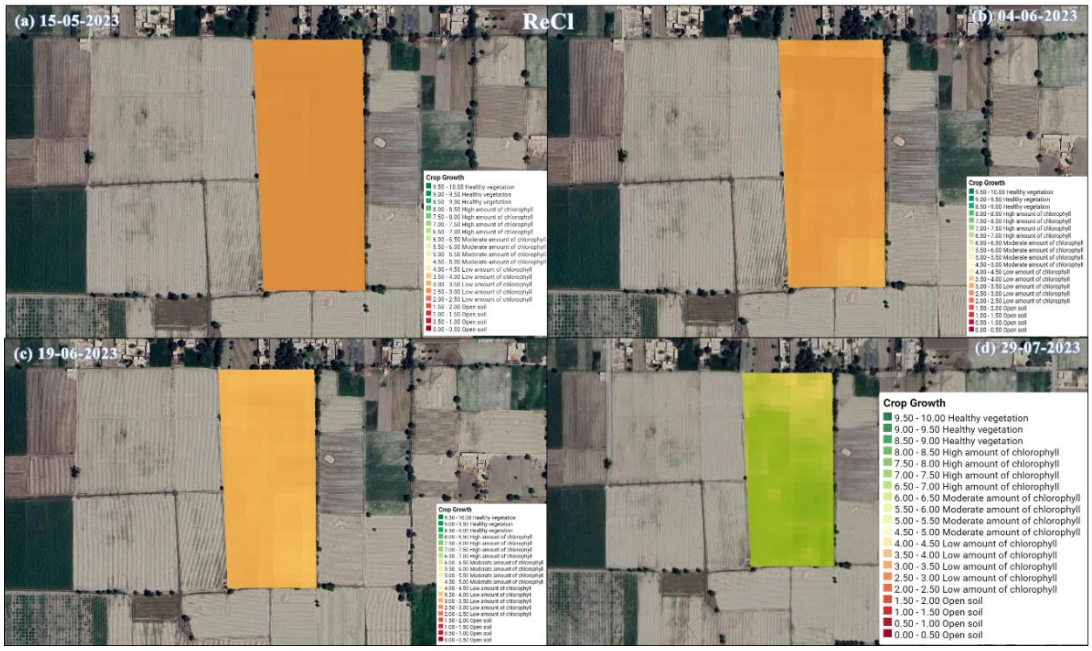

Figure 18: Red-Edge Chlorophyll Index (CI red-Edge or ReCI) of Cotton field from Sentinel-2 **for (a) 15-05-2023, (b) 04-06-2023, (c) 19-06-2023, and (d) 29-07-2023.**

Values and colors

On LIMS Crop Monitoring, values are displayed on the map in different color hues. The ReCl value range spans from the bright red representing -1 to the saturated green standing for 1.

- When canopy cover is around 80 percent need for swapping the NDVI for chlorophyll index arises.

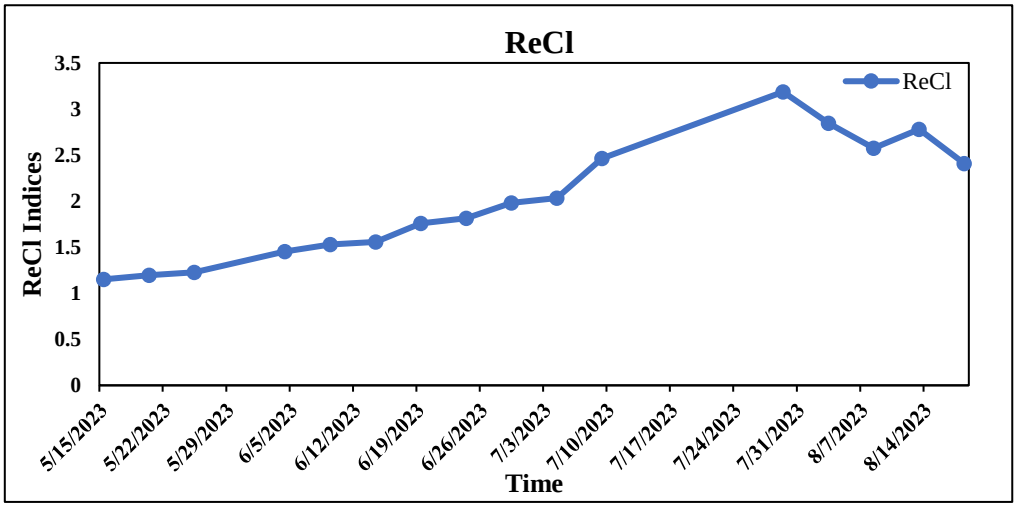

Figure 19: Red-Edge Chlorophyll Index (CI red-Edge or ReCI) Trend from May 2023 to August 2023.

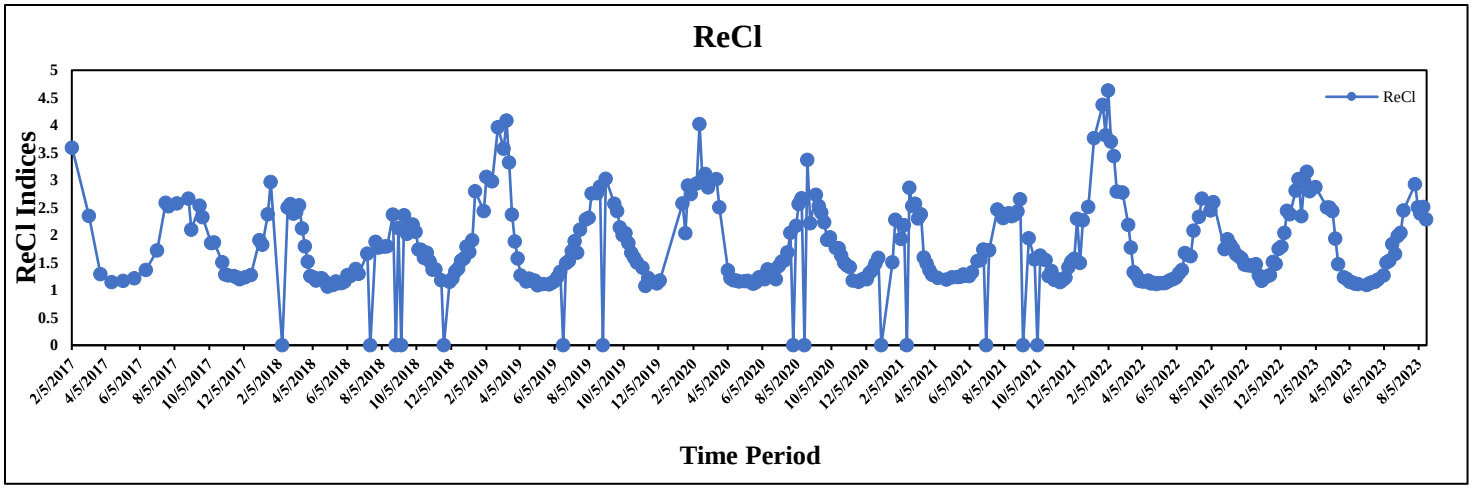

Figure 20: Red-Edge Chlorophyll Index (CI red-Edge or ReCl) Long Term Monitoring Trend from May 2017 to August 2023.

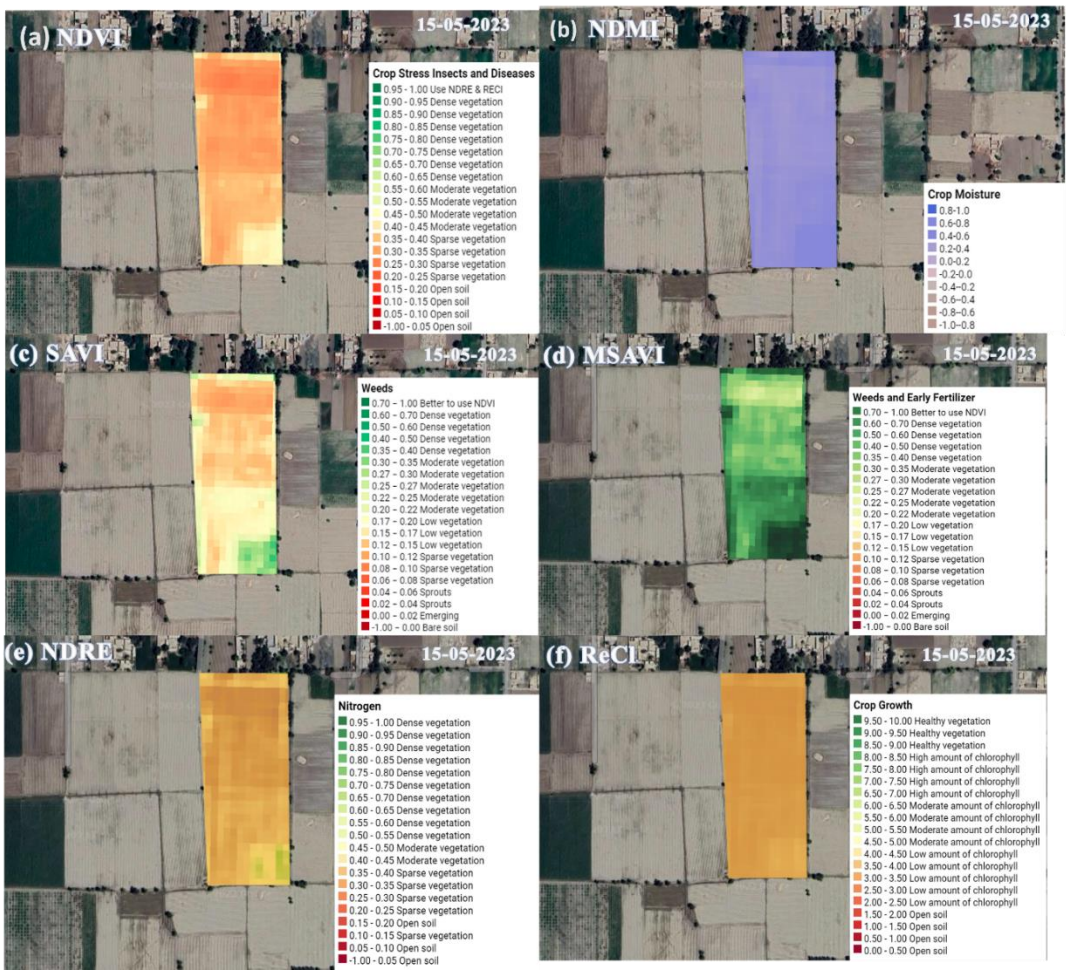

Figure 21: Comparison of Indices **(a) NDVI (b) NDMI (c) SAVI (d) MSAVI (e) NDRE (f) ReCl** for 15-05-2023.

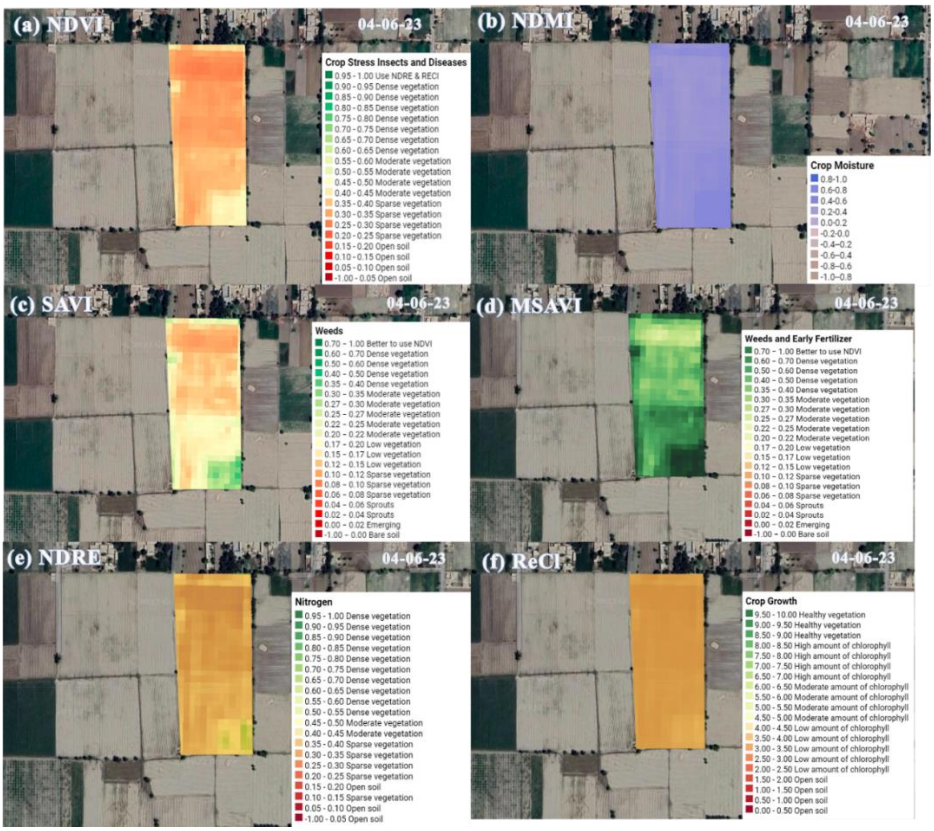

Figure 22: Comparison of Indices **(a) NDVI (b) NDMI (c) SAVI (d) MSAVI (e) NDRE (f) ReCl** for 04-06-2023.

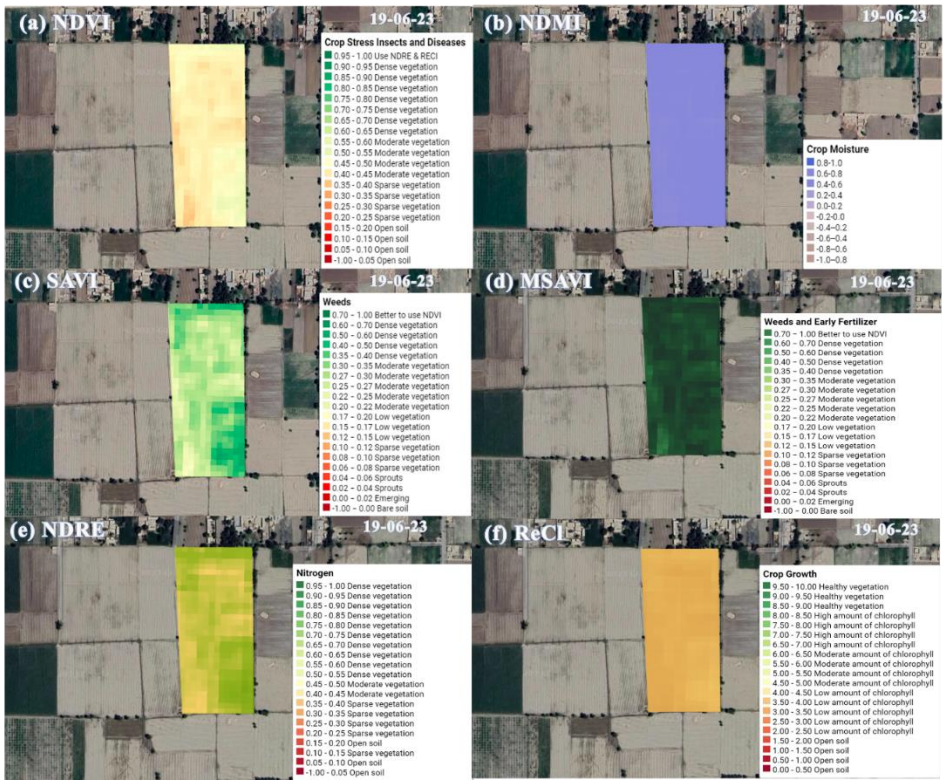

Figure 23: Comparison of Indices **(a) NDVI (b) NDMI (c) SAVI (d) MSAVI (e) NDRE (f) ReCl** for 19-06-2023.

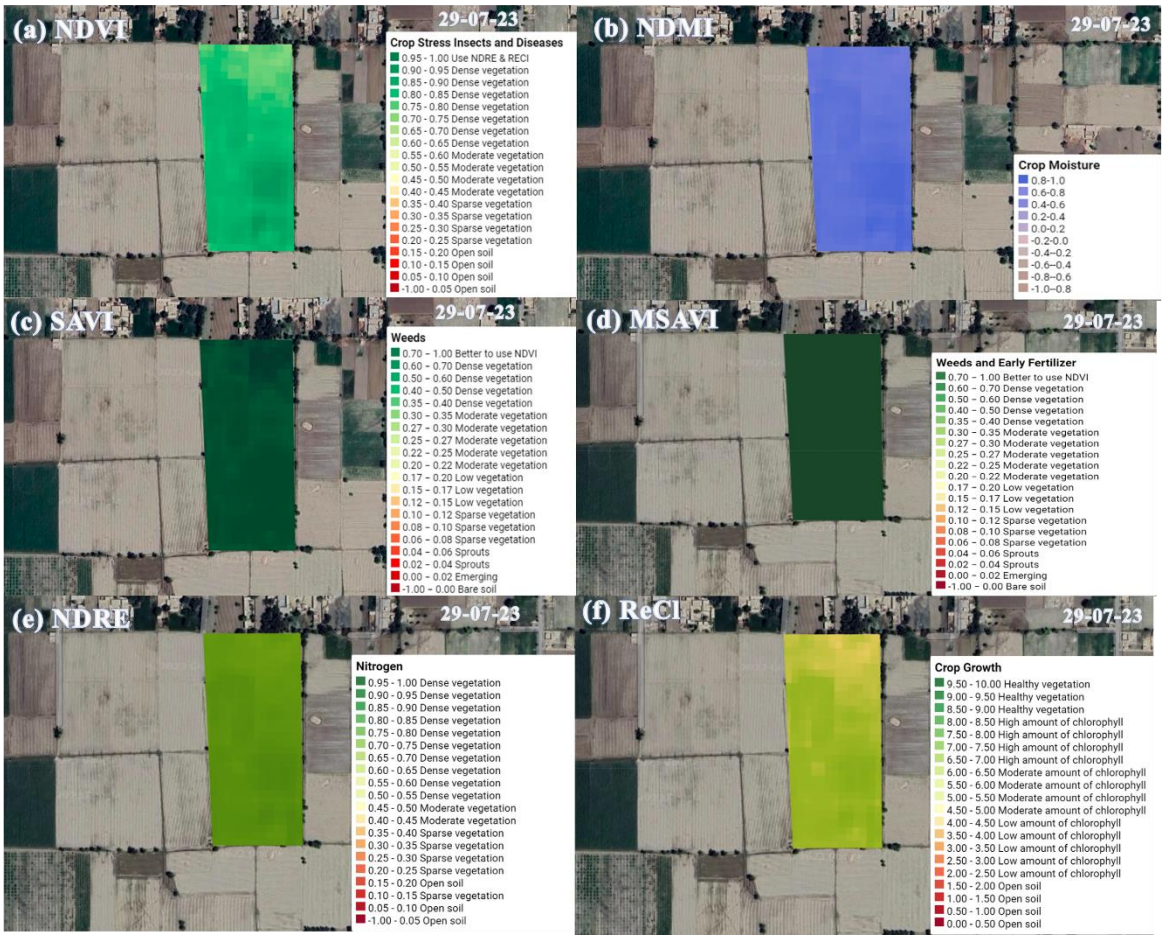

Figure 24: Comparison of Indices **(a) NDVI (b) NDMI (c) SAVI (d) MSAVI (e) NDRE (f) ReCl** for 29-07-2023.

The figures above (Figure 20, 21, 22, 23) correspond to the same field on different dates. In figure 20 (a) The NDVI shows that the whole field is covered while in SAVI we can observe that dark/light brown patches by low vegetation where the green parts may be due to the presence of weeds. In comparison to red light (used in NDVI), In NDRE "red edge" light may penetrate leaves significantly more deeply, producing readings with less saturation tendency and better expressing variability than NDVI in some phases. MSAVI is set for the purpose of mitigating soil effects applicable in areas with a high degree of soil bareness, crops with less vegetation or poor plant chlorophyll content. ReCl is useful in the stages of active vegetation, which is responsible for its greenness, depending on the level of nitrogen in the plant, this remote sensing vegetation index is useful for the detection of areas with a green or faded leaf.