CLIMATE GUIDANCE SERIES

# VEGETATION INDICES

OCTOBER 2024

OCHA

centre for humdata

*About this series: The climate crisis is intensifying humanitarian emergencies around the world, requiring humanitarians to incorporate climate data and forecasts into their analysis and planning. This guidance series has been developed to help humanitarians to access, analyze and interpret common types of climate and weather data, and to provide a common language for working with meteorological and hydrological services.*

# Key takeaways

- Vegetation indices such as Water Requirement Satisfaction Index, Normalized Difference Vegetation Index or Biomass are essential tools for understanding vegetation conditions and how they evolve over time.
- By identifying anomalies, it is possible to understand deviations in vegetation cover for the same period each year, allowing for the detection of unusual changes, which could impact humanitarian planning.
- Analysis of these indicators should be adapted to the local context taking account of different land cover types or climatic regions.
- Vegetation indices can be used to classify vegetation, monitor drought and detect crop diseases. They provide insight on key questions, including:
    - How does the current green vegetation compare to normal conditions for the season?
    - How has vegetation cover changed in recent weeks or months?
    - Which areas have experienced significant decreases in vegetation cover?
- Understanding vegetation conditions through these indices can provide early warnings of potential food insecurity, increase in food prices and environmental stress.
- By identifying areas at risk of drought or crop failure, humanitarian organizations can allocate resources more effectively, implement timely interventions and support vulnerable communities before a shock escalates.

# What are Vegetation Indices?

Vegetation indices are valuable tools for assessing the conditions of croplands and rangelands. They are calculated using remote sensing data, such as satellite imagery and aerial photography, along with rainfall and temperature measurements and seasonal crop calendars. Vegetation indices can be used to classify vegetation, monitor drought, detect crop diseases and more.

Vegetation indices can help humanitarians better understand potential crop failures and take proactive measures to prevent food crises. For example, OCHA's Chad Anticipatory Action Drought Framework[1] uses a trigger mechanism that combines seasonal rainfall estimates[2] with vegetation indices, providing windows of opportunity to mitigate the impacts of drought.

[1] Anticipatory Action Framework - Pilot in Chad: Drought
[2] Climate Guidance Series: Precipitation Forecasts

Vegetation indices can be categorized into three groups[3]:

- **Direct observation of vegetation:** These indices typically detect and measure vegetation characteristics directly using satellite data to show how healthy plants are in a specific area.

- **Indirect observation of vegetation:** These indices rely on several inputs such as remote sensing data, weather information, soil moisture levels, and water data to infer the condition of vegetation.

- **Composite indicators:** These indices combine multiple data inputs to create a comprehensive measure that acts as a proxy for assessing drought severity or evaluating crop performance throughout the growing season.

## Types of Vegetation Indices and their computation

### Direct observations

These indicators are derived directly from observations of vegetation status, primarily through remote sensing data collected via satellites. One example is the Normalized Difference Vegetation Index (NDVI), which is calculated using satellite imagery to assess the difference between near-infrared and red reflectance. Healthy plants reflect more near-infrared light and less red light, providing insights into their density and vigor. The NDVI, an indicator of green vegetation density, is widely used in agriculture to monitor crop health. It can also highlight changes in vegetation cover, signaling potential wildfires, the spread of diseases affecting vegetation or other environmental changes.

### Indirect observations

These indices typically combine several data sources that are not directly tied to the condition of vegetation or crops but relate to broader aspects of vegetation health, such as temperature and rainfall. For example, the Standardized Precipitation Index (SPI) assesses rainfall deficit or excess compared to seasonal averages, while the Water Requirement Satisfaction Index (WRSI) evaluates the extent to which water needs for specific crops are being met during the rainy season.

In this guide, we focus on WRSI as an example of an index that uses indirect observation, calculated using meteorological data collected from weather stations and satellite-based precipitation estimates. These data sources provide essential information on temperature, humidity, and solar radiation, allowing for a comprehensive evaluation of whether crop water requirements are being met and helping to identify areas at risk of water stress.

WRSI is tailored to the water needs of a specific crop, considering both water supply and crop water demands. Typically, WRSI is computed as a cumulative value starting at the beginning of the season, with values calculated at 10-day intervals (referred to as dekads) throughout the season. WRSI can provide insights into expected crop yield.

### Composite indicators

Composite indicators combine various data sources, including satellite-derived indicators, rainfall, seasonal crop calendars and other regional or crop-specific inputs. In this guide, we focus on Biomass, one of the most used composite indicators in the humanitarian sector as it provides a measure of agricultural productivity, which is closely linked to food security and food prices. This makes it a valuable tool for anticipating food shortages and guiding humanitarian responses.

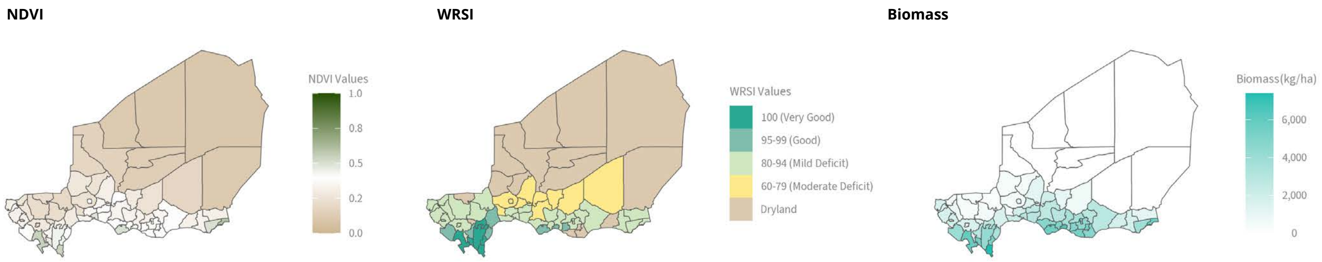
[3] The categories are adapted from WMO's Handbook of Drought Indicators and Indices.

Biomass is defined as the amount of vegetation within a given area and is related to the expected yield, vegetation density and health. Biomass values are typically calculated using different inputs, such as vegetation weight, height and vegetation cover from other indices such as NDVI. The amount of agricultural production harvested per unit of land area, referred to as the yield, is strongly correlated with Biomass.

# What do the values mean?

**Vegetation Indices for Niger - August 2022**

**NDVI, WRSI and Biomass**




The missing values are due to desert areas or drylands with sparse or minimal vegetation coverage.

Sources: WFP Data on HDX, FEWS NET and ACF

*Example of NDVI, WRSI and Biomass data for Niger in August 2022 when the OCHA anticipatory action[4] framework was activated.*

### Normalized Difference Vegetation Index

NDVI values range from -1 to 1. Positive NDVI values greater than 0.5 indicate the presence of healthy, green vegetation. The highest possible density of green vegetation corresponds to an NDVI close to +1. An NDVI value of zero suggests the absence of green vegetation, possibly indicating barren soil. Negative values are typically associated with non-vegetative land cover, such as bodies of water or urban areas.

| Land Cover | NDVI values |
|---|---|
| Water surfaces, man-made structures, rocks, clouds, snow | -1 to 0 exclusively |
| Barren soil | Between 0 and 0.1 |
| Sparse vegetation | Between 0.2 and 0.5 |
| Dense vegetation | Between 0.6 and 1 |

Vegetation conditions can change rapidly. As such, averaging NDVI values over a given time span can provide a more comprehensive view of the vegetation's state.

NDVI anomalies indicate deviations from average conditions. They are calculated by comparing current NDVI values to the long-term average for the same time period, which typically spans five to twenty years. Positive NDVI anomalies suggest healthier-than-average vegetation conditions, while negative anomalies indicate suboptimal state of vegetation health compared to the long-term average.

[4] https://www.unocha.org/publications/report/niger/impact-story-breaking-cycle-negative-coping-strategies-lessons-anticipatory-action-niger-2022

### Water Requirement Satisfaction Index

Crop water requirements vary throughout a crop's growth cycle; these changing needs are quantified using crop coefficients. Each crop type has its unique set of coefficients that estimate water use during different growth stages. These coefficients represent the ratio between water needs and potential water evaporation and transpiration, also referred to as evapotranspiration, which is typically determined by the crop's growing environment. Crops in hot, dry climates have a higher potential evaporation rate compared to those in cooler, more humid climates.

WRSI values are calculated cumulatively over time and usually correspond with the different growth stages between the estimated start and end of the season. The index values range from 0 to 100. A value of 100 indicates that the crop's water requirements are fully satisfied, while lower values suggest varying degrees of water stress, whereby the crop's water requirements cannot be satisfied. A WRSI value of 0 is assigned for seasons with no rainfall or other water sources. WRSI serves as a measure of how effectively a particular crop's water demands are being met throughout its growth cycle.

| < 50 | 50 - 59 | 60 - 79 | 80 - 94 | 95 - 99 | 100 |
|---|---|---|---|---|---|
| Crop Failure | Severe Deficit | Moderate Deficit | Average/Mild Deficit | Good | Very Good |

Instead of relying on a single crop coefficient in areas with multiple crops, the weighted average of crop coefficients should be used to adjust the water requirements. WRSI can be used for both rainfed crops and pasture. For pasture, the crop coefficient for forages or grass is used to adjust the water requirements. There is no need to use WRSI outside of a crop's growing season.

WRSI values are typically available with high spatial granularity, allowing for aggregation of data at small administrative divisions, such as admin level three or below. This enables a more detailed and localized analysis of water availability, facilitating a comprehensive understanding of its impact on crop performance in specific geographic regions.

### Biomass

Biomass is commonly measured as units of mass per unit area, such as kilograms per hectare (kg/ha), megagrams per hectare (Mg/ha), or tons per acre. The calculation process often involves field measurements, remote sensing data, and statistical models. Field measurements might include direct sampling of plant material, while remote sensing data can provide large-scale vegetation cover and health information. Statistical models integrate these inputs to estimate the total Biomass.

Interpreting Biomass data can be challenging due to the variability in Biomass values for different types of vegetation and regions. Factors such as species composition, vegetation age, and local environmental conditions can significantly influence Biomass measurements.

To address these challenges, Biomass anomalies compare a season's Biomass values to historical Biomass production. These anomalies help quantify variations in vegetation health and are typically expressed as a percentage of the average Biomass or as a percentage difference from the average. By analyzing Biomass anomalies, it is possible to identify trends, assess the impact of environmental changes, and make informed decisions about land use and conservation efforts.

# Questions to answer with Vegetation Indices

| Can the indicator answer the following questions: | WRSI | NDVI | Biomass |
|---|---|---|---|
| Has there been enough rainfall to crops during the current season? | Yes | Partially | Partially |
| How significant is the water deficit this season? Which stage of the growing season did the crop experience water deficit during? | Yes | Partially | Partially |
| How frequently do the crops grown in a region experience water deficit? | Yes | Partially | Partially |
| How is the overall crop health in a region? | Partially | Yes | Yes |
| Does this area generally have green vegetation? Which region has greener vegetation? | No | Yes | Partially |
| Which areas of land are dry and covered with dry vegetation, which may increase the risk of wildfires? | No | Yes | Yes |
| Which areas show a decrease in vegetation cover? (This may be an indicator of diseases or insect infestation.) | Partially | Yes | Yes |
| Are the seasonal conditions normal for the vegetation in a region, and what were the seasonal variations in vegetation cover? How much has vegetation cover changed over the last X weeks/months? | Partially | Yes | Yes |
| What is the current estimated crop growth stage? | No | Yes | Yes |
| How much vegetation survived the dry season? | No | Yes | Yes |
| At what point in the growing season is the most plant material produced? | Partially | Yes | Yes |
| Is it the right time to harvest crops? | Partially | Yes | Yes |
| How much yield is expected for the current season? Is it likely to be normal or below normal? | Partially | Partially | Yes |
| Does this area have non-green vegetation? How much non-green vegetation grows in the area? | No | No | Yes |
| Is there enough pasture for livestock? | Partially | Partially | Yes |
| Did other factors influence crop failure, other than lack of rainfall (e.g., floods, wildfires, diseases, deforestation)? | No | Yes | Yes |
| What caused a sudden decrease in vegetation cover? (e.g., floods, wildfires, diseases, deforestation) | No | No | No |
| Which exact types of vegetation grow in a region? | No | No | No |
| What were the exact rainfall, temperature, humidity, or evapotranspiration amounts for a region? | No | No | No |

# Common limitations with Vegetation Indices

Several factors should be considered when interpreting vegetation indices, including:

- Satellite-based rainfall estimates may have a degree of error due to biases in satellite sensors, persistent and thick cloud cover, or for pixels at the edges of the extent of the data source. These errors can cause inaccuracies with the rainfall inputs, and, consequently, compromise the results of the crop models and the balance of evapotranspiration. To mitigate these issues, use satellite rainfall data that integrates ground-based observations and comprehensively covers the region of interest.

- NDVI values indicate the greenness of vegetation. Areas with greener vegetation typically show higher NDVI values compared to areas with healthy vegetation that is less green. Furthermore, variations in agricultural practices and crop types can affect the greenness of vegetation. As such, it is crucial to consider the crop types present in a region or to use NDVI anomalies for more accurate comparisons.

- In areas with limited vegetation cover, certain soil types, such as sandy soils, have high reflection rates that can interfere with the values of vegetation indices. This high reflectance affects the spectral bands that vegetation indices calculations rely on, leading to inaccuracies in assessing vegetation greenness. In these situations, additional validation, such as field measurements or cross-validation with other remote sensing data, is required to ensure accuracy.

- Averaging values over large areas can obscure important details, such as the presence of micro-climates or localized destruction of vegetation.

- Biomass estimation relies on assumptions about vegetation that may not be applicable to the same vegetation in a different region. Therefore, estimates should always be used and validated within a local context.

## Common errors and misconceptions

- The initial stages or dekads of each rainy season vary slightly depending on the onset of the rains. To gain a more comprehensive understanding of the crop growth stages, consider ground data on planting dates.
- It is important to verify the use of correct crop coefficients for WRSI calculations. Each crop and climatic region has specific coefficients that can be used to adjust the specific climatic and crop conditions.
- In areas with only rainfed crops, the WRSI can be computed through the use of satellite precipitation datasets to estimate the evapotranspiration rates. However, for areas with both rainfed crops and irrigated crops, it is necessary to do additional monitoring of irrigation water usage and reassess actual evapotranspiration rates.
- NDVI has a strong correlation with Biomass, as plants produce Biomass through photosynthesis. Greater vegetation greenness indicates higher Biomass. However, at high Biomass levels, NDVI becomes saturated, meaning values do not change significantly past a certain level of vegetation cover. For areas with permanently dense vegetation, consider using other vegetation indices such as Enhanced Vegetation Index or Normalised Difference Red Edge.
- While Biomass and yield are strongly correlated, they are not equivalent. Biomass and yield are equal when the entire plant is harvested, but they differ when the harvest is focused on a particular part of the plant, such as the seeds, fruit or leaves.

## Resources

- NDVI on HDX: Download pre-computed tabular data (CSV format) on 10-day NDVI, long-term NDVI average and 10-day NDVI anomalies per subnational administrative region.[5]
- Biomass on HDX: Download tabular (XLSX format) and geographic information on yearly Biomass production and anomalies over West Africa from 1999 to 2023.[6]
- MODIS Vegetation Index Products[7]
- GIMMS Global Agricultural Monitoring[8]
- NASA Earthdata[9]
- FAO Earth Observation[10]
- Climate Engine[11]

[5] WFP NDVI Data at Subnational Level
[6] West Africa - Biomass Yearly Productions and Anomalies from 1999 to 2023
[7] MODIS Vegetation Index Products (NDVI and EVI)
[8] GIMMS Global Agricultural Monitoring
[9] NASA Earthdata
[10] FAO,GIEWS, Earth Observation
[11] Climate Engine