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Satellite - Based Drought Assessment Using Vegetation Indices: NDVI, NDWI, and NDDI

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Abstract: ***Drought is a recurring climatic hazard that significantly impacts agriculture, ecosystems, and water resources. Timely mitigation and sustainable resource management depend on accurate drought assessment. This study highlights the use of satellite - based remote sensing techniques for drought monitoring through vegetation indices such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Drought Index (NDDI). A more comprehensive understanding of the geographical and temporal subtleties of drought conditions can be gained by integrating vegetation - sensitive indices, such as NDVI, NDWI, and the more sophisticated NDDI, rather than depending just on conventional ground - based techniques, which may be constrained in scope and timeliness. Red and near - infrared reflectance are used by NDVI to quantify vegetation health, red and short - wave infrared reflectance is used by NDWI to evaluate plant water stress, and NDDI combines the two indices to produce a more sensitive predictor of drought severity. These indices make it possible to analyze drought conditions on a broad scale, economically, and promptly, particularly in areas with inadequate ground - based data. In the face of growing climate unpredictability, the accuracy of drought detection is improved by combining remote sensing data with meteorological parameters, providing important information for agricultural planning and water resource management.***

Keywords: remote sensing, NDVI, NDWI, NDDI, drought monitoring

1. Introduction

Drought is a major climatic event that is harmful to both human society and ecosystems. Accelerated climate change has led to a dramatic increase in global drought occurrences in recent years. Accurate and trustworthy global mapping and drought severity monitoring are necessary for water management and drought mitigation. Because agriculture depends on soil moisture reserves and water resources at various stages of crop growth, it is often the first industry to be affected by drought. The development of tools for drought monitoring and prediction would facilitate planning to mitigate the effects of drought.

The process of detecting and monitoring an area's physical characteristics by measuring its reflected and emitted radiation from a distance (often via a satellite or airplane) is known as remote sensing. Remote sensing technology is useful for rapidly obtaining information about a large area, but it can also be used to obtain information about remote areas where traditional techniques of continuous data collection are impractical. Because it uses satellite pictures to monitor vegetation conditions, soil moisture content, temperature fluctuations, and water body variations, remote sensing is essential for drought assessment. The extent of drought, its effects on ecosystems and agriculture, and the development of early warning systems for timely mitigation and intervention actions are all made possible by these findings.

There are several approaches for characterizing drought; however the use of drought indices is common. When comparing the different indices, the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Drought Index (NDDI) are better suited for tracking the characteristics of agricultural drought.

Normalized Difference Vegetative Index

NDVI utilizes the unique reflective properties of plants in the visible (red) and near - infrared (NIR) portions of the electromagnetic spectrum to measure the "greenness" or density of vegetation. The NDVI is determined by dividing the difference between the red and NIR bands by their sum, expressed as:

NDVI= (NIR – RED) / (NIR + RED) …. (Tucker 1979)

Where NIR and RED are the reflectance in the near - infrared and red bands.

Healthy vegetation absorbs most of the red light and reflects a large portion of the NIR radiation. Healthy, robust vegetation is indicated by a higher NDVI value when there is a significant difference between reflected NIR and red radiation. Conversely, when the NIR and red reflection differences are small, the NDVI value is lower, indicating poor vegetation or a partially vegetated surface. This implies the indicator approaches +1 when the vegetation is dense and healthy, and it falls when the vegetation is under stress or destroyed. In general, its values are positive for vegetation, such as crops, bushes, grasses, and woods, negative for water bodies, and nearly zero for rocks, sands, or concrete surfaces. Studies revealed that the accuracy of drought assessments was improved by integrating NDVI with meteorological data, particularly in areas with limited availability of adequate ground - based data.

Normalized Difference Water Index

NDWI is used to monitor the water content in vegetation canopies because it is sensitive to variations in the water content of leaves, which may signal early water stress.

NDWI is the ratio of difference between NIR and SWIR to the sum of NIR and SWIR bands, expressed as:

NDWI = (NIR - SWIR) / (NIR + SWIR) … [Gao, 1996].

Where, NIR and SWIR are the reflectance in the near - infrared and short - wave infrared bands.

Compared to NDVI, it is less susceptible to air scattering effects. The range of the index is - 1 to +1. Open water features have negative values, bare soil may have values close to zero, and vegetated surfaces typically have positive values. An area is generally considered to be experiencing drought circumstances if its average NDWI value is continuously less than 0.3, and non - drought conditions if its NDWI value is greater than 0.4 (Gulácsi and Kovács, 2015). It was found that NDWI was more susceptible to the advent of drought conditions than NDVI, as NDWI values declined more in response to drought circumstances than NDVI. Compared to NDVI, NDWI showed a larger correlation with precipitation, suggesting a greater ability to examine the water condition of the plants.

Normalized Difference Drought Index

NDDI is the ratio of the difference between NDVI and NDWI to the sum of NDVI and NDWI bands, it is expressed as:

NDDI = (NDVI –NDWI) / (NDVI +NDWI)

As an indicator of drought conditions, the NDDI value ranges from - 1 to 1, with higher values denoting a more severe drought. The NDVI is sensitive to vegetation, while the NDWI is sensitive to water resources or humidity. These two facts are used by NDDI in their drought prediction. Analysis revealed that combining data from visible, near - infrared and short - wave infrared channels increased sensitivity to drought severity. The suggested normalized difference drought index (NDDI) is a more sensitive measure of drought in grasslands than NDVI alone since it responded more strongly to summer drought conditions than a simple difference between NDVI and NDWI (Dobri et al., 2021).

2. Conclusion

Through a variety of applications, such as assessing vegetation extent, monitoring vegetation conditions, addressing drought, determining vegetation stress, detecting water bodies, and planning land use, remote sensing has been regularly used to track and identify changes in vegetation. For drought monitoring and assessment, the combination of satellite - based vegetative indices such as NDVI, NDWI, and NDDI provides a potent, economical, and rapid method. The NDVI measures the health of the vegetation, the NDWI measures the amount of water stress in plant canopies, and the NDDI combines the two to give a more accurate assessment of the severity of the drought. Remote sensing technology is becoming more and more important for sustainable environmental and agricultural management as climate change continues to increase the frequency and severity of droughts.

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