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Application of Microwave Remote Sensing (MRS) for Agriculture Application

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Abstract:
This study examines the possible effectiveness of microwave remote sensing in measuring soil moisture content and vegetation features for agricultural use. Microwave remote sensing may be used to assess soil moisture levels by taking advantage of the significant difference in dielectric characteristics between dry and wet soils. Utilizing high-resolution soil moisture data helps efficiently enhance irrigation schedules using precision agricultural techniques. In light of the increasing need for freshwater, it is crucial to optimize the use of water resources while simultaneously improving agricultural output by providing accurate and objective information obtained by remote sensing. Microwave remote sensing is a potential option for monitoring vegetation spatial distribution, physiological condition, and hydric needs in support of agricultural techniques since microwaves can penetrate cloud cover.

Keywords: microwave, microwave remote sensing, vegetation, soil moisture, dielectric constant,

Introduction

Agricultural irrigation is a major factor in managing water resources, responsible for more than 80% of the overall water use. Efficiently distributing freshwater for irrigation is crucial for implementing sustainable water management methods and achieving high agricultural yields in the face of a changing environment and growing water needs. Precise monitoring of agricultural output is necessary due to the increasing worries about land use change and the consequences of climate change on agriculture. Remote sensing provides a vital data resource for the identification and monitoring of crops. Integrating remote sensing data with other information in a Geographic Information System (GIS) is essential for making well-informed decisions in crop management and agricultural planning (Sharma R. et al., 2018).

With professional direction, remote sensing data may provide progressive agriculturalists with insightful analysis to evaluate crop health and pinpoint any field-level problems. Mostly used in India for agricultural acreage and production estimation is satellite remote sensing. Based on the biophysical characteristics of crops and soils, remote sensing technologies might transform the detection and characterisation of agricultural production (Liaghat and Balasundram, 2010). Many crop monitoring systems are used nowadays to obtain crop production statistics from visible and infrared remote sensing data. The effectiveness of these systems might be much improved by including microwave-based moisture data. Passive and active modalities help to define microwave remote sensing systems. Measuring radiometric emission as brightness temperature, passive microwave devices show a negative connection with rising soil moisture. On the other hand, active microwave systems pick up more robust radar backscatter signals with higher soil moisture content (Ulaby et al., 1986).

Objective

The primary objective of this study is to assess the potential utility of microwave remote sensing within the agricultural domain.

Microwave Remote Sensing and Soil Moisture

Microwave remote sensing systems acquire soil moisture information from the ground surface. These measurements are influenced by a multitude of factors, including land cover, vegetation density, and soil texture, thereby complicating the retrieval process. Extensive research has been undertaken to elucidate the interrelationships among emission, backscatter, soil moisture, and vegetation attributes.

Factors Influencing Soil Moisture Retrieval

Several parameters exert significant influence on soil moisture retrieval.

1. **The length of a frequency range:** Estimating soil moisture mostly makes use of the L and C frequency bands. The L-band radiation, which has longer wavelengths, may penetrate the soil profile deeper than the other types. The capacity to penetrate foliage and small plant structures is possessed by L-band Synthetic Aperture Radar (SAR) sensors. Soil and underlying arboreal components, including as trunks and branches, are both sensed by these sensors.
2. **The Angle of Incident -** According to T. Mo et al. (1984), when the incidence angle increases, the sensitivity of microwave sensors to soil moisture decreases. More of the electromagnetic signal is intercepted and attenuated by plants at higher incidence angles. Ulaby et al. (1986) found that soil property sensing is optimized at lower incidence angles, since surface roughness and vegetation have less of an effect on backscatter and emission fingerprints.
3. **Polarization-** Microwave devices, whether active or passive, can measure surface emitted and backscattered radiation using a variety of polarization configurations. Both cross-polarized (HV and VH) and co-polarized (HH and VV) types of active backscatter data acquisition are possible. Emission polarization may be measured by passive sensors in two ways: vertically (V) or horizontally (H). More accurate data may be extracted from different layers of the target surface using these polarization arrangements.
4. **Roughness of the Surface** - There is a strong relationship between surface roughness—a quantitative measure of surface irregularity—and radar backscatter variability. The incoming energy's wavelength determines the extent to which the surface undulates. Since the overall scattering surface area is amplified by an increase in surface roughness, backscatter is also enhanced. Unless they are disturbed by wind stress or currents, water bodies in SAR images usually show low backscatter, which is represented by dark tones (Ulaby et al., 1986).
5. **The Texture of the Soil -** Because different soil particles have different water retention capacities, the dielectric constant varies with soil texture. According to R. Bindlish and A. P. Barros (2002), the dielectric constant is more sensitive to soil moisture in wet environments than in dry ones. According to Mattikalli N. et al. (1998), different types of soil have different patterns of drainage and soil moisture content.
6. **Earth's surface** - Radar backscatter from soil surfaces is affected by differences in local incidence angles caused by topographical undulations. Because of their geometric orientation, slopes that face the sensor produce more radar backscatter. P. C. Dubois et al. (1995) found that under identical soil moisture levels, slopes angled away from the sensor result in little to no backscatter.

7. **The Depth of Penetration -** Factors such as frequency, radar polarization, and the dielectric characteristics of the layer above determine how far microwave radiation may travel into the subsurface. Soil information from deeper horizons may be retrieved by using radiation with longer wavelengths since it penetrates the soil medium more effectively. Attenuation of signal propagation is proportional to soil moisture content, which in turn controls penetration depth.
8. **The Impact of Vegetation -** The main component impacting the extraction of soil moisture from microwave remote sensing data is the vegetation canopy. Soil moisture estimate is affected by vegetation to varying degrees depending on its structural and physical properties. In order to statistically and qualitatively define vegetation, a wide variety of indices have been established, drawing upon multispectral satellite observations. The results of the Normalized Difference Vegetation Index (NDVI) are sensitive to the amount of chlorophyll in the leaves and correlate with the optical qualities of vegetation.

Uses of Microwave Remote Sensing in Crop Production

Crop health, damage from pests or stress, yield potential, and soil conditions may all be better understood with the use of remote sensing equipment. When it comes to mapping, satellite and aerial photos are important for crop categorization, health evaluation, viability assessment, and monitoring agricultural practices. These days, farmers rely more and more on remote sensing to keep tabs on and analyze their operations. Remote sensing's ability to provide repeated data without damaging crops is a major perk that makes it ideal for use in precision agriculture. According to Debeurs and Townsend (2008), this technique offers a more economical way to gather data from large areas. Below is a list of just a few of the many remote sensing applications that exist in the agricultural area.

1. **Identifying Crops -** Government agricultural planning relies on precise crop identification to aid in import/export strategy and budget allocation. When dealing with unusual or unclear crop traits, remote sensing is crucial. By analyzing the samples in a lab, we can learn everything about the crops and how they were grown. Accurately identifying crops requires familiarity with their whole life cycle, from germination through maturity, pollination, and senescence. Differentiation of crop types according to growth rate disparities is made possible by multi-temporal data collecting. Such data is useful for a variety of agricultural purposes, including but not limited to: predicting grain yields, tracking crop output, mapping crop rotations, evaluating soil productivity, identifying stress factors, assessing damage, and keeping tabs on farming activities.
2. **Tracking the Cover of Vegetation -** Classification of crops, area calculation, and yield evaluation all benefit greatly from remote sensing. Scientists rely heavily on digital image processing and aerial photography. When it comes to estimating the state of crops, remote sensing improves accuracy while decreasing the need for ground data collecting. agricultural health and productivity may be assessed using specific remote sensing methods that center on physical aspects of the agricultural system, such water availability and nutrient stress.
3. **Evaluation of Crop Health -** In order to evaluate biophysical markers of plant health, remote sensing offers spectral data in real time. Physiological changes brought on by stress may be detected by remote sensing methods by looking for changes in spectral reflectance/emission characteristics (Menon, 2012). Many variables affect how a crop grows, including soil moisture, air temperature, planting date, number of days in the growing season, and other environmental factors. Because of the hostile conditions it creates, drought causes serious problems for farming and the survival of many plant and

animal species (Siddiqui, 2004). Several vegetation indicators, including reflectance ratio, NDVI, PVI, and Chlorophyll Index, are often used to describe crop development and health.

4. **Evaluation of Nutrient and Water Levels -** When dealing with water and nutrient shortages, remote sensing and geographic information systems are vital. By detecting nutrient stress, fertilizer applications may be optimized in a cost-effective manner. Precision farming methods improve water consumption efficiency in semi-arid and arid environments. A lower value for stressed crops is accompanied by a greater value for healthy crops when it comes to vegetation indices such as NDVI, RVI, PVI, and GI.
5. **The Art of Weed Control -** Improved weed control procedures are made possible by precision weed management tactics. A potential technical development is the merging of precision agriculture with remote sensing. According to Johnson et al. (1997), image-based remote sensing has a lot of promise for weed identification in weed control that is site-specific. Farmers may be guided in the use of preventive control measures by weed prescription maps developed by Geographic Information Systems (GIS).
6. **Evapotranspiration of Crops -** Surface temperature (ST), Crop water stress index (CWSI), water deficit index (WDI), and stress index (SI) are a few vegetation indicators that measure the correlation between water stress and thermal traits of plants. Because soil water availability and crop evapotranspiration regulate plant temperature, measuring the energy released by cultivated areas helps in monitoring crop water stress. Agricultural water management relies heavily on remote sensing. One way to make these capabilities even better is to build hyperspectral sensors and use GIS and GPS to combine data from remote sensing with other types of spatial data.
7. **Projecting Harvest Success and Productivity -** Thenkabail et al. (2002) noted that statistical-empirical correlations between yield and vegetation indicators have been the main methods for using remote sensing techniques to anticipate agricultural production. Numerous variables impact agricultural productivity. These include crop type, weed pressure, insect and disease infestation, weather conditions, and the availability of water and nutrients.
8. **Agrarian Precision -** Modern agricultural production systems rely heavily on remote sensing technologies (Liaghat and Balasundram, 2010). Minimizing cultivation expenses and optimizing resource utilization efficiency via the integration of sensor-derived information into farm equipment is the major purpose of precision farming. The pinnacle of precision agricultural technology is Variable Rate Technology (VRT). Mobile agricultural equipment equipped with sensors and linked to a computer system may use GPS data to create maps of recommended inputs and then regulate the application of those inputs (NRC, 1997).
9. **Disease and Pest Control -** When it comes to tracking and measuring biotic and abiotic stress in crops, remote sensing has become an essential instrument. Insect defoliation evaluations using remote sensing can classify and understand changes in foliage, chlorosis, and yellowing of leaves over time by correlating spectral response variations with these variables (Franklin, 2001). Finding pests and diseases has never been easier or cheaper than with the use of remote sensing technologies.
10. **Analyzing Horticultural Crop Systems -** The analysis of various agricultural planting strategies has been greatly aided by remote sensing technologies. The ability to analyze and anticipate flower development patterns is a major benefit of this technology in horticulture.

11. **Mapping the Soil -** The use of remote sensing for soil mapping is widespread and essential. Soil mapping allows farmers to find out what kinds of soil are best for growing certain crops and how much water each sort of crop needs.
12. **Mapping and Monitoring Floods -** With the use of remote sensing technologies, agricultural specialists and farmers can pinpoint flood-prone and poorly-drained regions. In order to lessen the impact of flood catastrophes in the future, this data is essential.
13. **Mapping the Land -** Land mapping is made easier by remote sensing and has several uses, such as in landscaping and agricultural production. Accurate soil mapping is the backbone of precision agriculture, which allows for the focused use of different kinds of soil accordingly.
14. **Acquiring Meteorological Data -** Accurate decision-making and forecasting rely on up-to-date meteorological data, which may be best collected and stored by remote sensing.
15. **Intensifying the Crop -** Data on cropping patterns, rotation needs, and crop diversification in a specific soil environment may be acquired using remote sensing, which in turn enables agricultural intensification.
16. **Evaluation of Water Resources -** When it comes to mapping agriculturally viable water supplies inside a given plot of land, remote sensing is invaluable. Using remote sensing, farmers may assess the quantity and quality of water resources on their property.
17. **Tracking Climate Change and Planning for Agriculture -** When it comes to determining which crops are best suited for a certain area, climate change and weather patterns are two of the most important variables that may be monitored with the use of remote sensing technologies.

Future Prospects of Remote Sensing in Agriculture

Remote sensing technology offers substantial utility in assessing a diverse array of abiotic and biotic stresses across various crop species, facilitating the detection and management of prevalent crop challenges, including those faced by smallholder farmers. To optimally leverage crop-related information and stimulate economic growth, the establishment of state and district-level information systems based on remote sensing and Geographic Information System (GIS) data is imperative. Governments can harness remote sensing data to inform policy decisions and address national agricultural challenges to bolster agricultural development.

Emerging applications of remote sensing include the integration of nano-chips into plants and seeds for real-time crop monitoring. The Internet of Things (IoT) is poised to revolutionize soil parameter detection. The synergistic application of these and other innovative approaches will underscore the critical role of remote sensing in future agricultural production analysis.

Conclusion

Research in agriculture has shown that remote sensing is quite useful. Classification, monitoring, and evaluation of agricultural productivity are all greatly aided by this technology. The use of remote sensing is essential in agriculture because of the industry's sensitivity to climatic, soil, and physicochemical changes. The significance of thorough monitoring is highlighted by the fact that agricultural production systems are dynamic and subject to regional and temporal fluctuation. In order to evaluate and oversee farming operations, remote sensing is crucial, especially when combined with cutting-edge technology like GIS and GPS. Acreage estimation, growth monitoring, soil fertility evaluation, stress detection, pest and disease identification, drought and flood monitoring, yield forecasting, precision agriculture, sustainable agriculture, economic growth—all are possible with this technological suite in the agricultural sector.

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