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Utilising satellite remote sensing technologies for sustainable crop production

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Abstract

Although remote sensing technology is still in its early stages, it has the potential to transform sustainable agriculture. Remote sensing may help farmers make better decisions and enhance the sustainability of their operations by giving them with real-time information about their crops and the environment. Main applications of remote sensing technologies includes crop growth monitoring, crop yield prediction, precision nutrient management, pest and disease detection etc. Applying this technology would cooperate in sustainable crop production by minimising environmental degradation along with adapting according to climate change.

Keywords: Crop growth, remote sensing, sustainable

1. Introduction

In order to provide sustenance for an anticipated global population of 9.8 billion individuals by 2050, there is an urgent need for a significant and substantial increase in worldwide agricultural productivity. Smart agriculture refers to the utilization of information technology to enhance agricultural productivity, ensuring optimal production of high-quality crops while preserving natural resources and ecosystem balance thus ensuring sustainable crop production. Incorporating remote sensing technologies can aid in increased crop production in a sustainable manner which would help us to meet SDG 2 (Target 2.4) of zero hunger of United Nation. Furthermore, harnessing Remote Sensing (RS) as an innovative tool to confront agricultural challenges, particularly in developing nations, can yield positive outcomes for the global economy. By utilizing RS technology (Fig. 1), the cost of agricultural products can be better managed, ensuring affordability and accessibility. Moreover, it can mitigate the need for economic migration, which is often driven by prolonged periods of low crop yields. By leveraging RS capabilities, the distribution of wealth can be more equitably spread across the planet, promoting greater socio-economic balance and sustainability (Jung *et al*., 2021 and Khanal *et al*., 2020) [1, 2].

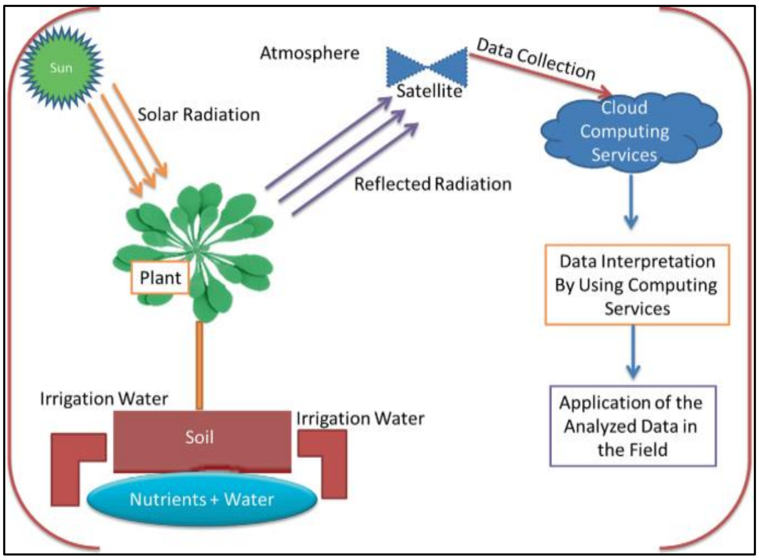

Fig 1: Application of remote sensing to collect ground data. (Source: Pandey *et al*., 2021) [4].

2. Application of remotes sensing technology in agriculture

The various applications of remote sensing in agriculture are described below:

a) Crop health and growth monitoring

Remote sensing can aid in monitoring the health and growth of crops throughout the growing season by detecting crop diseases and pests early. Furthermore, nutrients deficits may be identified with this method. Multispectral or hyperspectral data captured by satellite images and aerial photography can offer useful information on vegetation indices, chlorophyll content, and stress indicators such as PRI (photochemical reflectance index) for detecting disease symptoms. Through this technology parts of the field that need treatment can be recognised, including nutrient limitations, insect infestations, or water stress, and their changes or movement (Fig. 2). By examining these data, focused interventions and improved resource allocation can be done. RS establishes a strong connection between plant radiance and characteristics to extract important information, such as leaf area index (LAI), chlorophyll content, soil moisture content, OSAVI (optimized soil-adjusted vegetation index) for calculating aboveground biomass, leaf nitrogen content, and chlorophyll content, (CVI) chlorophyll vegetation index for representing relative abundance of vegetation and soil and (TVI) triangular vegetation index for predicting leaf nitrogen status.

To derive reliable information from RS products, a variety of elements such as crop phenological stage, crop type, soil type, location, wind speed, precipitation, humidity, solar radiation, nutrient availability, and so on must be taken into account. RS provides a variety of informative products, including plant density, organ computing, LAI, green cover fraction, leaf biochemical content, leaf orientation, height, soil and vegetation temperature, and soil moisture. This data is then further analyzed and interpreted to estimate crop health, disease incidence, irrigation period, nutrient insufficiency, and yield. Administering the proper quantity of nutrients at the proper date and in the correct location is crucial for sustainable crop development using remote sensing products such as NGRDI (normalized green red difference index). Farmers may develop nutrient maps and recommendation maps that direct precise fertilizing by using satellite imagery. This method decreases nutrient runoff and leaching, lowers fertilizer expenses, and prevents environmental degradation.

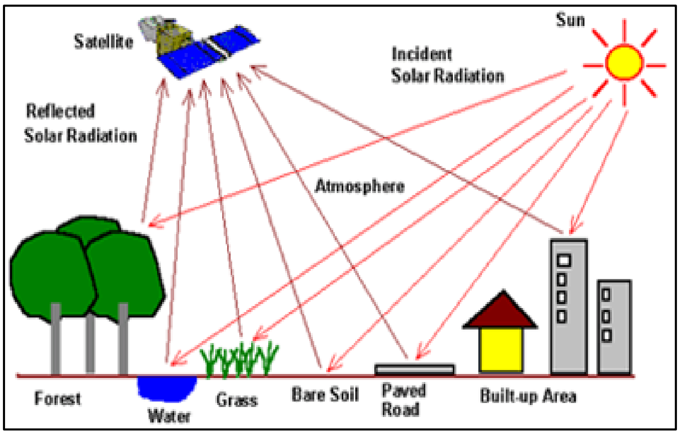

Fig 2: Illustration of working of remote sensing

b) Water Management

Efficacious water management is critical for sustainable crop production in agriculture due to water scarcity concerns. By providing various indices, remote sensing gives useful insights into soil moisture levels, evapotranspiration rates, and water stress in crops. Products such as NDVI (normalized difference vegetation index) for crop monitoring and empirical investigations, SAVI (soil-adjusted vegetation index) for enhancing NDVI sensitivity to soil backgrounds, CI-G to assess leaf chlorophyll content, WDRVI for increasing the dynamic range of NDVI, MSAVI to minimize the effect of bare soil on SAVI and CWSI (crop water stress index) for measuring canopy temperature changes and dynamics. Finally, farmers can maximize irrigation operations, lower water waste, and enhance water-use efficiency by using thermal images and vegetation indices obtained from remote sensing information. This helps to deal with water shortages while making sure that plants receive adequate water for maximum development.

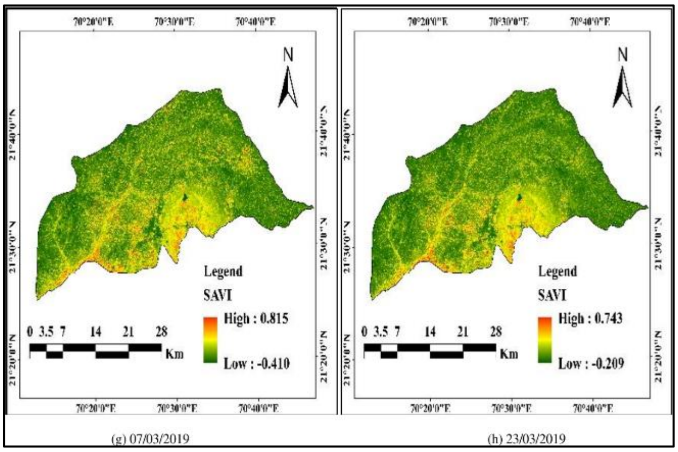

Fig 3: SAVI maps of study area using Landsat images (Nanasaheb *et al*., 2020) [3].

c) Crop Yield Prediction

Planning and decision-making in agriculture require accurate crop yield predictions. Various indices may be used for yield eg. NDVI, gNDVI (green normalized difference vegetation index- for assessing photosynthetic activity). With the use of remote sensing combined with machine learning algorithms, crop yields can be predictive with reasonable accuracy and yield variability within fields can be mapped. Also, it can help detect farm-level factors contributing to yield variability. Farmers can estimate potential yields, optimize harvest timing, and enhance supply chain management by analyzing factors such as vegetation indices, weather conditions, and crop growth stages. The benefits of this technology include reducing loss during harvest, ensuring market availability, and encouraging sustainable agricultural practices.

d) Crop and Land Management

Crop rotation strategies and land suitability can be assessed using remote sensing. The analysis of satellite imagery helps to identify erosion, nutrient depletion, and disease prone areas. This information empowers farmers to adopt suitable land management approaches, such as implementing cover cropping, practicing conservation tillage, or employing targeted pest control methods. These actions result in enhanced soil health, decreased input needs, and long-term sustainability gains.

e) Weather monitoring and Climate Change Adaptation

Crop production in India is largely influenced by agriculture by variation in rainfall intensity and distribution. Also day duration, and ambient temperatures impact crop vegetative and reproductive development. Satellite imageries may be processed to monitor rainfall pattern in region of interest. Farmers may use this to plan harvesting, crop planting, and fertilizer application schedules. Climate-related alterations, such as temperature and precipitation patterns, may be monitored using remote sensing technologies. To limit the effects of climate change on agricultural productivity, farmers may use this data to alter their practices, optimize planting periods, and employ climate-resilient techniques.

3. Advantages of using remote sensing technologies

1. Using remote sensing to map crop system help in scheduling planting periods. Such approaches may be employed as well to figure out which crops to grow. These changes will increase efficiency and minimize the time, effort, and costs associated with mapping large areas of land.
2. By making accurate forecasts of weather patterns, soil conditions, and irrigation needs, it becomes possible to promote the sustainable utilization of water and soil resources. This, in turn, helps to minimize the overexploitation of land and water bodies.
3. Excessive application of fertilizers and pesticides can lead to the contamination of soil and groundwater, adversely affecting beneficial soil microorganisms and non-target vegetation. Additionally, the improper use of fertilizers, insecticides, and pesticides poses health hazards to humans. By monitoring the growth and health of plants, farmers can identify crop requirements and effectively manage fertilizer programs, thus mitigating the risks associated with the misuse of chemical inputs.
4. By detecting pests and diseases at an early stage, farmers can effectively mitigate them without jeopardizing crop yields or causing harm to the environment.
5. Maintaining optimal crop health and nutrition is crucial for achieving high crop yields and ensuring their quality. By utilizing data gathered through remote sensing, farmers can assess crop nutrition levels and make informed decisions to maximize harvests in both the present and future growing seasons.
6. Sustainable technology, such as remote sensing, offers potential solutions for addressing global poverty, hunger, and climate change. By harnessing the power of remote sensing, we can create sustainable agricultural systems that promote the well-being of both people and the environment. Ultimately, this technology enables thriving coexistence and facilitates efforts to alleviate poverty, combat hunger, and mitigate the impacts of climate change.

4. Challenges of using remote sensing technologies

Certain challenges associated with utilising this technology are mentioned below:

1. **Technical skills:** When dealing with sensors and imaging technologies, it is critical to have technical and software understanding of image processing tools. Effective training of workers with the necessary skills and competence will aid in overcoming these obstacles.
2. **Existing data reproducibility and applicability:** The data acquired through this technology relies on various factors such as climate, crop characteristics, field conditions, and analysis methodologies. Consequently, there is a need to develop user-friendly and dependable tools along with real-time applications to ensure accurate and accessible information.
3. **Big data storage and utilization:** Large volumes of data generation and storage have suddenly become an issue. This might make real-time data processing more complicated and time consuming. As a result, optimizing cloud data management systems and improving the safety of sensitive data and user privacy is critical.
4. **Cost:** There is certain amount of cost involved in utilising this technology which may discourage its implementation by common farmers.

5. Conclusion

To feed the burgeoning population of the world, it is necessary to increase the agricultural productivity without degrading our environment. Thus, remote sensing technology holds great promise for sustainable crop production, offering real-time and precise information to empower farmers. Its application enables monitoring of crop health, optimizing water and nutrient management, yield prediction, and effective land management. As remote sensing advances, its combination with artificial intelligence and machine learning further enhances its capabilities for sustainable agriculture. Nevertheless, the promise of publicly accessible satellite images with coarse resolution for precision agriculture applications remains unexplored. The high price of remote sensing technology and data analysis services makes wider implementation difficult. Eliminating this barrier and training agricultural professionals can help technology acceptance. Cooperation between corporate and governmental sectors is critical for advancing remote sensing in agriculture for sustainable crop production.

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