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Advanced Technology of Using Satellite Data Fuels in Agriculture

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Abstract

In this era of 21st century, the area of utilising smartphones and other digital technologies for better cultivation practices have been diversified world-wide. The use of spatial satellite images at variable frequencies and resolutions have paved a way towards modernisation of agriculture. An immediate requirement in this sector is a progressive farm analysis, crucial for providing precise data and a deep understanding to address areas where deficiency is lacking. Within this context, the burgeoning concept of 'Smart Agriculture' presented, which makes use of the modern technologies to improve the quality and quantity of agricultural products. This introduction has facilitated a way to decrease the human interventions and exploration of resource-efficient methods to achieve higher yield potentials. The advanced technology of satellite data fuels uses satellite data to monitor crop growth and other climate-related conditions, such as biomass, temperature and precipitation, to improve farm management.

1. Introduction

Satellite imageries has played a vital role in crop classification, crop yield, crop planning and crop health assessment. Numerous technologies have been applied to map geographic distribution of crops and characteristic cropping patterns. The parameters in analysing crop health and yield can be attributed to nutrient stress or water availability, which can be analysed in a specific territory. The technology of using IOT, AI-based application of robotics, SRS, have provided accurate data on a very large scale for agricultural research and other applications with the right knowledge and opportunity, these satellite data images can be asserted to deal with various problems like desertification, soil erosion etc. Some of these new innovations have already enhanced a detailed study on crop classification based on various factors. Achieving SDGs is the primary moto towards utilisation of satellite data images putting forth the total utilisation of available natural resources. Achieving optimal allocation of water to different crops via efficient water management is vital for agricultural sustainability. By leveraging satellite imagery and advanced data analysis techniques, remote sensing has revolutionized the field of irrigation water allotment, enabling farmers and water managers to make informed decisions

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based on real-time information (Imtiyaz, 2018). With the help of terrestrial, aquatic, and aerial sensors, satellites and surveillance equipment, a large volume of geo-spatial data from diversifying sources is collected, analysed, and utilized for smart farming and shielding of crops. To explore diverse global issues and develop their sustainable solutions, these remote sensing images can be used efficiently (Goel et al., 2021).

2. Overview of the Satellites and Mobile Data Integration with Data Fuels

The power of Earth Observatory Satellite is ventured in its ability to monitor large areas of land regularly. It is a form of remote sensing emphasized on obtaining information about the earth's surface and atmosphere up-to a distance of 36,000 km away, in space. Sensors having high spatial resolution has less area coverage, hence, giving a precise information of the targeted area. The first satellite, EOS SAT-1, of the first Agri-focused satellite constellation, EOS SAT, was launched on January 3, 2023, by Polyakov's Noosphere group of companies. It supports precision agriculture by providing high quality data for analysis (EOSDA, 2023). Since, the last five decades of the launch of NASA Landsat-1, the application of satellite based remote sensing technologies has been initiated. The various satellite sensors like Landsat-8 and Sentinel-2A are used for recording the changes in agricultural production and productivity.

Smart farming motivates the development of new approaches using UAVs, UGVs to improve the profitability. On of the major challenges in adopting advanced farming technologies, is retrieving the satellite data of crops and integrating it with mobile data, to come out with something coherent and valuable. Since, satellite data is just number or image, it needs to be accurately converted into mobile data, understandable by the farmers. The sensor specific data of the parameters measured from crop or soil can be retrieved in multiple ways, by synchronisation of software applications with internet.

3. Major Instances of Using Satellite Data Fuels in Agriculture

3.1. Estimation of vegetative index (NDVI)

The satellite images of vegetation, depict the uniformity and growth patterns of crops, grown around the globe. Normalized Difference Vegetation Index (NDVI)

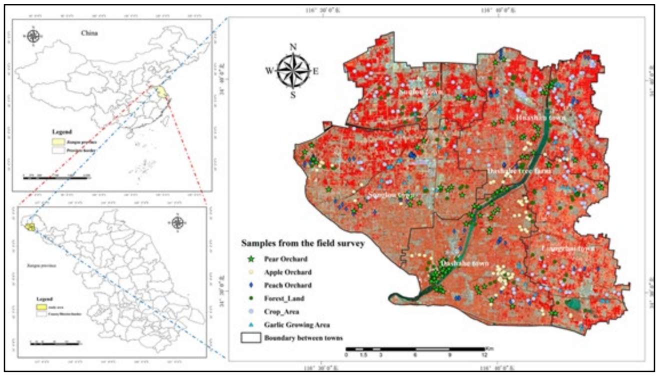

Figure 1: The picture on the left shows the map of China and the province map where the research area is located. The picture on the right is a false-colour image of the study area of the Dasha River Basin, which includes the collection points of different features. (Source: Zhou et al., 2022)

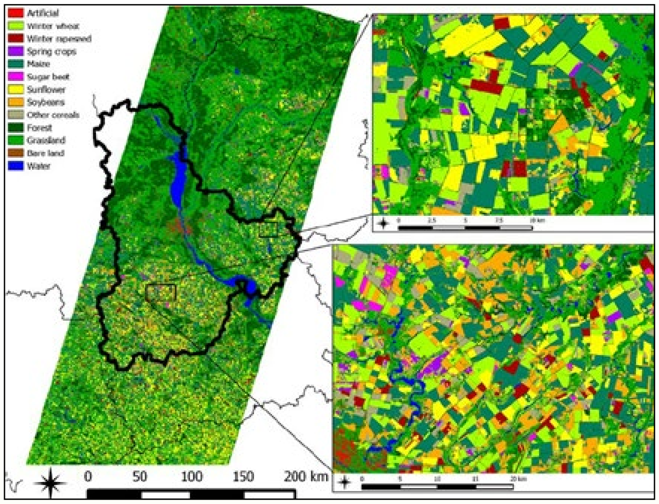

Figure 2: Final map obtained by classifying multi-temporal Landsat-8 imagery using a committee of MLP classifiers (Source: Kussul et al., 2015)

is an efficient indice to measure the vegetation. This could lead us to a detailed understanding of the major fluctuations and phenomenal changes occurring in the vegetation due to climatic interruptions or any other environmental alterations. Using multi-purpose imaging instrument, the AVHRR (Advanced Very High-Resolution Radiometer), various images of our planet's vegetation cover has been brought under observation. Most commonly, to determine the spatial circulation of vegetation from satellite images, the wavelength and intensity of the red light from visible spectrum and near infrared light region is generally considered. The calculation of NDVI is denoted by the following formula

NDVI=(NIR−red)/(NIR+red)

[where, 'NIR' is the reflectance of near infrared light, 'red' is the reflectance of red light]

For the green vegetation, the chlorophyll pigment present in the green leaves absorb maximum amount of visible light in the wavelength ranging from 400-700 nm, and majorly reflects near infrared light in the wavelength ranging from 700-1100 nm. Hence, for the green vegetation the reflectance value from the visible spectrum of light is less as compared to the reflectance value of near infrared light. Therefore, it indicates a healthy vegetation. For scanty and infrequent vegetation, the reflectance from visible spectrum will be comparatively more than the reflectance of the visible light for green vegetation, indicating the area consists of desert or grassland. The NDVI value for a given pixel ranges from -1 to +1. A value close to +1 refers to dense vegetation. a zero value indicates no vegetation, primarily formed from rocks and bare soils.

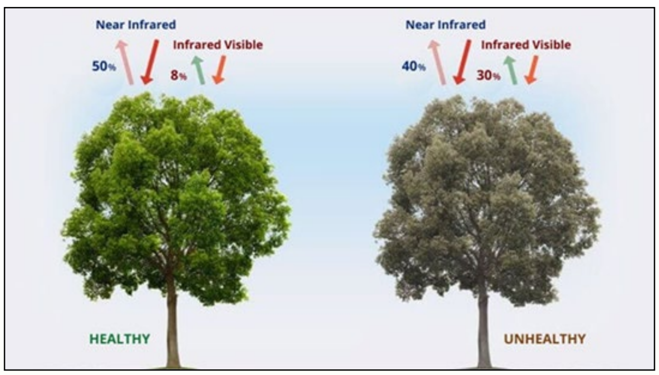

Figure 3: NDVI mapping in agriculture [Source: EOSDA]

3.2. Crop water management

Adequate accounting of crop water has been a concern in agriculture since beginning. Several uncertainties resulting from improper management of water resources may lead to economic crop failures resulting in a distress condition for the farmer. Therefore, considering the situation, several satellite-based monitoring approaches regarding crop water management has been developed. It is possible to study and monitor the evolution of irrigation reservoirs of an area. The water bodies absorb energy in wavelengths from red and near infrared spectral regions and thus the reflected energy makes the water bodies appear in dark colour in both multispectral and grey-sale images. The real time satellite data can be integrated with weather forecasts to allocate proper irrigation schedules, based on the specific needs of the crops. Thus, it results in optimized water usage, increased water efficiency and improved crop productivity.

Remote sensing images can estimate soil moisture over large areas but suffers from a problem of having low spatial resolution. The parameter is highly inconsistent in space and time, mainly due to topographic and atmospheric conditions. For irrigation scheduling, over a small scale the use of soil moisture sensors has been a common practice in cropping field systems (Fontanet et al., 2018). In recent years, the remote sensing techniques have been improved for near-surface soil moisture (NSSM) estimation. It represents the first 5 cm of the top soil profile. The images from Sentinel-1 can give an estimation of NSSM at 1km resolution (Fontanet et al., 2018).

Evapotranspiration being a vital component in hydro-ecological cycle, represents the total amount of water lost from the earth's surface. It requires an accurate estimation to understand the changes in water availability and thereby applying sustainable management practices to water resources. Satellite based images can be used to measure evapotranspiration using the energy balance, over large areas to identify regions of water stress. The surface energy balance algorithm for land (SEBAL) and mapping evapotranspiration at high resolution with internalized calibration (METRIC) models are the two widely used satellite-based surface energy balance approaches which makes use of the thermal infrared sensors to estimate evapotranspiration (Suwanlertcharoen et al., 2023).

Therefore, by harnessing the power of remote sensing combated with obtaining satellite imageries, we can pave the way for a better sustainable and water-secure future in agricultural field.

3.3. Weed control and management

Weeds can be best defined as plants grown in an area where they are undesirable. They are age-old living organisms, since the beginning of agriculture. From agronomic perspective, weeds significantly impede the cropping system indefinitely. They decrease the productivity as well as the quality of the harvested product, whether due to competition for water, sunlight, nutrients, space, allelopathy or parasitism (Monteiro & Santos, 2022). Several, physical, chemical and cultural

Figure 4: Mapping and monitoring irrigation channels in agriculture from sky. (Source: space4water, 2020)

weed control methods are being carried out to reduce the production losses. However, intensive mechanization leads to loss of soil fertility, soil erosion etc (Monteiro & Santos, 2022). Considerable use of herbicides for a long period of time, taints the environment causing diseases in humans and animals. On the other hand, several beneficial weeds are the valuable indicators of our biodiversity. So, there is a need to carry out sustainable weed management procedures associated with the use of smart sensors and remote-sensing technologies. Weed mapping is challenging because of the similarity in reflectance between weeds and crops. Remote-sensing methods, such as, IR sensors and light detection and ranging (LiDAR) technologies, attained astonishing results in mapping weed infestations in crops, resulting in the site-specific herbicide application strategies. Precision weed management is a concept based on sensing or observing and responding with management action to spatial and temporal variability in weeds. This technology works by integrating a variable rate control system with a sprayer for herbicide applications. The application at a varied rate can be fundamentally based on maps or sensors (Monteiro & Santos, 2022). Two major concepts for implementing site-specific variable-rate applications (VRA) are:

i) Map-based VRA- It works on the information contained in a digital map, obtained from the satellite imageries.

ii) Sensors-based VRA – It uses data from real time sensors to assess the field properties of weeds.

Since, the satellite-based remote sensing is well suited for surveying over a large area, it lacks precision in fostering smaller areas, with high resolution imageries. So, for an improved site-specific weed management, through detailed observations, unmanned aerial vehicles (UAVs) are required. Multispectral and hyperspectral imaging sensors mounted on UAVs have been used successfully to detect weeds and distinguish species. This kind of technology can provide valuable information that is not obtained by RGB cameras or not visible to the naked eye (Monteiro & Santos, 2022). Satellite imagery is mainly relevant for detecting large, dense weed patches that have unique spectral characteristics in low-resolution images. In one of the representative cases, it was to examine whether Sentinel-2 images are useful in the detection of *Cirsium arvense* (Rasmussen et al., 2021). Fifteen fields infested with *C. arvense* were used to evaluate the possibilities of utilising the normalised difference vegetation index (NDVI) from Sentinel-2 images as a weed classifier, which showed that weeds are present in larger patches. High resolution RGB images from UAV confirmed that *Cirsium arvense* dominated weed population was much less aggregated than reported previously. The potential herbicide savings using Sentinel-2 images were on an average 24% (Rasmussen et al., 2021). Whereas there was much higher potential herbicide saving for higher image resolution. This aspect limited the use of Sentinel-2 images for weed detection. Therefore, switching to precision technologies in weed control would contribute to sustainable ecosystem and develop mechanisms inherent to weed management for an improved agricultural yield.

3.4. Nutrient management

In these diverse applications of using satellite data in agriculture one of the reasons of using remote sensing technologies, is that it provides a technique that is not only non-intrusive but also cost-effective when it comes to the acquisition of essential information on the state of health of crops and the nutrients that they contain (Singh et al., 2023). Efficient nutrient management is an act of directing the amount, time, method of nutrient application, with a maximum agricultural yield and minimum nutrient losses. The management strategies ensure, crops have enough amount of the primary nutrients i.e., nitrogen, potassium and phosphorus. Remote sensing can detect crop nutrient deficits by analysing spectral signatures of nutrient stress symptoms. Hyper-spectral imaging allows crop analysis in hundreds of small and contiguous spectral bands. This method identifies slight nutrient deficits in plant species (Singh et al., 2023). By mapping the spectral signatures of soils, satellite imaging can detect and quantify nutrients

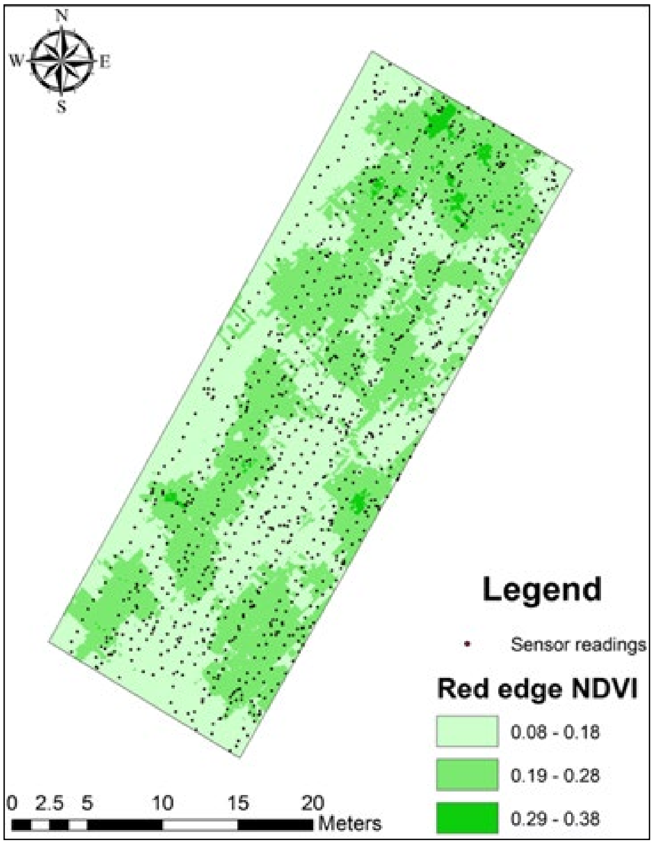

Figure 5: Weed mapping in cotton using ground-based sensors and GIS (Source: Papadopoulos et al., 2018)

such as phosphorus, potassium, magnesium, calcium, and nitrogen (Papadopoulos, 2018). High resolution satellite images can be used to identify areas of low nitrogen, phosphorus levels which enables the farmers to identify areas where fertiliser may be needed. The accuracy of high-resolution satellite imaging also makes it a valuable tool for monitoring soil health over time. By tracking changes in soil nutrient levels, farmers can identify areas where additional fertilizer may be needed and make adjustments accordingly (Papadopoulos, 2018). High-resolution, multi-spectral remote sensing images can provide crucial information for mapping soil nutrients at the field scale. For example, Sentinel-2, with a revisit period of 5–10 days and a spatial resolution of 10 m, captures 13 image bands, including visible light, near-infrared, and short-wave infrared, providing valuable spectral information for inferring the soil nutrient content (Zhang et al., 2023). LiDAR technology creates 3D crop canopy models by measuring the sensor-target distance with laser pulses. LiDAR data can assess plant height, biomass, and canopy structure nutrient status indicators (Singh et al., 2023). Remote sensing data optimises nutrient distribution in variable rate application systems, minimising waste and maximising plant nutrition. Targeted approaches improve efficiency, cost, and environmental sustainability. Remote sensing data optimises nutrient distribution in variable rate application systems, minimising waste and maximising plant nutrition (Singh et al., 2023). Therefore, real time crop health monitoring can be assessed through satellite data fuels, for accurate nutrient management.

4. Conclusion

In this backdrop, we came to know about the various agricultural aspects, which makes use of satellite data fuels. The utility of remote sensing for distinguishing various soil properties, precision management of water facilities lead towards a nano-scale analysis. Many progressive farmers have started implementing satellite-based farming, thus, adapting themselves to the modern technology. As the mechanization advances, many other emerging technologies, like, IOT, AI combines together to convey sustainable management of agricultural practices.

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