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Original Article

Application Of Remote Sensing Methods In Agriculture

Prof. Adhore M. D.

ABSTRACT

With advances in satellite, airborne and ground based remote sensing, reflectance data are increasingly being used in agriculture. This paper reviews various remote sensing methods designed to optimize profitability of agricultural crop production and protect the environment. The paper presents examples of the use of remote sensing data in crop yield forecasting, assessing nutritional requirements of plants and nutrient content in soil, determining plant water demand and weed control.

Keywords : remote sensing; vegetation indices; agronomy; plant protection; crop irrigation.

Prof. Adhore M. D.

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INTRODUCTION

Remote sensing is the process of obtaining information about objects without coming into direct contact with the object. The carrier of information in remote sensing is electromagnetic radiation, which travels in vacuum at the speed of light in the form of waves of different lengths. The most useful wavelengths in remote sensing cover visible light (VIS), and extends through the near (NIR) and shortwave (SWIR) infrared, to thermal infrared (TIR) and microwave bands. Passive remote sensing sensors record incident radiation reflected or emitted from the objects while active sensors emit their own radiation, which interacts with the target to be investigated and returns to the measuring instrument.

REMOTE SENSING APPLICATION IN AGRICULTURE

Remote sensing can be divided into three categories: ground-based, airborne and satellite. when evaluating a remote sensing platform, spatial and spectral resolution must also be taken into account. The spatial resolution defines the pixel size of satellite or airborne images covering the earth surface and relates to the dimensions of the smallest object that can be recognized on the ground. A sensor's spectral resolution indicates the width of spectral bands in which the sensor can collect reflected radiance

GROUND-BASED REMOTE SENSING

According to Jackson (1986) handheld remote sensing instruments are very useful for small-scale operational field monitoring of biotic and abiotic stress agents. This technology has better temporal, spectral, and spatial resolutions in comparison to airborne and satellite remote sensing. A limiting factor of handheld remote sensing is one of efficiency and often time reduced to evaluating small areas when compared with aircraft and satellite mounted sensors, which can be used to be used to evaluate much larger areas at a time. Forecasting yield, nutritional requirements of plants, detection of pest damage, water demands and weed control are the most commonly undertaken problems in studies making use of opportunities of field spectrometers in agriculture.

AIRBORNE REMOTE SENSING

Up to date, airborne remote sensing is mainly realized with the use of piloted aircrafts, however, in recent years they are more often replaced by Unmanned Aerial Vehicles (UAVs), which are aircraft remotely piloted from a ground station. UAVs are typically low cost, light weight and low airspeed aircrafts that are well suited for remotely sensed data gathering. At present, there are two expansive stages for UAVs, in particular the 'Settled Wing' and 'Rotating Wing' sorts. Settled wing UAVs have the benefit of having the capacity to fly at high speeds for long terms with less complex streamlined components. Some of them don't require a runway or launcher for departure and landing. The revolving wing UAVs have the upside of having the capacity to take off and arrive vertically and float over an objective. Be that as it may, as a result of mechanical multifaceted nature and abbreviated battery control, they have a short flight extend .

SATELLITE IMAGERY

Historically, satellite imagery has been used for crop type mapping, general crop condition assessment, and crop acreage estimation. Typically, these applications were used over large areas due to the limited spatial resolution of sensors. Finer resolutions of more recent satellite sensors, however, are now enabling within field assessment of problems such as drought stress, flooding and hail damage.

A growing number of satellite remote sensing applications does not mean that this technology is free from limitations. Stafford (2000) stressed that satellite images can be affected by variable weather conditions. Lamb and Brown (2001) indicated that the low-resolution satellite images beneficial only for large-scale studies and may not be appropriate for the small-scale farms. Additionally, satellites providing higher-resolution images, e.g., QuickBird (2.4 m in VNIR) and ASTER (15 m), have long revisit times (1-3.5 and 16 days respectively), making them of limited utility for any application that might require frequent images. To reduce the revisit time, satellites are often deployed in constellations consisting of a few synchronized satellites, which are coordinated and overlap in ground coverage.

FORECASTING OF YIELD

Remote sensing has been used to forecast crop yields based primarily upon statistical–empirical relationships between yield and vegetation indices (Thenkabail et al. 2002, Casa and Jones 2005). Information on expected yield is very important for government agencies, commodity traders and producers in planning harvest, storage, transportation and marketing activities. The sooner this information is available, the lower the economic risk, translating into greater efficiency and increased return on investments

GROUND-BASED REMOTE SENSING

Walsh et al. (2012), conducting research on winter wheat, using ground based spectra to forecast yield at the beginning of shooting stage. Many authors draw attention to the development phase of plants, as a critical component of yield forecasting (Basnyat and McConkey 2001, Wójtowicz et al. 2005, Piekarczyk 2011a). For instance, the most accurate yield forecasts of winter oilseed rape were achieved when the spectral measurements were performed in the phase of full budding of the crop (Wójtowicz et al. 2005). However, Piekarczyk et al. (2011a) showed that the strongest relationship between the spectral data and the winter rape yield was obtained at the beginning of the flowering stage, while wheat yields were most accurately predicted when the plants were in the shooting phase. Many studies have shown the usefulness of the NDVI index for yields forecasting (Basnyat and McConkey 2001, Piekarczyk et al. 2004, Wójtowicz et al. 2005, Walsh et al. 2012), but good correlations with predicted yield were also obtained for RVI (Ratio Vegetation Index) and ELAI (Estimated Leaf Area Index) indices (Wójtowicz et al. 2005). According to Piekarczyk et al. (2011b), before oilseed rape flowering the strongest correlation with yield was best when indices were calculated on the basis of reflectance in green and NIR wavelengths (550 and 775 nm, respectively). For yield forecasting, at the time of rape flowering, indices calculated on the basis of reflectance in NIR wavelengths and their logarithmic transformation were better than non-transformed spectral data (Piekarczyk 2011a).

AIRBORNE REMOTE SENSING

The usefulness of aerial photographs for forecasting maize yield, using portions of the VIS and NIR ranges several times during the growing season, has been studied as well (Chang et al. 2003). Airborne remote sensing data can substantially improve crop yield forecasting models. Launay and Guerif (2005) developed such a model that assimilates information obtained from images taken throughout the growing season. Yield estimates were improved decreasing the root mean square error (RMSE) from 20% to about 10%. The robustness of the model depended on the number and timing of images which defines the number and the type of plant biophysical parameters that can be assessed. When yield estimations were compiled for areas for which the soil was poorly characterized the forecasts generated by the model were improved (the RMSE decreased from 21% to 15%) if late in the season remote sensing data were assimilated. The authors also found that the crop model was considerably less reliable in severe drought conditions.

NUTRITIONAL REQUIREMENTS OF PLANTS
GROUND-BASED REMOTE SENSING

Ground level remote sensing methods are also used to determine the nutritional requirements of plants. Li et al. (2008a) using a handheld radiometer capable of measuring in the 325–1075 nm range, demonstrated a positive linear relationship between RVI and nitrogen uptake in winter wheat (R2=0.60 and RMSE=30.5%). In the study conducted by Stroppiana et al. (2009) a spectral range from 350 to 2500 nm was applied to estimate plant nitrogen concentration in paddy rice, by means of normalized difference indices derived via a the combination of all possible wavelengths within that range. The best correlation (R2=0.65) between plant nitrogen concentration and a normalized difference index was obtained in that study by using reflectance data in the visible part of the spectrum (503 and 480 nm). A good correlation between canopy reflectance and leaf nitrogen accumulation was also obtained by Zhu et al. (2008) in a study of rice (Oryza sativa L.) and wheat (Triticum aestivum L.). The best results were achieved when a ratio of reflectance in 810 nm to reflectance in 660 nm and a ratio of reflectance in 870 nm to reflectance in 660 nm were used in the calculations (R2=0.84 and 0.85, respectively). Another way developed to assess nitrogen status in a crop field is measuring the reflectance with active sensors like GreenSeeker (NTech Industries, Inc, Ukiach, CA, USA) and CropCircle (Holland Scientific Inc., Lincoln, Nebrasca, USA).

AIRBORNE REMOTE SENSING

An interesting example of using airborne hyperspectral images for plant nutritional stress detection is presented by Quemada et al. (2014) who compared reliability of ground level and airborne sensing methods to distinguish between nitrogen-deficient and nitrogen-sufficient maize plots. Readings at ground level were taken with SPAD (Minolta Camera Co., Osaka, Japan), Dualex and Multiplex (FORCE-A, Orsay, France) sensors, and airborne data were acquired by the hyperspectral sensors Micro-Hyperspec VNIR imager (Headwall Photonics, Fitchburg, MA, USA). This camera acquired radiance imagery in 260 bands in the 400-885 nm region, 300 m over the experimental site. The study showed that vegetation indices based on airborne measurements were as reliable as measurements taken with ground-level equipment used for assessing crop nitrogen status.

DETECTION OF DISEASE AND PEST DAMAGE
GROUND-BASED REMOTE SENSING

Variability in the reflectance spectra of plants resulting from the occurrence and severity of pests and disease allows their identification using remote sensing data. Spectral characteristics of healthy and infested plants are significantly different. In the VIS range a healthy leaf reflects radiation in a small amount due to strong absorption by photosynthetic pigments, while the spectral reflectance in NIR bands is relatively high and is determined mostly by leaf internal structure and dry matter.

Ground based spectral reflectance proved to be very helpful in detection of pest damage in crops. Genc et al. (2008), using a handheld radiometer reliably assessed the sunn pest (Eurygaster integriceps) damage to wheat, with the help of NDVI and structure insensitive pigment index (SIPI – Table 1). The study conducted by Ranjitha et al. (2014) also showed differences in reflectance between healthy and pest damaged plants. Out of three vegetation indices (RVI, NDVI, GRVI – Table 1) tested in the study, GRVI appeared to be the most sensitive to thrips (Thrips tabaci Lind) damage of cotton.

AIRBORNE REMOTE SENSING

When using airborne imagery to detect infested plants in agricultural crops it is important to select a sensor with appropriate spectral and spatial resolution. Mewes (2010) compared the effectiveness of the identification of wheat plants infected with brown rust??? (Puccinia recondita f. sp. tritici) with two hyperspectral cameras, one of which (AISA-DUAL, Specim LTD, Oulu, Finland) recorded the reflected radiation in the 498 channels in the range of 400 - 2500 nm with a spectral resolution of 2.5 - 5.8 nm and the second (ROSIS, German Space Agency, DLR) in the 115 channels in the range of 383 - 839 nm with a spectral resolution of 5 nm. The accuracy with which healthy and infested plants were identified in the AISA-DUAL images was higher than in the ROSIS images (respectively 84.32% and 80.33%), and was associated with stronger correlations at longer NIR wavelengths. AISA images were recorded from a lower altitude than ROSIS images (2300 m and 2880 m, respectively) what resulted in higher spatial resolution (1.5 m and 2.0 m, respectively) and stronger AISA signal intensity due to lower atmospheric absorption and scattering of the signal reflected from the field surface. Both sensors had the same Signal to Noise Ratio (>500:1) and images were taken almost at the same time, thus obtained imagery data could be directly compared

SATELLITE REMOTE SENSING

The occurrence of plant diseases and pests in agricultural crops can also be observed using satellite images. Apan et al. (2004) demonstrated that Hyperion satellite hyperspectral imagery could be used to detect orange rust (Puccinia kuehnii) disease in sugarcane. Chen et al. (2007) used Landsat multispectral imagery to successfully detect severe infestations of the take-all disease (Gaeumannomyces graminis) in wheat. Franke and Menz (2007) evaluated high resolution QuickBird satellite multispectral imagery for detecting powdery mildew (Blumeria graminis) and leaf rust (Puccinia recondita) in winter wheat. Results demonstrated that multispectral images are generally suitable to detect infield heterogeneities in wheat vigor, particularly for later stages of fungal infections, but only moderately appropriate for distinguishing early infection levels in wheat

CONCLUSIONS

The examples described above, in many cases relate to the use of remote sensing in precision agriculture, which has been developing rapidly in recent years. The main purpose of this farm management method is to optimize returns on inputs, while ensuring environmental stewardship. Highly advanced technologies used in precision agriculture require constant access to detailed information characterizing the environmental conditions under which this production takes place. Such information may be obtained from airborne and satellite images at the field scale.

Data collected from satellite, airborne and ground levels facilitate monitoring weed infestations, damages caused by pests and plant pathogens, thereby making it possible to counteract quickly. The ability to use remote sensing data to determine fertilization needs of plants based on the nutrient content of crops and soils helps to increase yields and improve the quality of harvested seeds and fruits, which is important for improving the crop profitability. Accurate determination of the nutritional requirements of plants at critical stages during the field season helps to optimize fertilization as well as reduce potential adverse impacts associated with offsite transport of agrochemicals. Remote sensing has also been used to assess the water needs of plants and determine the date of commencement of irrigation, making it easier to manage crop production under conditions of water stress.

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