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The Role of Remote sensing and GIS in Agriculture

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Abstract

Agriculture plays a vital role in every nation economy every nation. It represents a substantial trading industry for an economically strong country. Remote sensing and Geographic information system used to analyze and visualize agricultural environments has proved to be very beneficial to farming community as well as industry. In this paper I tried to overview the application of remote sensing and geographic information system in agriculture. Reliable and timely information on types of crops grown, their area and expected yield is importance for government for agriculturally based country. The intrinsic characteristics of agriculture make remote sensing an ideal technique for its monitoring and management (Chen et al., 2004). These characteristics include: (a) Agricultural activities are usually carried out in large spatial regions, which makes the conventional field survey or census time-consuming and usually costly; (b) the per-unit-area economic output from agriculture is not so significant in comparison with other industries; (c) most of the crops are annual herbs having different growth and development stages in different seasons which means that agricultural activities have obvious phenological rhythms and the intra-annual change may be very drastic; (d) agriculture is strongly affected by human activities and management where timely and accurate monitoring information is required.. Remote sensing technology has been applied in agriculture extensively since its early stage in the 1960s. Now several global and national operational systems of monitoring agriculture with remote sensing have been operated. The number of similar operational systems at regional scale is much more. These systems provide timely and valuable information for agricultural production, management and policy-making. On the other hand, the demands arising from the applications in agricultural sectors have also enhanced the progress and innovation in remote sensing technology.

Key word: Agriculture, Remote sensing and GIS, crop model and yield estimation

1. Introduction

1.1 Background of the review

Application in Agriculture has been increased emphasis on the potential utility of using remote sensing platforms to obtain real time assessments of the agricultural landscape. Precision agriculture is a production system that promotes variable management practices within a field, according to site conditions. This system is based on new tools and sources of information provided by modern technologies. These include the global positioning system (GPS), geographic information systems (GIS), yield monitoring devices, soil, plant and pest sensors, remote sensing, and variablerate technologies for applicators of inputs (Seelan et al., 2003). Satellite remote sensing, in conjunction with geographic information systems (GIS), has been widely applied and been recognized as a powerful and effective tool in detecting land use and land cover change. It provides cost-effective multi-spectral and multi-temporal data, and turns them into information valuable for understanding and monitoring land development patterns. GIS technology provides a flexible environment for storing, analyzing, and displaying digital data necessary for change detection and database development. Satellite imagery has been used to monitor discrete land cover types by spectral classification or to estimate biophysical characteristics of land surfaces via linear relationships with spectral reflectances or indices (Steininger, 1996). In Andaman Island it was used to identify and map rice growing areas and assessment of soil constraints.

Remote sensing in Agriculture

Remote sensing can be defined as the science, technology and art of acquiring information about an object Which are not in the physical contact with the object itself. It have some components:

1. A source of Energy
2. Interactions of energy with the atmosphere
3. Interactions of energy with earth surface
4. A sensor with platform

The scientists have revealed major application of remote sensing in agriculture including estimation of crop yield and vegetation vigor, assessment of water demand and development of vegetation, crop mapping, monitoring of land cover/use changes as well as in precision agriculture and irrigation management.

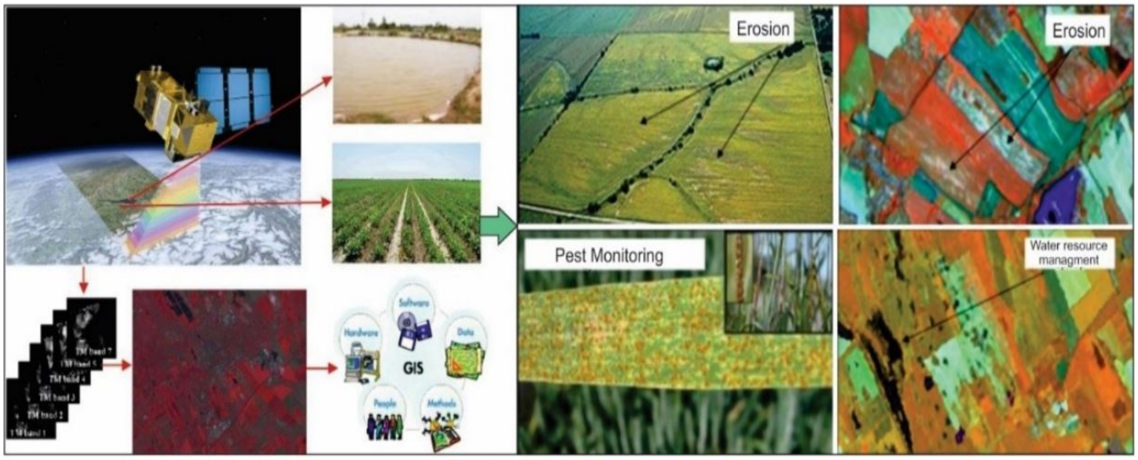

Figure 1 Application of Remote sensing and GIS in agriculture

(https://regi.tankonyvtar.hu/hu/tartalom/tamop425/0027_FHT7/ch01s07.html)

When electromagnetic energy reaches the Earth's surface there are three possible energy interactions with the surface feature:

Reflection: occurs when radiation "bounces" off the target and is redirected

Absorption: occurs when radiation (energy) is absorbed into the target

Transmission: occurs when radiation passes through a target.

$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

Where: $E_I(\lambda)$ = Incident energy (from sun)

$E_R(\lambda)$ = Reflected energy

$E_A(\lambda)$ = Absorbed energy

$E_T(\lambda)$ = Transmitted energy

Application in Crop-Irrigation Demand Monitoring

Agriculture is the major consumer of water, utilizing more than 70% of the global fresh water. Hence, the role of irrigation water plays a significant part in increasing land productivity. Land surface evapotranspiration (ET) is one of the main components of the water balance that is responsible for water loss (Michailidis et al., 2009) and it is of prime interest for environmental applications, such as optimizing irrigation water use, irrigation system performance, crop water deficit, etc. Also, poor irrigation timing and insufficient applications of water are universal factors that limit agriculture production in many arid and semi-arid agricultural regions. In the context of these problems, remote sensing technology has been emerged as an effective tool to monitor irrigated lands over a variety of climatic conditions and locations over the last few decades. It helps in determining when and how much to irrigate by monitoring plant water status, by measuring rates of evapotranspiration and by estimating crop coefficients. The effective use of surface water and the monitoring of consumptive use of water using remote sensing techniques has been a topic of great interest for irrigation water policy makers.

quantification through assimilation approaches. Crop and soil model with GIS can be used to detect methane emission from fields (Matthews et al., (2000) similarly it is used to estimate global food production and the impacts of global warming using GIS and crop model. There are several ways to reduce crop model uncertainty with remote sensing. One possibility is remote sensing images can be used classify agricultural fields and crop types, In this way crop models can be selected to use with this classification corresponding to soil input data. Remote sensing can also be used to estimate crop growth indicator that can be integrated with crop models.

2 Materials and Methods

To identify the potential land for any particular crop, GIS is the best technique as it brings all the data on a single platform for the analysis. Different vegetation indices like NDVI, FPAR and TVI. are widely used to monitor crop health which is also directly proportional to yield. In case of crop insurance, actual damage can be assessed. Claims and compensations can be given on fair basis. To monitor crop health, its growth and production various factors come into play such as temperature, irrigation facilities and the most important soil health condition.

The NDVI is a widely used remote sensing indicator for crop growth monitoring, farmland management and crop production prediction [19]. For NDVI analyse, (near-infrared, NIR) bands of satellite data’s used and calculated as: NDVI = (NIR-R) / (NIR+R)

Crop growth monitoring and yield forecasting programs typically use the NDVI as a crucial indicator of the crop condition. Indices of NDVI changes between -1.0 and 1.0. It means, if vegetation development well accrued in the field, most of the pixel values of the image indicate 1.0 or near to 1.0.

Crop Modelling

It is possible to combine crop models and remote sensing in the way of evaluate yield variables from remote sensed data for each time step in the model simulations, thus the use of remote sensing allows us to fill the missing model parameters during the recalibration in field scale

(Batchelor et al., 2002). Additionally, getting data from crop models in field scale -remote sense allows transferring the results from field scale to regional scale (Priya and Shibasaki, 2001). Many ways of using remote sensing data with crop models have been suggested (Wiegand et al., 1986 and Dele´colle et al., 1992). One way is estimating LAI (leaf area index) values by remote sensing for calibrating into the crop models. Other way is early estimates of the final yield but this method needs many remote sensing data during the growing season to use in crop models. Baret et al., (2006) combined remote sensing observation with crop models for providing stress the world are now available using satellite acquisition. Thus, satellite products and sophisticated computational techniques for the management of water can play an important role in present and future of water resources. The satellite remote sensing for hydrological applications includes, but not limited to rainfall (Global Precipitation Measurements (GPM) and Tropical Rainfall Measuring Mission (TRMM); Soil moisture (Soil Moisture Active Passive (SMAP) and Soil Moisture Ocean Salinity

Crop Identification and Crop Mapping

Crop distribution and acreage, as well as yield, is the basic information necessary for agricultural management and policy-making (Pradhan, 2001). Remote sensing of the extent and distribution of individual crop types has proven useful to a wide range of end-users, including governments, farmers, and scientists (Allen et al., 2002). The traditional method of crop identification is supervised classification of multiple land resource satellite (including Landsat MSS, TM, ETM+, SPOT-XS, IRS-LISS, CBERS, etc.) remotely sensed images throughout the growing season. This approach usually requires a lot of manual interpretation and cloud-free imagery for critical phenological stages which could be barriers for operational implementation over large areas and in multiple years (Broge and Mortensen, 2002; Doraiswamy et al., 2005; Kressler and Steinnocher, 1999). The Advanced Very High Resolution Radiometer (AVHRR) series of sensors onboard the National Oceanic and Atmospheric Administration (NOAA) satellites and the Moderate Resolution Imaging Spectroradiometer (MODIS) offer a unique combination of spectral and temporal resolutions, making them alternatives for large scale crop type mapping with novel classification techniques such as time series analysis and so on (Broge and Mortensen, 2002; Doraiswamy et al., 2005). The former is more accurate, but may be expensive and time-consuming when applied to a large area. The latter has the characters of low-cost and rapidness, but is low in accuracy because of the restriction of spatial resolution. Furthermore, SAR data is used in the discrimination of agricultural land use classes which can eliminate the influence of cloud and time (Soares et al., 1997; Chakraborty et al., 1997; Shao et al., 2001).

Confusion between natural vegetation and cropland is a major source of error in remote sensing-based crop mapping with low-resolution imagery. Sometimes this is true even with high-resolution imagery. This kind of confusion is also obvious in regions with very complicated crop-planting patterns which can be generated from complicated topography or land ownership. For example, Loveland et al. (1999) reported that nearly 60% of the problems addressed in the post classification process for the International Geosphere Biosphere Programme's Data and Information System (IGBP-DIS) global land cover data set arose from confusion between natural vegetation and cropland. This problem was also noted in the MODIS classification of agricultural land use. The most obvious confusion in this regard arose because of seasonal variation in the Normalized Differentiated Vegetation Index (NDVI) signals caused by seasonal variation in illumination geometry that mimicked a phenological cycle (Spanner et al., 1990; McIver and Friedl, 2002). The accuracy of a method to estimate the variability of cropland is affected by lots of factors, such as the data used, scale, crop type, etc. There are lots of researches on it in the past years. Agricultural land use has as specific characteristic that the surface reflectance changes regularly in time with the growth of a crop. This may cause it difficult to calculate accurately the total sown area of a specific crop in case of different types of cropping systems. Satellite data must cover the key phenological phase of the cropping system (Thenkabail et al., 2000).

Crop Yield Estimation and Prediction

Crop yield and production data are key indicators for national food security and sustainable development of society. Early and accurately gathering knowledge of crop yield and production or the changes of production is very important. Regional and national crop yield estimation and prediction with remote sensing are of great interest for scientists, policy-makers and the general public. Crop yield estimation with remote sensing is not only for the staple crops such as wheat, maize, rice, cotton, soybean, but also for some marginal crops. The techniques and methods to estimate crop yield and production include statistical sampling methods, agro-climate models, crop growth models, remote sensing, and some integrated methods. Because of the specific character of remote sensing, for example, the field of view and swath width is wide and the period of detecting the earth surface is short, remote sensing has been used to estimate crop yield and production at a large scale in many countries (Fuller, 1998; Huang et al., 2002; Hochheim and Barber, 1998; Jiao et al., 2005; Potdar, 1993; Groten, 1993; Weissteiner et al., 2004). Crop yield estimation with space-born remotely sensed data can be traced back to mid-20th century. The National Aeronautics and Space Administration (NASA), NOAA and the United States Department of Agriculture (USDA) implemented a large area crop inventory experiment

(LACIE) project in the years 1974–1978 and agricultural and a resources inventory surveys though aerospace remote sensing (AgRISTARS) project in the years 1980–1985 (Wang, 1996; Allen et al., 2002). Important information and many experiences about crop monitoring with remote sensing were gained from these tasks. From then on, European and other countries also developed crop yield estimation and crop monitoring systems. Remote sensing-based crop yield estimation is a prominent example of the macro-research of remote sensing of vegetation (Boogaard et al., 2002). Because of the occurrence of a seasonal rhythm of vegetation, the micro-structure of plant cells and the macro-structure of vegetation canopies changes accordingly and the spectral response of individual vegetation types or of a population also changes periodically. So human can carry out many researches such as vegetation growth monitoring and biomass estimation depending on the multi-spectral response of vegetation to derive them and learn their changing information. With the development of remote sensing, the researches of remote sensing of vegetation have developed practicably. Scientists have put forward Vegetation Index (VI) models which are indicators to vegetation and are linear or non-linear combinations of multi-spectral data (Dadhwal and Ray, 2000). The different combinations of measured reflectance in the visible (Rv) and near-infrared (Rn) parts of the spectrum compose the core of VI (Carlson and Ripley, 1997; Gitelson and Kaufman, 1998). Remote sensing-based crop yield estimation is a series of techniques and methods to forecast crop yield before harvesting of the target crops. Based on the theories of biology and spectroscopy and cognition of crop foliage and canopy spectral response, the crop classes are identified and the spectral data of different crops in different spectral band are acquired through the sensors. Then using the spectra data, we can monitor the crop growth and establish various models for crop yield forecasting. Generally, there are three categories of models based on remote sensing: empirical models, physiological models and crop growth models.

Crop Growth Model

A crop growth model describes the primary physiological mechanisms of crop growth such as phenological development, photosynthesis and dry matter partitioning, and their interactions with the underlying environmental factors using mechanistic and sometimes empirical equations (Delecolle et al., 1992).

Using crop growth models to estimate crop yield requires a lot of inputs that are specific to the crop, soil characteristics, management practices and local climate conditions. So it has limitations to use this kind of models in large regions because fewer inputs are generally available at this scale. Remote sensing has shown to be capable of providing certain crop characteristics and some other parameters. So a crop growth model can be combined with remote sensing and use input parameters which are derived from remote sensing for a larger region (Guerif et al., 1993; Maas,

1988).

3. Results and Discussion

In order to implement these programs effectively it is vital to use the latest technologies like remote sensing and GIS. By using these technologies the same task can be completed within half or even in lesser time frame with minimum number of resources and high accuracy. Balancing the inputs and outputs on a crop farm is essential to its success and cost-effectiveness. The ability of GIS to study and envisage agricultural environments and workflows has proved to be favorable to those involved in the farming industry.

Detecting nutrient stresses using remote sensing and GIS are important in site specific nutrient management and thereby can reduce the cost of cultivation as well as increase the fertilizer use efficiency. GIS is an integral part of automated field operations, also referred to as precision agriculture or satellite farming. Using data collected from remote sensors, and also from sensors mounted directly on farm machinery, farmers have improved decision-making capabilities for planning their cultivation to maximize yields.

Remote sensing and GIS-based agriculture monitoring is an important component of the food security information system which provides reliable and timely crop area estimates and crop production forecasts at national, regional and global scales. Formulated indices from spatial-temporal satellite images as well as other ancillary environmental data like groundwater condition, soil quality and expert knowledge may give more reliable model on crop development and predicting yield. For utilizing these kinds of advanced technologies, require a high level of ability to use software devices and computer technologies as well as the high level of theoretical and practical expert knowledge in the application sphere.

References

Allen, Rich, George Hanuschak, and Mike Craig. "History of remote sensing for crop acreage in USDA's National Agricultural Statistics Service." (2002).

Baret, Frédéric, Vincent Houlès, and Martine Guerif. "Quantification of plant stress using remote sensing observations and crop models: the case of nitrogen management." *Journal of Experimental Botany* 58, no. 4 (2007): 869-880.

Batchelor, William D., Bruno Basso, and Joel O. Paz. "Examples of strategies to analyze spatial and temporal yield variability using crop models." *European Journal of Agronomy* 18, no. 1-2 (2002): 141-158.

Boogaard, H. L., H. Eerens, I. Supit, C. A. Van Diepen, I. Piccard, and P. Kempeneers. "Description of the MARS crop yield forecasting system (MCYFS)." *Joint Research Centre, Study contract* 19226-2002 (2002): 02-F1FED.

Broge, N. H., and J. V. Mortensen. "Deriving green crop area index and canopy chlorophyll density of winter wheat from spectral reflectance data." *Remote sensing of environment* 81, no. 1 (2002): 45-57.

Dadhwal, V. K., and S. S. Ray. "Crop assessment using remote sensing-Part II: Crop condition and yield assessment." *Indian Journal of Agricultural Economics* 55 (2000): 55-67.

Delécolle, R., S. J. Maas, Martine Guerif, and Frédéric Baret. "Remote sensing and crop production models: present trends." *ISPRS Journal of Photogrammetry and Remote Sensing* 47, no. 2-3 (1992): 145-161.

Fuller, D. O. "Trends in NDVI time series and their relation to rangeland and crop production in Senegal, 1987-1993." *International Journal of Remote Sensing* 19, no. 10 (1998): 2013-2018.

Guerif, Martine, Seguin de Brisis, and Bernard Seguin. "Combined NOAA-AVHRR and SPOT-HRV data for assessing crop yields of semiarid environments." *EARSeL Advances in Remote Sensing* 2, no. 2 (1993): 110-123.

Loveland, Thomas R., Zhiliang Zhu, Donald O. Ohlen, Jessyln F. Brown, Bradley C. Reed, and Limin Yang. "An analysis of the IGBP global land-cover characterization process." *Photogrammetric engineering and remote sensing* 65 (1999): 1021-1032.

Matthews, R. B., R. Wassmann, and J. Arah. "Using a crop/soil simulation model and GIS techniques to assess methane emissions from rice fields in Asia. I. Model development." *Nutrient Cycling in Agroecosystems* 58, no. 1 (2000): 141-159.

Michailidis, Anastasios, Konstadinos Mattas, Irene Tzouramani, and Diamantis Karamouzis. "A socioeconomic valuation of an irrigation system project based on real option analysis approach." *Water Resources Management* 23, no. 10 (2009): 1989-2001.

Potdar, M. B. "Sorghum yield modelling based on crop growth parameters determined from visible and near-IR channel NOAA AVHRR data." *International Journal of Remote Sensing* 14, no. 5 (1993): 895-905.

Pradhan, Sushil. "Crop area estimation using GIS, remote sensing and area frame sampling." *International Journal of Applied Earth Observation and Geoinformation* 3, no. 1 (2001): 86-92.

Seelan, Santhosh K., Soizik Laguette, Grant M. Casady, and George A. Seielstad. "Remote sensing applications for precision agriculture: A learning community approach." *Remote sensing of environment* 88, no. 1-2 (2003): 157-169.

Soares, Joao Vianei, Camilo Daleles Rennó, Antonio Roberto Formaggio, Corina da Costa Freitas Yanasse, and Alejandro Cesar Frery. "An investigation of the selection of texture features for crop discrimination using SAR imagery." *Remote Sensing of Environment* 59, no. 2 (1997): 234-247.

Steininger, M. K. "Tropical secondary forest regrowth in the Amazon: age, area and change estimation with Thematic Mapper data." *International Journal of Remote Sensing* 17, no. 1 (1996): 9-27.

Spanner, Michael A., Lars L. Pierce, David L. Peterson, and Steven W. Running. "Remote sensing of temperate coniferous forest leaf area index The influence of canopy closure, understory vegetation and background reflectance." *TitleREMOTE SENSING* 11, no. 1 (1990): 95-111.

Thenkabail, Prasad S., Ronald B. Smith, and Eddy De Pauw. "Hyperspectral vegetation indices and their relationships with agricultural crop characteristics." *Remote sensing of Environment* 71, no. 2 (2000): 158-182.