Productivity Estimation and Conditon Assessement of horticulture Crop from Satellite Based High Resolution Imagery: A Review

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Abstract - This paper reviews the state-of-art and identifies research directions of crop modelling and management (CMM). The CMM can be use in a wide range of agriculture activities including field crop production, horticulture, dairy farming and forest management. CMM use geospatial technology tool: Remote Sensing which assist the user to collect, analyze and interpret spatial data. CMM in precision agriculture helps to achieve increase in crop production with minimal input. The review explores different Indian Remote Sensing (IRS) satellites available for the application of crop modelling. Satellite image resolution is one of the major concerns for accurate analysis of horticulture crop. The study investigates the benefit of Super Resolution Reconstruction (SRR) algorithm which is considered to be one of the most promising techniques to enhance the spatial resolution. The review also provides the applications of data mining, soft computing for remote sensing and General Purpose Graphic Processing Unit (GPGPU) architecture for high speed data processing that can be used in CMM. The exploration concludes with an innovative model for integration of CMM with Geographic Information System (GIS) which can benefit “demand and supply chain management", and crop insurance.

Keywords—crop model; Super Resolution Reconstruction; General Purpose Graphic Processing Unit

I. INTRODUCTION

In today’s agriculture world India contribute major production of horticulture crop, and considered as the world's second largest horticulture producer. During the year 2012-13 India’s annual production of horticultural crops in the country was about 240 million tones, wherein the fruits production accounts for 72 million tones and vegetables production is for 134 million tones. As per the records of Indian agriculture ministry, horticulture crop helped the country to generate a foreign exchange of Rs 14,000 crore. Agriculture is major sector in developing India, 55% of its population and providing 16.5% of its annual GDP. The agriculture industry as a whole generates US $ 17.5 million alone in export. India is bestowed with wide-ranging agro-climate, which is highly favorable for growing a large number of horticultural crops such as nuts, fruits, flowers, vegetables including root tuber and ornamental crops, medicinal and aromatic plants, spices and plantation crops like arecanut, cashew and cocoa etc.

Changing markets, technological innovation and organizational progress in recent years have increased the intensity and scale of agricultural land use. Producer deal with very broad and rapidly expanding range of technology, in areas such as weed control, direct seeding and varieties selection, all of which are required to optimize productivity, protect the environment and maintain or improve the profitability. In the past the main focus of agronomic research has been on crop production only but recently, profitable crop production, the quality of the environment has become an important issue that agricultural producer must address. So the agricultural manager requires strategies for optimize the profitability of the crop production while maintaining soil quality and minimizing environmental degradation. Solution of these new challenges requires consideration of how numerous components interact to effect plant growth. With shrinking land and scarce natural resources the path ahead for the Indian horticulture should be to diversify into hi-tech horticulture to improve the productivity and quality and meet the demand. To achieve this goal, future agriculture research will require more effort and resource than present research activity.

The application of aerial or satellite imaging is the first step towards the successful application of CMM for horticulture crops [37]. The use of CMM for horticultural crops has potential for increasing net returns and optimizing resource use [38]. The delineation of orchards and spatial analysis using geospatial technology can provide additional information for management decision making, such as the determination of horticultural crop yield, the quantification and scheduling of precise and proper fertilizer, irrigation needs, and the application of pesticides for pest and disease management. Ultimately, it will improve profits for producers [8]. Remote sensing has become a universal tool for general detection of health condition of orchards on a larger scale. Digital imaging technology increasingly being used for intensive site-specific management of orchards as well, for instance: estimating the amount of fruits on individual trees, fruit quality, and also leaf area index or crown cover.

The overall goal of this review is to explore studies that use
remote sensing technology for conducting CMM of horticulture crop. Another objective of this paper is to help horticulture crop managers and other stakeholders to understand the applications of geospatial technology to increase the productivity and develop good demand and supply chain.

II. CROP MODELLING IN HORTICULTURE

A. Crop Modelling

Crop models are tools of systems research which helps in solving problems related to crop production. A MODEL attempts to simulate the way in which a crop responds to its environment. Model outputs are usually value-added parameters that are more closely linked to crop yield than the inputs.

Crop modeling enables scientist to define projections of future agricultural yields and restate research priorities. Researchers can estimate the importance and effect of various parameters and arrive at conclusion about which factors should be studied more in future to increase the understanding of system. Crop growth is very complex phenomenon and a product of a series of interactions of water, soil, plant and weather. Thus, Crop model must possess potential to help understand basic interactions in soil-plant-atmosphere system. Figure I represents crop model in general.

In India, we still predominantly use traditional techniques such as field based crop cutting experiments (CCE) to assess the crop yield and acreage. It is worthwhile to note that in India all crop exports and import decisions are still based on historical production data (previous year’s production records), a more scientific way of assessing the yield and acreage in advance way is done by using remote sensing and GIS techniques. The ramifications of taking crucial export and import decisions is based on historical data that is based on perceived shortage or surplus. Agricultural data is currently generated by multiple agencies in multifarious ways; both conventional field surveys based as well as advance information technology based

B. Crop Modelling and Precision Agriculture

Precision agriculture (PA) - also known as precision farming, variable rate technology (VRT) and site specific agriculture – is one of the nurturing agriculture technologies of 21st century, as it symbolizes a better balance between reliance on traditional knowledge and information - and management - intensive technologies. Precision agriculture changes an agriculturalist viewpoint, because focus of attention changes from average field conditions to the variation of those conditions.

Precision farming takes advantages of Geospatial technology, and is a combination of essential tools: Remote Sensing, Geographic Information Systems, Global Positioning Systems (GPS), Information Technology (IT) Variable Rate Technology (VRT), Crop Models, Yield Monitors and Precision Irrigation.

Agricultural sustainability in India can be achieved only if the natural resource base upon which it relies is well managed. Modern frontier technologies involving system approach towards efficient crop and input management, and scientific land and water use planning, is thereby the need of this century sustainable agricultural management.

V. Radha Krishna Murthy [26] discusses various crop growth modeling approaches viz. Statistical, Mechanistic, Deterministic, Stochastic, Dynamic, Static and Simulation etc. Role of climate change in crop modeling and applications of crop growth models in agricultural meteorology are also discussed. A few successfully used crop growth models in agrometeorology are discussed in detail.

V.K. Dadhwal [27] Crop growth and productivity are determined by a large number of weather, soil and management variables, which vary significantly across space. Remote Sensing (RS) data, acquired repetitively over agricultural land help in identification and mapping of crops and also in assessing crop vigour. As RS data and techniques have improved, the initial efforts that directly related RS-derived vegetation indices (VI) to crop yield have been replaced by approaches that involve retrieved biophysical quantities from RS data. Thus, crop simulation models (CSM) that have been successful in field-scale applications are being adapted in a GIS framework to model and monitor crop growth with remote sensing inputs making assessments sensitive to seasonal weather factors, local variability and crop management signals. The RS data can provide information of crop environment, crop distribution, leaf area index (LAI), and crop phenology. This information is integrated in CSM, in a number of ways such as use as direct forcing variable, use for re-calibrating specific parameters, or use simulation-observation differences in a variable to correct yield prediction. A number of case studies that demonstrated such use of RS data and demonstrated applications of CSM-RS linkage are presented.

C. Crop Modelling and Precision Agriculture

Precision Agriculture (PA) technologies provide three basic requirements for precise and sustainable agricultural management. These are: Ability to identify precise location of field, gather and analysis information on spatio - temporal variability of soil and crop conditions at field level, and adjust input use and farming practices to maximize benefits from each field location.
Advantages of PA: PA promises to revolutionize form management as it offers a variety of potential benefits in profitability, productivity, sustainability, crop quality, environmental protection, on - farm quality of life, food safety, and rural economic development.

Refinement and wider application of PA technologies in India can help in lowering production costs, enhancing higher productivity and environmental benefits, and better utilization of natural resources. When PA technologies judiciously implemented, farmers could be benefited in many ways. In the short term, growers can use forecast based on remote sensing and alleviate problems such as water stress, nutrient deficiency and pests/diseases more affectivity. Database - building benefits will be in the form of accurate farm document keeping for effective management of inputs, property, machinery and labor, and efficient monitoring of environmental quality through recording the amounts and location of input through applying at exact locations that produce maximum profit margins. PA technologies also increase opportunities for skilled employment in farming, and provide new tools for evaluating multifunctional character (including non - market functions) or agriculture and land.

Advantage of CMM: The aim of main aim of constructing crop models is to obtain an estimate of the harvestable (economic) yield. According to the amount of data and knowledge that is available within a particular field, models with different levels of complexity are developed. The advantages of CMM in general include the ability to provide a framework for understanding a system and for investigating how manipulating it affects its various components, assess long-term impact of particular interventions, make available an analysis of the risks involved in adopting a particular strategy and provide answers quicker and more cheaply than is possible with traditional experimentation.

III. GEOSPATIAL TECHNOLOGY

Remote Sensing

Remote sensing can be defined as a technology that is employed to acquire information about an object by detecting the energy reflected or emitted by that object when the distance between the object and the sensor is far greater than any linear dimension of the sensor [1]. However, remote sensing has been described in various ways by numerous authors [2-4].

Remote sensing techniques have been used for land cover mapping activities for over 30 years, even before the term was coined, and they played an important role in many developments that we enjoy today. “Mapping forest vegetation from aerial photographs was first attempted in the 1850s using a camera carried aloft in a hot air balloon” [5] and has been used for the identification and monitoring of agricultural land use targets since the late 19th century [6].

The backscatter signature from each crop in a microwave image using active sensors varies according to the target’s characteristics, such as leaf moisture, plant separation and number of leaves per square meter or canopy over the ground [7]. The crop growth models predict the characteristics of different crops at given times, and provide inputs to the radar models, which estimate the backscatter from each crop of interest. In this context, the use of microwave images may be an alternative to direct field measurement when many of the fields become inaccessible due to the wet season conditions.

A. Image processing of remotely sensed data

Image processing is an aspect of the computer vision area that involves two steps: low level and high level as described in Rao and Jain [16]. Low-level vision is based on the extraction of features, resulting in a segmented image with labelled different regions, where the shapes, spatial interrelationships, and surfaces of objects may be described. The high-level vision consistently attempts to interpret the labels obtained from low-level processing using a priori information about the scene’s domain. Thus, they considered the two main steps in image processing: segmentation and interpretation. The basic steps involved in general image processing are also discussed in Gonzalez and Wood [17] as acquisition (capturing image), pre-processing (quality improvement), segmentation, and interpretation.

B. Remote Sensing image classification:

In remote sensing image classification, techniques are most generally applied to the spectral data of a single-date image or to the varying spectral data of a series of multi-spectral or multi-date images [19]. The complexity of image classification techniques can range from the use of a simple threshold value for a single spectral band to complex decision rules that operate on multivariate data. Numerous classification approaches have been used with varying degrees of success. Despite the considerable recent developments, the accuracy with which thematic maps may be derived from remotely sensed data is still often judged too low for operational use [20].

C. Remote Sensing in Horticulture Crop CMM:

Remotely sensed images are a quick and inexpensive means to differentiate agriculture crops or orchards from other land-uses [8]. The remotely sensed images are the best possible resource to differentiate the spatial variation of crops, including horticultural crops. Several studies have been conducted over the years to delineate or classify forests or shrubs, e.g., horticultural plants, based on satellite and aerial images for precision agriculture decision making [8,42-50].

Many fruit and nut orchards are close to, within, or adjacent to, forested land cover [8]. Differentiating the plants from forest trees is a difficult task, but it can be achieved with advanced image processing. The total reflectance of a forest canopy is the combination of illuminated and shaded components of the tree crown as well as the background because of the bidirectional behavior of forest canopy [41]. With advanced image processing techniques and use of high resolution multispectral and hyperspectral imagery, most fruit and nut plants can be distinguished from the mixed vegetation of tall forest trees and dwarf grass or other small shrubs if their unique spectral characteristics are known, especially with
respect to the land covers such as forests or grasses [37].

These spectral reflectance curves are useful for researchers engaged in developing CMM for individual fruit and nut crops through the use of remote sensing. The curves would guide researchers to decide which band images they need to procure to obtain distinguishable digital information. Again, these curves also point towards obtaining the digital number range (0–255) for a crop at a particular band using the reflectance percentage (Y-axis info of the curves) with respect to the wavelengths (X-axis info of the curves).

D. Multispectral and Hyperspectral Remotely Sensed Images:

- Multispectral or hyperspectral images are preferred from accurate classification of different crops in CMM.
- These different techniques operate at different wavelengths.
- Multispectral remote sensing involves the acquisition of visible, near infrared, and short-wave infrared images in several broad wavelength bands and Hyperspectral imaging systems acquire images in over one hundred contiguous spectral bands.
- While multispectral imagery is useful to discriminate land surface features and landscape patterns, hyperspectral imagery allows for identification and characterization of materials. In addition to mapping distribution of materials, assessment of individual pixels is often useful for detecting unique objects in the scene.
- Well developed scientific application areas include geology and mineral exploration; forestry; marine, coastal zone, inland waters and wetlands; agriculture; ecology; urban; snow and ice; and atmosphere. Hyperspectral sensors pose an advantage over multispectral sensors in their ability to identify and quantify molecular absorption. The high spectral resolution of a Hyperspectral imager allows for detection, identification and quantification of surface materials, as well as inferring biological and chemical processes.

E. Classification of crops:

Remote sensing image classification involves the grouping of all or selected land cover features into summary categories that allow the interpretation of the earth’s surface imaged by the imaging sensor. In remote sensing image classification, techniques are most generally applied to the spectral data of a single-date image or to the varying spectral data of a series of multi-spectral or multi-date images [21].

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Martin and Heilman [23] conducted special measurement of several rice varieties with different morphological characteristics using a portable radiometer in Thematic Mapper spectral bands. They observed that vegetation indices were highly correlated with leaf area index (LAI), however, vegetation indices were insensitive to morphological differences among varieties.

Berg and Gregorie [24] adopted remote sensing techniques for area estimation of rice in West Africa. Area estimation was done at two stages of crop development; three months and one month before harvest. The methodology was based on visual interpretation as well as digital analysis of two Landsat images.

In chickpea, Vyas et al. [25] reported remote sensing based acreage estimate using IRS-1A LISS-I data. The relative deviation of acreage estimate was 1.89 per cent to that of Official estimate by Bureau of Economics and statistics (BES) in Hamirpur district of U.P.

F. Available IRS satellite for crop modelling

The Indian space pioneer and the architect of Indian Space Program Dr. Vikram Sarabhai, under whose chairmanship, the Indian National Committee for Space Research (INCOISAR) was formed in 1962 dreamt that India should be sine-qua-none (Meaning – Essential Element or condition) in the application of advanced technologies like space. Since then, India has made impressive progress in this field. Space technology has not only enhanced India's communication capabilities, but has also contributed in meteorological forecasting, providing advanced disaster warning, search and rescue measures and distance education to remote areas. As a frame of reference, satellite image data provide global context information on the location and extent of human activities, which can assist in the planning and coordination of global change research.

Its mandate of the Indian Space Research Organization is the development of technologies related to space and their application to India's development. Since its formation, ISRO has launched numerous satellites under the Indian Remote Sensing (IRS) satellite series. The IRS series provide remote sensing services and are composed of the 1 (A, B, C, D). The recent launches are named based on their area of application including OceanSat, CartoSat, ResourceSat. Some of the satellites have alternate designations based on the launch number and vehicle (P series for PSLV). ISRO and the Department of Space (India) have jointly formed Antrix Corp Ltd, for promoting and marketing IRS satellites.

Remote sensing has enabled mapping, studying, monitoring and management of various resources like agriculture, forestry, geology, water, ocean etc. It has further enabled monitoring of environment and thereby helping in conservation. In the last four decades it has grown as a major tool for collecting information on almost every aspect on the earth. With the availability of very high spatial resolution satellites in the recent years, the applications have multiplied. In India remote sensing has been used for various applications during the last four decades and has contributed significantly towards development.
India has its own satellites like Indian Remote Sensing Satellite (IRS) series - Resourcesat, Cartosat, Oceansat etc which provide required data for carrying out various projects. Some of the important projects carried out in the country include Groundwater Prospects Mapping under Drinking Water Mission, Forecasting Agricultural output using Space, Agrometeorology and Land based observations (FASAL), Forest Cover/Type Mapping, Grassland Mapping, Biodiversity Characterization, Snow & Glacier Studies, Land Use/Cover mapping, Coastal Studies, Coral and Mangroves Studies, Wasteland Mapping etc. The information generated by large number of projects have been used by various departments, industries and others for different

we have different satellites operating over our study region, namely LIS III with resolution of 23.5m, Cartosat 1 with resolution 2.5m and Cartosat 2 with resolution of 1m are available, our application requires collection of satellite data for every 15days or 20day duration LISS-III will supports our purpose but we need high temporal resolution, than Cartosat 1/2 aerial images will be the best, but the duration to capture Cartosat 1/2 around once in 40day and LIS III images can be obtained once in 20days . LIS III will cost approximately 7000 rupees for each 141kmx141km dimension and RS2/L4FMX/5.8m of dimension 70kmx70km with 15 scenes cost 12,000 rupees. The cost of satellite aerial image ranges between 7,000 rupees to 12,000rupees.

G. Super Resolution based Image Reconstruction (SR):

Super-resolution is the task of obtaining a high-resolution image of a scene given low resolution image(s) of the scene. Applications of super-resolution include satellite, forensic, medical imaging, surveillance et al. [8]. Obtaining high-resolution images directly via better hardware (better image sensors, larger chip size) is quite costly. Image interpolation methods are not considered as super-resolution methods since even the ideal sinc interpolation cannot recover the high frequency components that are lost in the low-resolution sampling process. Most of the super-resolution approaches work on the principle of combining multiple slightly-shifted low-resolution images of the scene [9]. This involves image registration, interpolation and deblurring as the basic operations. However, this technique is numerically limited to small increases in resolution. There also exist methods based on techniques like gradient profile priors [10] and sparse representation of images in an over-complete dictionary [11]. A recent approach based on a single image was proposed in [12] that exploits the redundancy of patches within the image and combines this information with example-based techniques such as [13].

Super-resolution mapping is a relatively new field in remote sensing whereby classification is undertaken at a finer spatial resolution than that of the input remotely sensed multiple-waveband imagery. A variety of different methods for super-resolution mapping have been proposed, including spatial pixel swapping, spatial simulated annealing and Hopfield neural networks, feed-forward back-propagation neural networks and geostatistical methods. There is, therefore, a need for greater inter-comparison between the various methods available, and a super-resolution inter-comparison study would be a welcome step towards this goal [14].

A geostatistical optimization algorithm is proposed [15] for super-resolution land cover classification from remotely sensed imagery. The algorithm requires as input, a soft classification of land cover obtained from a remotely sensed image. A super-resolution (sub-pixel scale) grid is defined. The soft land cover proportions (pixel scale) are then transformed into a hard classification (subpixel scale) by allocating hard classes randomly to the sub-pixels. The number allocated per pixel is determined in proportion to the original land cover proportion per pixel. The algorithm optimizes the match between a target and current realization of the two-point histogram by swapping sub-pixel classes within pixels such that the original class proportions defined per pixel are maintained. The algorithm is demonstrated for two simple simulated images. The advantages of the approach are its ability to recreate any target spatial distribution and to work with features that are both large and small relative to the pixel size, in combination.

Need for SR: The spatial resolution of Multispectral or hyperspectral images can be improved to a greater magnitude, and this help accurate analysis and detection of any crop from the satellite image.

H. Data mining, soft computing tools:

Soft computing is a set of “inexact” computing techniques, which are able to model and analyze very complex problems. For these complex problems, more conventional methods have not been able to produce cost-effective, analytical, or complete solutions. Soft computing has been extensively studied and applied in the last three decades for scientific research and engineering computing. In agricultural and biological engineering, researchers and engineers have developed methods of fuzzy logic, artificial neural networks, genetic algorithms, decision trees, and support vector machines to study soil and water regimes related to crop growth, analyze the operation of food processing, and support decision-making in precision farming. With the concepts and methods, applications of soft computing in the field of agricultural and biological engineering are presented, especially in the soil and water context for crop management and decision support in precision agriculture [28].

Thomson and Ross developed a coupled sensor- and model based irrigation scheduling method [29]. Based on this work Thomson [29] described a concept by which readings from sensors could be used to re-parameterize or adjust inputs to a crop simulation model. Readings from sensors and the modeled results were used synergistically in an adaptive learning scheme.

One of the most recent advances in the field of remote sensing has been the adaptation of Artificial Neural Networks (ANN) in a wide range of applications and image analysis and the number of reported application has been steadily increasing. The literature shows that the use of different types of neural networks has been found for various
applications of remote sensing data. The most commonly encountered ANNs in remote sensing are Multilayer perceptron (MLP) type. Among others, applications are found employing the SOM, LVQ, and Hopfield neural networks methods for the classification of remote sensing images. Several researchers also compared the results from neural networks with the results from different conventional classifiers.

In the field of remote sensing, one of the main applications of neural networks is the image classification, including: supervised classification [30]; unsupervised classification [31]; and image segmentation. Some of other uses of neural networks in remote sensing are also found, such as in geometric correction and image compression [32] etc. Different types of neural networks have been used on a variety of remotely sensed data including optical high (Landsat TM, SPOT) and low (NOAA-AVHRR) resolution multi-spectral imagery, data from Imaging Spectrometers (AVIRIS) and SAR data (ERS-1, RADARSAT). Although early experiments made use of single source data, recent research has demonstrated the flexibility of neural networks in the fusion of multi-source data for improved land use and land cover classification.

I. The integration of GIS for image processing:

A GIS is a broad term which encompasses a large range of applications. These applications commonly fulfill the five M’s of GIS: mapping, measurement, monitoring, modeling, and management [33]. The integration of remote sensing and Geographic Information Systems (GIS) has received considerable attention in the literature [35]. The handling of spatial data usually involves processes of data acquisition, storage and maintenance, analysis and output. For many years, this has been done using analogue data sources and manual processing the introduction of modern technologies has led to an increased use of computers and information technology in all aspects of spatial data handling. The software technology used in this domain is Geographic Information Systems (GIS). GIS is being used by various disciplines as tools for spatial data handling in a geographic environment.

J. Supply chain management and crop insurance:

The CMM gives the appropriate scenario of crop yield based on these parameters demand supply chain can be established. This will reduce the delay of reaching the crops to any geographic territory. CMM generated parameters can be used by a government or agriculture insurance agencies based on these parameters they can allocate their financial budget.

K. General purpose graphic processing unit:

When any image processing applications run on normal computers they take huge time for processing the data, the provided data is enormous in magnitude. To increase the processing speed we need to adapt parallel processor architecture. The best solution is to use NVIDIA Tesla GPGPU along with CUDA programs will increase the speed 10X time faster. This will help to perform CMM for large agriculture area.

IV. Conclusion

This paper provides a comprehensive review on the development and application CMM for horticulture crops. The review also confirmed that not many studies (compared to row crop agriculture) have been conducted so far on CMM for horticulture crops. This review paper provides detailed investigation of CMM for horticulture crops specifically related to India. The study provides a detailed application of geospatial and information technology for CMM in general. They can be replicated as described or modified based on local requirements and needs. This study also provides details of super resolution techniques can be used to improve the spatial resolution of satellite image for accurate analysis. Finally, this review paper would encourage researchers to advance the CMM for horticulture crops as is being done in other row crop cases. The exploration concludes with an innovative model for integration of CMM with Geographic Information System (GIS) which can benefit “demand and supply chain management”, and crop insurance.

ACKNOWLEDGMENT

We would like to express our hearty gratitude to Principal, KLS GIT, Belgaum and KLS society for providing opportunity to do research work. We would like to express thanks to KSRSAC, Bangalore and VTU Belgaum. We thank Dr. T.GK Murty Ex- Director, ISRO Banglore.

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