Application of Geoinformatics in Automated Crop Inventory

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ABSTRACT

An attempt has been made in this study to review the role of geoinformatics to discriminate different crops at various levels of classification, monitoring crop growth and prediction of the crop yield. The suitability of geoinformatics techniques suited to Indian conditions has also been assessed. Development in applications of computers and information technology has enhanced the capability of gathering huge and mottled data as well as information, ranging from historical data, ground truth values and aerial photography to satellite data. Thus remote sensing data and the information derived from it, is attractive to agricultural management system in the India. It is concluded that, in addition to the remote sensing technology, the use of many other techniques such as ground observations, reviews, GIS and soil analysis is highly appreciable.

Keywords

Remote Sensing, Crop Yield, Geoinformatics, GIS, GPS, RDBMS, Satellite Data, Crop Inventory, Crop Models.

1. INTRODUCTION

India covers contains about one fourth of earths geographical area, whereas it caters about one seventh of world population. Food grain demand is gradually increasing due to escalating population, improved socio economic conditions and food habits. Prognostic study indicates that in approaching 30 years the food grain production has to be doubled to meet out the growing need. Food grain production depends upon a variety of earth factors. These factors may be clubbed as, above surface, surface and below surface parameters. For optimal and sustained food grain production new methods, monitoring techniques and predictive crop growth and yield model are always welcomed. Generally the required data for monitoring, evaluation, and modelling is not available or insufficient. Therefore there is pressing need to update and generate the required data and automated crop inventory using the contemporary capabilities of geoinformatics.

Geoinformatics may be broadly defined as the combination of technology and science dealing by means of the spatial information, its acquisition, its qualification and classification, its processing, storage and dissemination. Geo-informatics is an integrated tool to collect process and generate information from spatial and non spatial data. Geoinformatics is an appropriate blending of modules like Remote Sensing (RS), Global Positioning System (GPS), Geographical Information System (GIS) and Relational Data Base Management System (RDBMS).

Data collected by remote sensing system and some other means is processed, managed, analyzed and disseminate by Geographical Information System (GIS). RS is the technology used to acquire information regarding an object, a process and some phenomena without being in contact. RS is generally based on information collected from satellites or airplanes, using sensors operating in various parts of the electromagnetic spectrum. GPS tools are used to acquire particular measurement of an object's position in terms of latitude, longitude and altitude. These technologies endow with a cost effective way to study the atmosphere, geosphere and biosphere interactions at global scale whereas at micro scale also, space technology exhibits appropriate inputs for optimal use of available natural resources.

To keep an eye on the changes in the crop cover using remote sensing and modelling crop growth, crop yield and drafting agricultural practices for optimal crop yield using GIS is a good example of micro and macro-level applications. Relational Data Base Management System (RDBMS) is software that manages the data to produce relevant information in a very effectual manner. Outputs of geo-informatics provide a superb solution for the modeling and monitoring of crop at a range of scales and thus support planning and management of agricultural resources.

It is established fact that agricultural research has been benefited from conglomeration of technological advances largely developed for other industries. The industrialization brought mechanization and chemical fertilizers to agriculture. The technological development has offered efficient agricultural practices including genetic engineering and automation for more food per unit of natural resources. The information technology improved the potential for integrating the technological and industrial advances into sustainable agriculture production system. The application of the computer in agriculture research initially exploited for the adaptation of statistical formula or complex model in digital form for simple and precision agriculture.

Currently computers are being used for automation and to expand decision support systems (DSS) for the agricultural production and fortification research. Recently geographic information systems and remote sensing technology has come up with a capable role in agricultural research predominantly in crop yield prediction in addition to crop suitability studies and site specific resource allocation.

In this paper an attempt has been made to review the role of Geoinformatics to discriminate different crops at various levels of classification, monitoring crop growth and prediction of the crop yield. The suitability of geoinformatics techniques suited to Indian conditions has also been assessed.

The planning and management of agriculture goad to optimize the food production per unit of natural resources. Information captured on soil and water conservation and acreage estimation of different crops using recent technologies such as remote sensing and GIS may lead to optimal agricultural production. Laboratory and farm level studies has clearly brought out the fact that adaptation of integrated land water and crop management practices, integrated manure and pest management practices have positive impact on augmenting the agriculture production.

Information related to agricultural inputs collectively with reliable data on already existing acreage and land under a range of crops, types of soils and problems related to soils, water availability in irrigation systems and management of natural and other crop related disasters will facilitate evolution of suitable strategies to keep going the pace of developments in agricultural research.

The kind of information thus needed to develop a computer system included (1) crop signature tables showing the upper and lower limits of crop color variation at various crop ages, (2) physical factors such as climate, soils, salts problems (3) cultural factors such as location of producing area to markets, land costs, export crops, farming patterns (4) a land use code (5) base maps and (6) a crop calendar of the area.

With a view to handle these complex problems, the technology based on remote sensing provides a number of benefits over conventional methods. The benefits include ease of use and multi spectral data for providing passionate information, potential to provide multi temporal data to give a picture of long term and seasonal changes and availability of descriptions with minimum distortion.

Development in the information technology has enhanced the capability of gathering huge and mottled information, ranging from historical data and aerial photography to space borne data, ground truth values and other forms of ancillary data. In addition to remote sensing, the other methods and techniques that can be comprehensively employ such as GPS, GIS and ground observations as well as soil analysis in order to get quality estimation of crop yield management system in the India.

2. APPLICATION AREAS

From a limited study it has been found that Geoinformatics can support the development and intensification of the quality of agricultural research. Applications and contributions of geo-informatics are very significant largely in the areas of crop yield estimation, spatial modeling, spatial sampling, classification, integrated surveys and web based applications.

2.1 Crop Yield Estimation

Estimation of Crop yield well before the harvest at regional and national scale is imperative because of the budding need for the planning at micro-level and predominantly the demand for crop insurance (Anup et al. 2005). Crop yield estimation plays a significant role in economy development (Hayes and Decker, 1996). Currently it is being done by extensive field surveys and crop cutting experimentation. This enables decision makers and planners to predict the amount of crop import and export. In most of the developing countries the crop yield estimation is generally based on traditional methods of data collection which is based on ground based field surveys (Reynolds et al. 2000).

Conventional methods have been found to be expensive, time consuming and are prone to large errors due to incomplete and inaccurate ground observations, leading to deprived crop area estimations and crop yield assessment. In most of the developing countries the required data is generally available too late for any appropriate decision making. Objective, consistent and possibly inexpensive and or faster methods that can be used for monitoring of crop growth and an early estimation of crop yield are imperative. Data captured through remote sensing has the prospective, capacity and the potential to exhibit spatial information at global scale.

3. DIFFERENT APPROACHES

This section briefly portrays the different approaches and technologies used for crop inventory.

3.1 Aerial Photography

To obtain crop yield information, one must be able to recognize tone, pattern, texture and other features. Crop yield information is used in conjunction with crop acreage statistics to obtain crop production. There are two distinct aspects of yield determination (1) the forecast of yield based on characteristics of the plant or crop and relationship based on experience in prior years, and (2) estimates of the yield known from the actual weight of the harvest crop for the current year. After the World War II various researchers used the emerged concept of aerial photography for the optimized use of resources for the agriculture and crop inventory.

Goodman (1959) used black and white photography for crop identification. Author developed the techniques primarily based on ground appearance and the equivalent aerial photographic form of selected fields at nine intervals during the growing season.

Goodman (1964) used three sets of criteria that can be read or inferred from aerial photographs, that serve as indicators for crop identification (1) farmstead features such as barns, granaries, and silos; (2) crop associations; and (3) the uses that are made of particular crops.

Anson (1966) found that CIR photography have more impact than black & white and color photographs for the extraction of vegetative details. It permits making a ready peculiarity between soil and vegetation that is not always possible using black & white photography. The background can be approximately has the same tone as the plants in case of black and white photograph, making photo interpretation more difficult.

Various researchers in the past found that use of photographs or spectral values is an important information source for predicting crop yields and has been focused on the possibilities of forecasting yield from plant measurements. Houseman and Huddleston (1966) cite results which have been promising form making forecast of field crops such as cotton, maize, wheat, soybeans and a typical example is cited by Small (1967) for tree crops such as walnuts, oranges and filberts.

Johnson et al. (1969) identified crops based on the image color and developed a computer land use mapping system. The authors indicate that overall poor results were due to color variations based on seasonal crop variations and film quality control.

In a photographic study by Roberts and Gialdini (1970) nine crops were grown in small plots to evaluate tone differences resulting from differences in the radiation reflected from the vegetation only and not confounded by radiation reflected from the soils through varying degrees of canopy closure. It was shown that no single film filter combination can be used to discriminate among all the crops.

Yost et al. (1970) attempted to extract land use information by making quantitative colorimetric measurements of additive and subtractive color infrared film. Additive color was found to be the best method for discrimination, separation positives and color infrared were second and third, respectively. The brightness or density of the image was not effective for identification.

Coleman et al. (1974) utilized the photography to attempt to show a more cost effective method of detecting and subsequently regulating cotton farming practices to aid in the control of pink bollworm. Researchers also had shown that for the purpose of identification of crops the higher the availability of temporal data and higher will be the expected accuracy.

3.2 Multispectral Scanners

Multispectral scanners (MSS) have certain advantages and disadvantages when compared to photography. Landgrebe et al. (1967) showed the ability to differentiate wheat from other agricultural crops using multispectral data in a computer format with pattern recognition techniques. An important consideration in the task of species identification is the stage of growth of the crop.

Early work at LARS (Laboratory for Applications of Remote Sensing) at Prudue University showed the easy separability of MSS data into the broad surface-feature grouping of green vegetation, water and bare soil (Kristof, 1969). The identification and mapping of specific crop species requires the acquisition of sufficient and accurate ground observations as training sets for computer implemented analysis.

Hoffer and Goddrick (1971) demonstrated that the influence of geographic area is closely related to changes in the crop maturity. They used MSS data over four flight lines extending across 100 miles of agricultural land in central Illions and were able to separate wheat from other crops with over 90 percent of accuracy on test fields.

3.3 Radar

The advantages and limitation of using either airborne or spacborne radars fro crop identification are discussed by Morain et al., (1970). He points out that many of the radar studies have concentrated on seasonal change between crops and that numerous variables must be considered in making even the simplest determinations.

Morain and Coiner (1970) and Schwarz and Caspall (1968) worked with imagery from Radar, they shown that major agricultural crops can be segregated, though not unambiguously identified, using simple two-dimensional plots of HH and HV films.

3.4 Satellite Data

Estimation models for Crop area and yield have been studied for a long time, and numerous good quality models have been developed, but these conventional models have been developed primarily from the point of view of meteorology and biology without concern of remote sensing, and thus cannot meet the requirements of today's society. The utilization of remote sensing data for agricultural development was investigated in the USA in 1971 under Corn Blight Watch Experiment (CBWE). The remote sensing data has been proven effective in predicting crop yield and provide representative and spatially exhaustive information on the development of the model for the crop growth monitoring. Another experiment carried out using Landsat data was CITARS - Crop Identification Technology Assessment for Remote Sensing. It aimed at identification of two major crops corn and soybean and testing the concept of signature extraction.

Large area crop inventory Experiment (LACIE) carried out during 1974-78 was a major international study carried out in major wheat growing areas of the world. The models used in LACIE were statistical models, in which yields is modeled as function of air temperature and rainfall and the project was reported one of the first examples in which production is forecasted through satellite remote sensing and measured meteorological observations on the ground (Doraiswamy et al., 2003).

As of today a large number of researchers and academicians are working for methodological expansion in field of investigation. In India remarkable spurt in the remote sensing activities has started with the launch of the IRS (Indian Remote Sensing Satellite) 1A in the year 1988. India launched a variety of satellites devoted to particular area of relevance such as ResourceSat, CartoSat, and OceanSat.

The remote sensing data has been proven effective in predicting crop yield and provide representative and spatially exhaustive information on the development of the model for the crop growth monitoring. Various indices based on remote sensing have been employed to estimate the yield of several types of crops. For instance, the normalized difference vegetation index (NDVI) has been used to estimate the yield of rice (Rouse et al., 1974). However, yield estimation with remote sensing has limitations, mainly due to the indirect nature of the link between the NDVI and biomass but also due to the sensor spatial resolution or insufficient repeat coverage.

Tucker et al. (1980) used ground - based spectral radiometers to identify the relationship NDVI and crop yield and proved the high correlation among the crop yields and NDVI. Das et al. (1993) used greenness and transformed vegetation indices to predict wheat yield at 85–110 days before harvest in India. These early studies led to crop yield estimation in several countries using satellite imagery.

Lennington and Sorensen, 1984, Gallego et al., 1993 and Mccloy et al., 1987, proposed the models based primarily on remote sensing, that congregate the requirements for optimum quality and management over quite large areas. The studies also proved that these are different from the traditional models.

Rudoff and Batista (1990) estimated sugarcane crop in Brasil using remote sensing and an agrometeorological model based on a model developed by Doorenbos and Kassam (1979) where yield is related to multiple regression approach used to integrate the vegetation index from Landsat and the yield from the agrometeorological model. Such estimations explained 50, 54 and 69% of the yield variation in the 3 growing seasons analyzed. The authors also tested the accuracy of sugarcane yield estimations using only the RS or the agrometeorological model only. The results were poorer compared to the combinations of both (Rudorf and Batista, 1990).

Goyal (1990) carried out a study in Sultanpur district of Uttar Pradesh to assess the crop area and yield estimation. The study demonstrated that remote sensing satellite spectral data and consequent vegetation indices can be used for the mapping. Conjunctive use of satellite derived information and the ground based yield data have enhanced the estimation of crop yield. For this study the Landsat (Thematic Mapper-TM) satellite data and the crop yield data from crop cutting experimentation have been used. It was observed that NDVI as compared to RVI (Ratio Vegetation Index) exhibits higher capability to classification of vegetation vigor and estimation of crop yield. An effort was also made to enumerate the effect of the misclassification. An attempt was also made to investigate the worth of spectral data in forecasting the crop yield and the correlation between wheat yield and the spectral parameters acquired through the hand held spectral radiometers.

Singh and Goyal (1993), Singh and Goyal (2000) and Singh et al. (2002) carried out extensive study for estimation of wheat crop yield for Rohtak district in Haryana. They used data from the crop cutting experiments of the year 1995 and 1996 and multi spectral data from the IRS-1B (LISS II) data for 17th February, 1996. Estimation of crop yield by means of indices RVI and NDVI have been observed. The efficiency of the observed estimation as compared to the usual estimator worked out to be 1.42 and 1.28 respectively. The proposed model also confirmed that the estimation of crop yield at district level may be obtained by dropping the number of crop cutting experiments to nearly 2/3 with no loss in the precision and thus ensuing the savings in cost. The study also demonstrated that synthetic estimator is more good at your job as compared to the direct estimator and the standardized error of the direct estimator as well as synthetic estimator at Tehsil level is within 5 per cent.

The NDVI from the National Oceanic and Atmospheric Administration – Advanced Very High Resolution Radiometer (NOAA–AVHRR) amid spatial resolution of 1000 m exhibits a strong correlation with wheat yield in Italy (Benedetti and Rossini, 1993).

A large number of studies observed that as compared with low-temporal resolution measurements, high-spatial resolution sensors can more accurately forecast crop yield. Hamar et al., (1996) proposed a linear regression model to forecast corn and wheat yield at regional scale. The model was purely based on vegetation spectral indices obtained using Landsat (MSS) data.

Gupta (2002) developed an incorporated methodology for estimation of wheat crop yield utilizing the survey data from the crop cutting experiment as well as the spectral data from the satellite obtained as NDVI. The study also demonstrated that the usefulness of remote sensing data associated with the crop yield parameters from crop cutting experiments can greatly enhance the efficiency of the estimation methods of crop yield for small area.

(Langley et al. 2001; Nordberg and Evertson 2003) explored the crop cover changes over large areas and shown that the remote sensing technology offers a realistic and economical means. The technology of remote sensing extends possible data collection from current time to over more than a few decades back as well as its potential capacity for systematic interpretation at a range of scales. Due to this fact the colossal efforts have been made by application specialists and researchers to delineate crop cover from local scale to global scale by using remote sensing data. Jung et al. 2006, highlighted the different mapping approaches with their strong points and weaknesses.

Ahmad et al., 2003 developed a technique that supports GIS for the identification of different crops in Yamunanagar district of Haryana. In this paper the different factors responsible for crop growth were recognized, index for the suitability by means of Spatial Analytic Hierarchy Process was identified and captured. Obtained index was also compared with the Composite development index.

Ferencz et al., 2004, presented two methods for estimating the yield of different crops in Hungary using remote sensing data of Landsat (Thematic Mapper). The requirement of the pre processing steps like atmospheric, geometric, radiometric and scattering correction has also been discussed. They used a new vegetation index GYURI - General Yield Unified Reference Index based on fitting of double Gaussian curve to the NOAA-AVHRR data during the period of crop growth. They also investigated one more method using only NOAA-AVHRR county-level yield data. The county-level yield data and consequently the obtained vegetation index GYURI for eight dissimilar crops for eight years. The proposed method is inexpensive and simple to use.

A new approach of estimation of crop yield incorporating multi resolution satellite data was proposed by Das, 2004. The attempt was made to incorporate the satellite spectral data and spatial sampling values for estimation of crop yield, crop acreage and crop yield forecasting. The proposed method used satellite data of coarse resolution, that is inexpensive and covers a large area as compared with higher resolution. The study also demonstrated the higher efficiency of multiple frame sampling estimates as compared to estimations using single index. Supervised maximum likelihood classification approach was used for the classification of satellite data. The study also discussed about the noise during the classification which is just due to the presence of the mixed pixels. A new model of classification based on fuzzy classification developed by indicator Kriging is also proposed in the study.

Anup et al. 2005, considered different parameters like NDVI, surface temperature, soil moisture and rainfall data for crop yield review and prediction using piecewise linear regression model with breakpoint. Crop production environment contains inherent sources of heterogeneity and their non linear behavior. A non linear Quasi-Newton multivariate optimization approach has been utilized, that reasonably minimizes errors and inconsistency in yield prediction. A function based on minimization of least square loss has been employed through iterative convergence by predefined empirical equation that provided tolerable lower residual values with forecasting values very close to observed ones ($R^2 = 0.86$) for soybean crop and ($R^2 = 0.78$) for Corn crop. This study also proved that crop yield predicted based on data obtained before harvest is of acceptable accuracy.

Ren et al. 2008 proposed a method of crop yield estimation using the MODIS-NDVI data on a regional scale. With the intention of improving the quality of obtained remote sensing data and the accuracy of yield estimation, the filter known as Savitzky–Golay filter was utilized to smooth the 10 days NDVI data. A stepwise regression method was employed to establish a linear relationship between the spatial accumulation of NDVI and the production of winter wheat. To validate the obtained results the data from the ground surveys was used and the errors were compared with the values from agro-climate models. The obtained results proved that the relative errors of the predicted yield using MODIS-NDVI are between 4.62 and 5.40 percent and that calculated RMSE was 214.16 kg/ha lower than the RMSE (233.35 kg/ ha of agro-climate models.

Hu and Mo (2011) proposed a process based model of crop growth which is known as VIP-Vegetation Interface Processes model to estimate crop yield using remote sensing data over the North China Plain. Statistical yield records and values of

NDVI from Terra-MODIS were used to obtain the spatial pattern of one of the key parameter, maximum catalytic capacity for assimilation. It was shown in the study that photosynthetic parameters acquired from remote sensing data are reliable for prediction of regional production using a process based model.

Mkhabela et al. 2011, proposed a new model to estimate the crop yield using MODIS data and NDVI. Regression and correlation analyses were carried out using 10 days composite NDVI data and running average NDVI with the maximum correlation coefficients as the independent variables and crop yield as the dependent variable. The ability and the robustness of the generated regression model to predict crops grain yield was testing with removal of one year at a time and new regression models were obtained, which were then used to predict the yield for the missing year. Results proved that MODIS-NDVI values can be used very effectively to predict the crop yield. They summarize that accurate crop grain yield forecasts using the proposed regression models can be made one to two months before the harvest.

Chimnarong et al., 2012 discussed the use of remote sensing data as a reliable and efficient means of gathering the information required in order to map crop type acreage and condition. The study area comprised of four provinces, Khon Kean, Chaiyaphum, Nong Bue Lum Phu and Mahasarakham in Northeastern of Thailand. Landsat5 TM digital data (Dec, 2011) was evaluated for the potential utility of remote sensing derived NDVI for sugarcane production estimation. Sum of NDVI of individual sampling fields were correlated with the actual production (ton/ha). NDVI that describes the healthiness of crop is one of the factors of yield variability. The result showed correlation 0.75 for sum NDVI image and sugarcane production. The other factors which influence variations are color of leaf and age of cane. The study suggested the integration of remote sensing satellite data with other parameters like age of the crop and variety difference to improve the accuracy.

Mishra et al. 2013, proposed a model based on energy balance known as ALEXI - Atmosphere Land Exchange Inverse (ALEXI) model, which is used to deduce root zone soil moisture for North Alabama, USA. The obtained soil moisture estimates were further utilized in crop simulation model popularly known as DSSAT - Decision Support System for Agrotechnology Transfer. The study area contains a mixture of irrigated and rainfed cornfields. The results designate that the model forced with the ALEXI moisture estimates generated yield simulations that compared positively with observed yields. The results shown that the ALEXI model is able to detect the soil moisture signal from the mixed rainfed and irrigation corn fields and the signal was of adequate strength to produce enough simulations of recorded yields over a 10 years period.

Wang et al. 2014, proposed the model to determine the optimal spectral index and the best time for predicting grain yield and grain protein content in wheat by fusion of multi temporal and multi sensor remote sensing data. Four field experiments were carried out at different locations, cultivars and nitrogen rates in two growing seasons of winter wheat. The results illustrated that the NDVI estimated by fusion, exhibits high consistency with the SPOT-5 NDVI, which confirmed the usefulness of related algorithm. The use of RVI at the initial filling stage obtained enhanced accuracy in wheat yield prediction. In addition, the accumulated spectral index from jointing to initial filling stage gave higher prediction accuracy for protein content and grain yield, respectively, than the spectral index at a single period. These results help provide a technical method for the prediction of grain yield and protein content in wheat with remote sensing at a large scale. This prediction model based on multi temporal remote sensing data can be suitable for the much clear sky conditions during the main growth period of winter wheat.

Here it can be concluded that RS techniques have been extensively used in research for yield forecast but played a small role in understanding the cause of spatial yield variability. Also, it has been argued that while RS might not be suitable in developing countries because of their stratified agricultural systems and very small farm sizes. However, this problem is hard to overcome in the near-future because of the inability of RS to estimate yield in mixed agriculture. But, the increased availability of high-spatial resolution RS at a reasonable cost make this technique a possible interesting alternative for yield forecast.

4. CONCLUSIONS

Based on the literature review the advances in the development of international research on crop monitoring and crop yield estimation can be separated into the following stages (MacDonald and Hall, 1980, Sun et al., 1996):-

(1) before the 1940, qualitative analysis all the way through comparison and relating meteorological conditions and crop yield was put forward.

(2) during 1950-70, statistics emerged very quickly, and the regression models between the crop yield and weather conditions were utilized very effectively. With the invent of aerial photography and rapid expansion and application of computers, researchers and application scientists put forward many crop simulation models.

(3) during 1970-90, with the launch of satellites, the researchers began to use remote sensing techniques for the estimation of crop yield at global scale, which lift up the yield estimation models to a higher level.

(4) in the 1990-2000, researchers focus more on the combination of high resolution satellite images, vegetation indices and statistical procedures to estimate global crop yield.

(5) the current stage of the technological development engrossed the amalgamation of the remote sensing , GIS and GPS (Rao and Rao, 1987, Tennakoon et al., 1992). Due to the theoretical and scientific achievements in the yield estimation using remote sensing in the present decade, the researchers and the application scientists frequently use multi date high resolution satellite and meteorological data with the support of the GIS to estimate yield, and they also operate on coarse resolution data as a sampling tool to improve the precision. Chronological growth in terms of Crop Inventory using geo informatics is shown in Table1

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Table 1. Chronological Growth of Crop Inventory using Geoinformatics

Period	Technology	Features
Before 1940	Crop Cutting Experiments	Qualitative Analysis
1950-1970	Aerial Photography and Computers	Regression Models based on statistical data
1970-1990	Satellite Imagery	Crop Yields at Global Scale
1990-2000	High Resolution Satellite Imagery	Statistical as well as Vegetation Indices
2000 onwards	amalgamation of the remote sensing, GIS and GPS	Crop Inventory based on crop simulation models and crop growth models.

It is also concluded that the crop yield and growth monitoring both affected by many composite factors, such as natural disasters with the intention of occur suddenly and are beyond man's control as well as those habitat factors that can be controlled by human. Although it is possible to acquire the reliable and timely information about the earth resources by the means of remote sensing, yet it is not adequate to monitor the growth and estimate the yield of crops in the absence of other parameters (Sun et al. 1996). Thus, in addition to remote sensing, the use of many other techniques such as ground observations, reviews, GIS and soil analysis is highly appreciable. Based on the intensive studies in the past, it is evident that the research using Geoinformatics to obtain the agricultural statistics can be carried out in three phases. Overall flow diagram for the crop yield model using remote sensing is shown in Fig 1.

Phase 1 : Capture Remote Sensing Data and Field Survey data

Phase 2 : Pre-processing and analysis of the collected data

Phase 3 : Design of proposed model and obtain the results

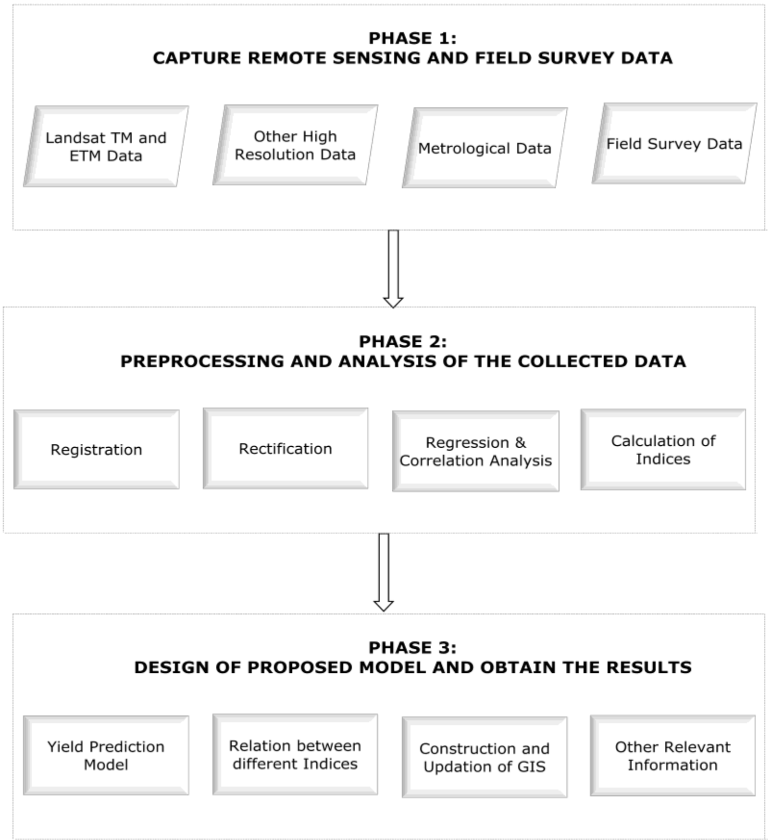

Fig 1: Overall flow diagram for the crop yield model using remote sensing

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