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17. Remote Sensing and GIS in Soil, Water and Crop Management

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Abstract:

Remote sensing data, both optical and microwave form the core of soil inventory, crop area enumeration, crop condition assessment and production forecasting. Space borne spectral measurements with moderate spatial resolution have been used at operational level for deriving information on salt affected soils and to study their temporal behavior, which is useful for planning and monitoring reclamation programmes. Crop yield is estimated using spectral yield models and also crop growth simulation models. FASAL approach also involves using econometric models to forecast the area and production before the crop sowing operations. Yield models were also developed between NDVI and yield and yield map was generated using crop cutting experiments. The study showed very high efficiency of stratified sampling plan generated for CCE based on NDVI values. Using remote sensing to assess and monitor insect defoliation, spectral response to chlorosis, yellowing leaves, and foliage reductions over a given period of time has been used to relate those differences' correlations, classifications, and interpretations. The remote sensing data of NOAA AVHRR (for district level), MODIS and Resourcesat-2, Advanced Wide Field Sensor, AWiFS (for sub-district level) along with rainfall data are used for drought assessment. The soil maps for the study area was prepared using IRS-1B LISS-II data at 1:50,000 scale. Suitability criteria for groundnut crop in terms of climate, soil and site parameters were developed following FAO approach and incorporated as decision rules in GIS environment. Spaceborne spectral measurements with moderate spatial resolution have been used at operational level for deriving information on salt affected soils and to study their temporal behavior, which is useful for planning and monitoring reclamation programmes.

Keywords:

Remote sensing; GIS; Crop production; Crop yield forecasting; drought monitoring.

17.1 Introduction:

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers to sense information about the Earth features.

A recent report by the FAO projects that an increase in world population to 9.15 billion by 2050, which may need the current food production to increase by 60%. Many efforts are underway to increase overall production to feed the burgeoning population by increasing efficiency in production such as high intensity agriculture, efficient water use, and high yield varieties. Agricultural production follows strong seasonal patterns related to the biological lifecycle of crops.

The production also depends on the physical landscape (e.g., soil type), as well as climatic driving variables and agricultural management practices. All these variables are highly variable in space and time. Moreover, as productivity can change within short time periods, due to unfavorable growing conditions, agricultural monitoring systems need to be real time for higher productivity.

Therefore, use of remote sensing is indispensable in monitoring of soil characters, agricultural field, crop & soil health, water management and its quality, and atmospheric conditions with emphasis to yield. During the last two decades, remote sensing techniques are applied to explore agricultural applications such as crop discrimination, crop acreage estimation, crop condition assessment, soil moisture estimation, yield estimation, precision agriculture, soil survey, agriculture water management, agro meteorological and agro advisories. The application of remote sensing in agriculture, i.e. in crops and soils is extremely complex because of highly dynamic and inherent complexity of biological materials and soils (Myers, 1983). However, remote-sensing technology provides many advantages over the traditional methods in agricultural resources survey. The advantages include (a) capability of synoptic view, (b) potential for fast survey, (c) capability of repetitive coverage to detect the changes, (d) low cost involvement, (e) higher accuracy, and, (f) use of hyperspectral data for increased information. As mentioned, there are many applications of remote sensing in the agricultural sector. Below is a summary of these applications.

Electromagnetic energy is all that energy which moves with the velocity of light in a harmonic wave pattern. The wave concept explains the propagation of electromagnetic energy, but this energy is detectable only in terms of its interaction with matter. Electromagnetic radiation consists of an electrical field (E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (C). A number of interactions are possible when electromagnetic energy encounters matter depending on its properties, whether solid, liquid or gas.

Energy may be (i) transmitted, through the substance, (ii) absorbed by a substance, (iii) emitted by a substance, (iv) scattered, i.e., deflected in all directions and lost, and ultimately (v) reflected. If it is returned unchanged from the surface of a substance with the angle equal and opposite to the angle of incidence, it is termed specular reflectance (as in a mirror). If radiation is reflected equally in all directions, it is termed diffuse. Real materials lie somewhere in between. The science of remote sensing detects and records changes in electromagnetic radiation by magnitude, direction, wavelength, polarization and phase. The resulting images and data are interpreted remotely to identify the characteristics of the matter that produced the changes in the recorded electromagnetic radiation. Basic processes of remote sensing are depicted in pictorial form and are listed as follows:

- Energy source (sun or transmitter)
- Transmission of energy from source to object
- Energy interaction with object surface
- Transmission of energy to sensor
- Scattering and absorption by atmosphere
- Detection, measurement and output by sensor
- Data acquisition, recording, pre-processing and analysis/interpretation

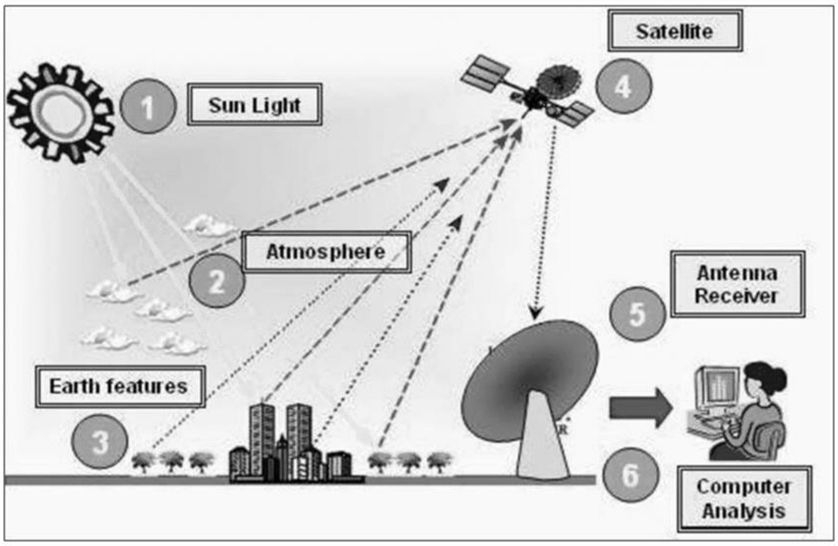

Figure 17.1: Remote Sensing Processes

In India, agriculture is one of the major application areas of the remote sensing technology. Various national level agricultural applications have been developed which showcases the use of remote sensing data provided by the sensors/satellites launched by the country's space agency, Indian Space Research Organization (ISRO). Some of these applications include, crop acreage and production estimation, cropping system analysis, agricultural water management, drought assessment and monitoring, horticultural development, precision farming, soil resources mapping, potential fishing zone forecast, watershed development, climate impact on agriculture and so on (Navalgund and Ray, 2000, Panigrahy and Ray, 2006, Navalgund et al., 2007). A few of these applications, after reaching operational level, have been transferred to the user departments. This has resulted in the institutionalization of the remote sensing applications at district and state level in the country. Crop monitoring, drought assessment and weather forecast information for decision support at farmer level as well as local administration level are some of the examples.

The spectral characteristics of different objects are unique in nature and can be utilized to derive information such as temperature, water content etc. The use of visible, infrared and microwaves to evaluate any physical features has been well established. It is used to distinguish vegetation from bare soil, water, and other similar features based on the responses of the targets to these wavelength regions (Figure 17.2).

Also, it can be used in monitoring crop growth, land use pattern and land cover changes, mapping of water resources and monitoring of water status, weather forecasting and crop yield estimation, and monitoring diseases and pest infestations. Thus the application of remote sensing data in agriculture can provide a timely, efficient, and cost efficient approach (Justice et al., 2002). Several agro meteorological applications are also possible. It is very useful to forecast crop yields by using remote sensing inputs in conjunction with crop simulation models. For complementing traditional meteorological and crop status data collection methods, the space based satellite technology is becoming increasingly important, since ground and air-based platforms are time consuming and limited in their use

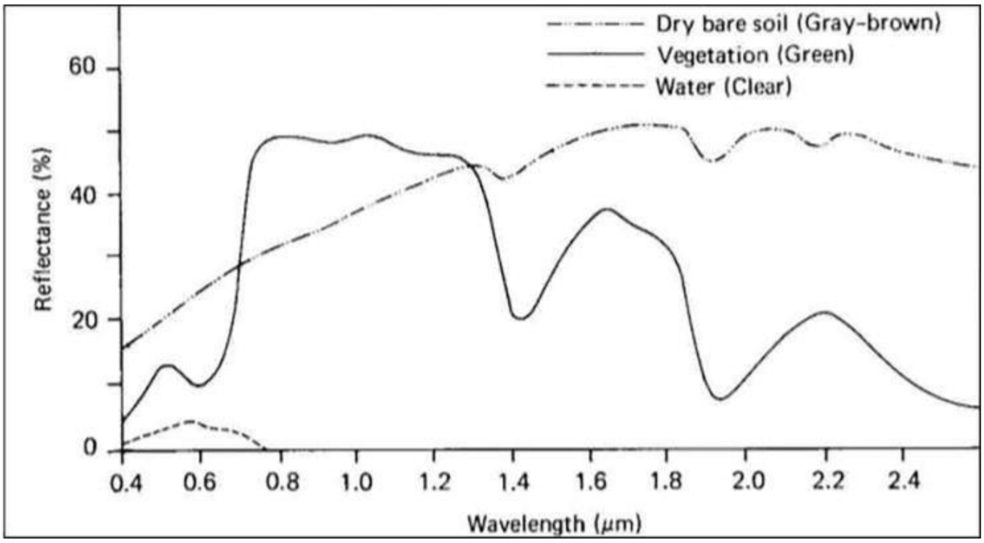

Figure 17.2: Typical Spectral Reflectance Curves for Vegetation, Dry Bare Soil and Water

17.2 Remote Sensing and GIS In Resource Mapping:

The information on soils with regard to their nature, physical –chemical characteristics and spatial distribution is of paramount importance in formulating any optimal land use plan. Hitherto such information had been generated through traditional soil surveys using topographical sheets or cadastral maps as database. This approach is not only costly and cost- prohibitive but at the same time impractical for inaccessible terrain. The availability of aerial photographs and subsequent development of air photo interpretation techniques in the 1960's augmented the soil survey programmed substantially. With the advancement in the sensor technology, ground based studies of the spectral reflectance characteristics were made to study the contribution of various soil parameters, namely soil texture, organic matter, iron oxide, soil moisture, etc. (Baumgardner *et al*. 1970; Stoner *et al*. 1980, Rao *etal*. 2001 Seghal *et al*. 1985, Dwivedi *et al*. 2000).

The understanding of the spectral response pattern of soils, thus developed, was utilized in the analysis of spaceborne multi-spectral data from Earth Resources Satellite (ERTS-1) later renamed as Land sat 1, for generating information on soil resources.

The relationship between physiography of an area and soils has been widely recognized as the factors involved in the physiographic processes corresponds close to that of soil formation. The relationship between landscape features and soil conditions makes possible for prediction about nature and distribution pattern of different kind of soils. For mapping soils identification of lithology and physiography of the area is very important. For deriving the information on parent material, the spectral signature in the analog multispectral satellite data is correlated with the data available in the published geological maps.

The correlation, thus observed is validated in the field. Information about the relief is available in the topographic maps and field observations, reasonably reliable data on terrain physiography could be generated. Having delineated broad physiographic units and the underlying parent material, the next step is to further categorize the physiographic units based on surface drainage pattern, soil erosion status and land use/ land cover. These features are manifested in the multi-spectral images as individual or combinations of various image elements namely; tone, texture, size, shape and association. Each subdivision of the broad physiographic unit comprises a unique soil category. The soil mapping has been carried out at 1:50000 scale and the soil units were classified up to family as per the USDA taxonomic classification.

17.3 Remotes Ensign and GIS in Land Degradation Mapping and Monitoring:

Land degradation, generally, signifies a loss or reduction of land productivity as a result of human activity (UNEP, 1993). The term 'land' includes land and local water resources, the land surface and its natural vegetation. Land degradation is a natural process, and is accelerated by human activities on land. The major processes of land degradation *viz*., Erosion, Waterlogging, Salinity, Areas affected by Industrial effluents and minig were mapped at 1:50000 scale.

The major category other than erosions is areas affected by salinity. Space borne spectral measurements with moderate spatial resolution have been used at operational level for deriving information on salt affected soils and to study their temporal behavior, which is useful for planning and monitoring reclamation programmes (Singh and Dwivedi, 1989, Dwivedi *et al*. 2001. Annonymous, 2018b). Salt-affected soils with salt encrustation at the surface are, generally, smoother in image texture than non-saline surface and cause high reflectance in the visible and near infrared bands. Strongly saline-sodic respectively reflect more incident radiation (35-60%) as compared to moderately saline-sodic soils (pH: 9.0-9.8, ECe: 8.30 and ESP: 15-40).

17.4 Remote Sensing and GIS in Land Productivity Assessment:

The soil / land productivity assessment is one of the several soil survey interpretations which plays a critical role in the generation action plan for sustainable development of soil and water resources. An experiment has been carried out with the objective of assessing the land productivity using remote sensing and GIS techniques (Ravisankar, 2001). To assess the land productivity, initially soil map of the study areas are prepared at suitable scale. The land productivity index (LPI) of the area are assessed with respect to crops, pasture and forest / trees, following parametric approach of Riquire et al (1970).

GIS tools were used for calculating LPI values for soil types and for deriving area weighted LPI values for soil mapping units and in the generation of Land Productivity map for the study area. The LPI varied from 8 – 65 for crops and forest / tree species and 8 – 58 for pasture for different soil mapping units. The study revealed that in the test site all soil mapping units have better coefficient of improvement with respect to crops (0.7 to 2.6) and minimum for forest / tree species (1.0 to 2.0).

17.5 Remote Sensing and GIS in Crop Yield Forecasting:

Crop forecasting is essential for various agricultural planning purposes, including pricing, export/import, contingency measures, etc. Crop forecasting using remote sensing data started in late 80s in Space Applications Centre of ISRO under the Department of Agriculture & Cooperation (DAC)'s sponsored project CAPE (Crop Acreage and Production Estimation).

This later on developed into a national level programme, called FASAL (Forecasting Agriculture using Space, Agro-meteorology and Land based observations), which is in operation since August, 2006. FASAL project aims at providing multiple pre-harvest production forecasts of crops at National/State/District level (Parihar and Oza, 2006).

Remote sensing data, both optical and microwave form the core of crop area enumeration, crop condition assessment and production forecasting. Crop yield is estimated using agro meteorological/spectral yield models and also crop growth simulation models. FASAL approach also involves using econometric models to forecast the area and production before the crop sowing operations.

FASAL is a multi-institutional programme (Figure 17.3), which integrates the activity from many organizations viz., India Meteorological Department Crop Yield Forecasting, Space Applications Centre of Indian Space Research Organization, Directorate of Economics & Statistics, Ministry of Agriculture and others.

Currently, under FASAL project, National and State Level multiple forecasts are being issued for 5 crops (Rice (Kharif & Rabi), Jute, Rapeseed & Mustard, Winter Potato and Wheat). From the year 2013-14 onwards, State and District level forecasts are generated for Cotton, Sugarcane and Rabi (winter season) Sorghum. While multi-date SAR (Synthetic Aperture Radar) data of Indian SAR satellite RISAT-1 is used for Rice (Kharif & Rabi) and Jute, multi-date Resourcesat-2 AWiFS (Advanced Wide Field Sensor) data, with 56 m spatial resolution, are used for other crops. LISS III data, with 23.5 m resolution, is being used for district level assessments. Stratified random sampling approach is followed for crop area estimation.

All those states, which together contribute more than 90% of the particular crop's area in the country, are considered for area and production assessment. Hierarchical/ logical classification approach is followed for classifying multi-date SAR data. A hybrid (combination of supervised and unsupervised) classification method is followed for multi-date optical data, while maximum likelihood (MXL) is followed for single date optical data.

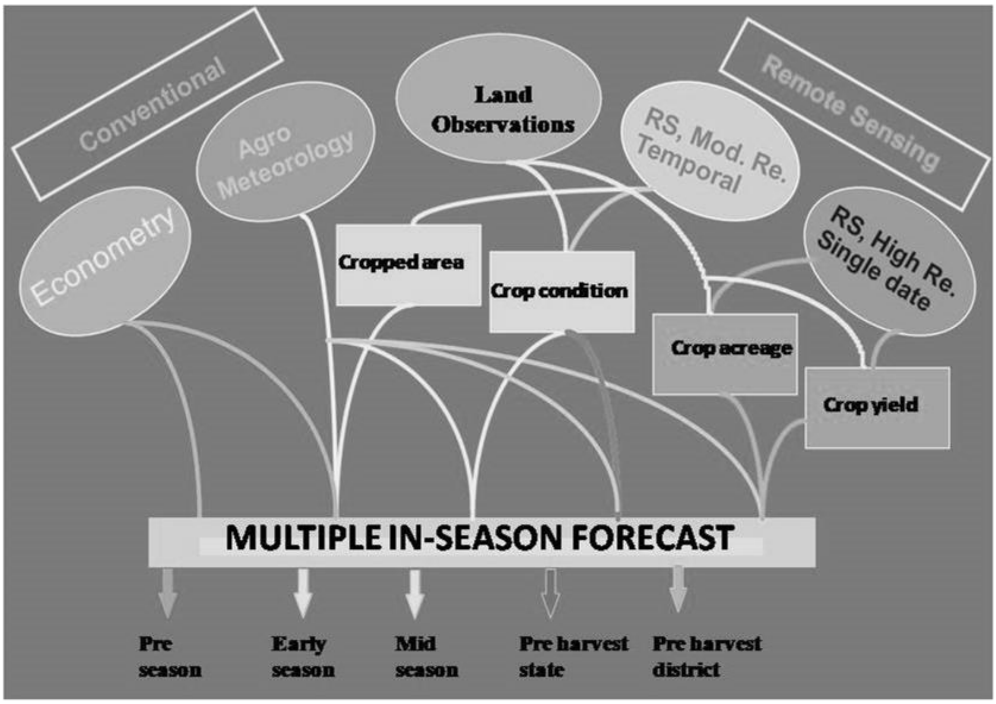

Figure 17.3: Approaches Followed for Multiple Forecasts Under FASAL Programme (Source: SAC, ISRO)

Indigenously developed software, called FASALSoft (Manthira Moorthi et al., 2014) is used for carrying out the digital analysis of remote sensing data. The yield forecasts are generated under FASAL programme by India Meteorological Department, correlation weighted empirical agro-meteorological models. For Rice and Wheat crops the final yield forecasts are being given using physical models with inputs from remote sensing data (Chakraborty et al., 2005; Tripathy et al., 2013).

Typically, in an agricultural year, 16 crop forecasts are generated. A comparison with the official estimates of Ministry of Agriculture showed that the Remote sensing based area estimates, at national level, are within -0.5 to -8.8 %, while differences in production estimates ranged between -11.2 to 5.6 %.

17.5.1 Ground Truth Collection Using Smart Phone:

Ground truth (GT) is an essential component for remote sensing data analysis. Ground truth includes collection of GPS Reading, Photographs, preparing a Sketch of the field Layout and filling -up of GT form. Earlier GT was being collected using a GPS, a camera and filling up of a form. A recent initiative was made for Smartphone based GT collection. An Android based application was developed by National Remote Sensing Centre of ISRO. State Agriculture Department officials collected GT using Smartphones provided by MNCFC. The GT information directly comes to Bhuvan server (ISRO’s Geoportal), which can be downloaded and used real-time.

17.5.2 Remote Sensing Based Crop Cutting Experiments:

Crop cutting experiments (CCE) are carried for each crop to estimate crop yield at district and state level. The conventional method CCE planning does not consider the current crop condition, which may result error in sampling. To overcome this, remote sensing driven Crop Cutting Experiments (CCE) planning was carried out in Bihar state for Rice crop during Kharif season of 2013.

The work was carried out jointly with Bihar Agriculture Department. Rice Crop Map was generated using such as RISAT-1 MRS data. Resourcesat-2 AWiFS time composite NDVI during September 2nd Fortnight to October 1st Fortnight was extracted for rice area. Three classes (A, B, C) were defined based on frequency distribution of NDVI values. Crop cutting experiment was carried out under the supervision of MNCFC. Yield models were developed between NDVI and yield and yield map was generated. The study showed very high efficiency of stratified sampling plan generated for CCE based on NDVI values.

17.5.3 Crop Emergence Progression:

The NDVI (Normalized Difference Vegetation Index) product derived from the Indian geostationary satellite INSAT-3A based CCD camera is extremely useful for vegetation monitoring, because of its high temporal frequency (half an hour) (Nigam et al., 2011). The spatial resolution of the data is 1 km. The 10 day NDVI product was used to monitor the Rabi season crop emergence based on a methodology developed by Space Applications Centre, ISRO (Vyas et al., 2011). Since Satellite data sees the crop only after spectral emergence (i.e. the time when crops are big enough to start registering spectral signature) this was called as emergence area progression. The analysis was carried out for 6 states (Punjab, Haryana, Rajasthan, UP, MP and Bihar) at every 10 day interval during December, 2013 to February, 2014.

17.6 Remote Sensing and GIS In Pest and Disease Monitoring:

Crop stress caused by biotic and abiotic factors can be monitored and quantified with remote sensing. To prevent the spread of insects and take effective control measures, remote sensing methodologies need to be perfected for identifying insect breeding grounds. Using remote sensing to assess and monitor insect defoliation, spectral response to chlorosis, yellowing leaves, and foliage reductions over a given period of time has been used to relate those differences' correlations, classifications, and interpretations. Lee *et al* (2010), for example, have applied remote sensing to map and detect defoliation, characterize pest destruction pattern, and provide information to pest management decision support systems.

The authors of William et al.(1979) analyzed Landsat imagery before and after defoliation to determine which vegetation types were healthy and unhealthy. A study conducted by Debeurs and Townsend (2008) concluded that MODIS data could be used for estimating vegetation indices in plots and determining insect-damaged defoliation. Using remote sensing technology to identify pest-infested and diseased plants has proven to be an effective and inexpensive method reported by Riedell et al (2004). For detecting specific insect pests and identifying disease damage on oat, they used remote sensing techniques.

It is suggested that remote sensing can be used to measure canopy characteristics and spectral reflectance differences in oat crop canopies in order to assess insect infestation damage and disease infection damage. Wheat Streak Mosaic disease management in the wheat crop can be supported by accurate detection and quantification of disease using the Landasat 5TM image, according to Mirik (2013). Using multispectral remote sensing, Franke and Menz (2007) concluded that fungal wheat diseases can be monitored with high resolution images.

17.7 Remote Sensing and GIS in Drought and Flood Impact Assessment on Agriculture:

Agriculture, in India, is strongly affected by two major hydro-meteorological disasters, namely drought and flood. Drought is a perennial feature. 16 per cent of India's total area is drought prone and approximately, 50 million people are annually affected by droughts (DAC, 2009). Over 68-70% of total sown area in India is vulnerable to drought. Similarly, around 40 million hectares of land in India is prone to floods as per National Flood Commission report. Assessment of agricultural condition during drought or flood is essential for taking various relief and rehabilitation measures. Since both these disasters impact large area, satellite based monitoring is extremely useful.

17.7.1 Agricultural Drought Assessment:

In India, operational agricultural drought assessment using remote sensing data is carried under a major programme called National Agricultural Drought Assessment & Monitoring System (NADAMS). NADAMS project, developed by National Remote Sensing Centre, provides near real-time information on prevalence, severity level and persistence of agricultural drought at state/ district/sub-district level (Murthy & Sesha Sai, 2011).

Currently, it covers 13 states of India (Andhra Pradesh, Bihar, Chattisgarh, Gujarat, Haryana, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, and Uttar Pradesh), which are predominantly agriculture based and prone to drought situation. In four states (Andhra Pradesh, Karnataka, Haryana and Maharashtra), the assessment is carried out at subdistrict level. The remote sensing data of NOAA AVHRR (for district level), MODIS and Resourcesat-2, Advanced Wide Field Sensor, AWiFS (for sub-district level) along with rainfall data are used for drought assessment (Choudhary et al., 2011).

Various spectral indices, such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) & Shortwave Angle Slope Index (SASI) are computed and integrated with Soil Moisture Index and District Level Rainfall to assess the drought condition. Agricultural conditions are monitored at state/district level using daily NOAA AVHRR/ MODIS data. Fortnightly/monthly report of drought condition is provided to all the concerned central and state government agencies under NADAMS. MNCFC has started providing periodic Drought Assessment Reports from the Kharif season of 2012 (Ray et al., 2014). Recently a drought geo-portal has been created (www.ncfc.gov.in), where users can access the images, maps, assessments and NDVI profiles.

17.7.2 Rice Flooded Area Mapping:

Another study was carried out to assess the impact of flood on Rice crop in Odisha state of India post Phailin cyclone of October 12, 2013. RISAT SAR derived rice map was integrated with flood inundation map developed National Remote Sensing Centre to map the areas of rice crop under flood. Total ten districts were affected by cyclone and rice inundation was more than 4% of rice area. Four Districts namely Baleshwar, Bhadrak, Kendrapara and Jajpur more than 15% of rice was severely affected by cyclone. A post-analysis ground truth was conducted which showed the accuracy of the rice flooded area mapping was 89%.

17.7.3 Rabi Season Crop Alert:

As mentioned earlier the drought assessment is generally carried out during the Kharif (Rainy) season. Though majority of crop growing area in Rabi (winter) season is irrigated, it is essential to monitor the agricultural condition to identify any alert situation for necessary intervention measures. The crop condition was assessed using MODIS Vegetation Indices 16-Day Composite data and MODIS Land Surface Temperature 8-day Composite data. Vegetation Condition Index of NDVI and NDWI and Temperature Condition Index (Kogan, 1995) were derived using past ten years' satellite data. Based on the above three mentioned parameters, and by using a logical modeling approach, the district were divided into normal, watch and alert. This exercise was carried out for 8 states namely Bihar, Haryana, Punjab, Rajasthan, Uttar Pradesh, Madhya Pradesh and West Bengal. The analysis showed that the crop situation was normal during the Rabi season of 2013-14.

17.8 Remote Sensing and GIS in Crop Acreage Estimation:

The acreage estimation procedure broadly involves 1) selection of single date data corresponding to the maximum vegetative growth stage of crop 2) identification of representative sites of various crops and their heterogeneity on image based on ground truth 3) generation of representative signatures for the training sites 4) classification of image using training statistics and 5) estimation of area of the crop using administrative boundary like district mask. The estimation can be done on sampling basis or by means of total enumeration approach. In the cases of estimation of crop acreages for large areas like states wherein analysis of large amount data and ground data collection are involved, stratified sampling procedure is being used operationally. The study area is divided into homogenous strata based on crop proportion and vigor as manifested on the satellite data and each strata is subdivided into segments of required size usually 5 X 5 km. About 10-15 percent of the sample segments are randomly selected for digital analysis and standard statistical methods are employed to aggregate crop estimates at district / state levels.

In order to choose most optimum bio-window, it is necessary to obtain the crop calendar and sowing progression of different crops cultivated in the study area for better crop discrimination. Based on the sowing date and its phenology, ideal bio window should be choosen for data selection. Using single date, cloud free optical data during the maximum vegetative stage of the crop growth, district level pre-harvest acreage and production of large area covering crops viz., paddy, wheat, sorghum, ground nut, rapeseed-mustard and cotton is being estimated on operational basis under the crop acreage and production estimation (CAPE) project. An extended project viz., forecasting agricultural output satellite, Agro-meteorological and Land Observations (FASAL) is in progress to provide multiple forecasts at district, state and national level (Navalgund *et. al*. 1991, Dadhwal V K. 1999, Sesha Sai *et al*. 2010 and Ramana K V. *et al.* 2017). With the launch of AWiFS, the high temporal revisit period has been exploited for discrimination of early and late rice crop transplantations.

17.9 Remote Sensing and GIS in Cropping System Analysis:

Remote sensing provides valuable information on the distribution and condition of crops at different spatial hierarchies and has the highest compatibility for analysis in GIS environment. Information on other natural resources that are of significant importance towards agricultural production can be integrated to generate information for sustainable agriculture. Integration of soil suitability for the cultivation of cotton crop along with the spatial distribution of cotton crop, as derived from remote sensing data through a conformity analysis enabled to delineate cotton crop grown under different suitability regimes.

This information is useful towards planning for efficient production of cotton crop by apportioning those land parcels that are highly suitable for cultivation of cotton. Rice is the major food grain cereal crop grown in South Asia and is cultivated mostly during the monsoon (rainy) season. Since the scope is limited for horizontal expansion, increased cropping intensity on the existing agricultural lands is one of the best crop management options. In this context, post kharif rice fallows offer a considerable scope for achieving sustainable production by introduction of short duration leguminous crops.

17.9.1 Production Estimation:

Crop yield is influenced by many factors such as genotype, soil characteristics, cultural practices adopted, metrological conditions and influence of pests and diseases. Spectral data of a crop is the integrated manifestation of the effect of all theses factors. Development of reliable crop yield models with minimal data is a major thrust area. A major challenge often confronted in agricultural crop production, despite the development of advanced agricultural technology, is the damage caused to agricultural crops by pest and diseases. Crop losses can be due to biotic factors like pests, diseases, weeds and abiotic factors like flood, drought, cyclones hailstorms etc. damages is known only after considerable damage has been occurred.

Statistical, meteorological and / or spectral models are used for crop yield estimation. Remote sensing based models adopt two approaches viz., single date spectral index and multi-date spectral index-growth profile are in vogue. The single date data spectral index approach relies solely upon the data acquisition within a narrow critical period of maximum vegetation growth phase while multi-date approach depends spectral data at different stages of crop growth within the season. In addition, attempts are also underway to incorporate the spectral information in the process-based models and crop simulation models to improve the predictive capabilities of the remote sensing based crop production estimation.

17.10 Crop Monitoring and Condition Assessment:

Condition of the crop is affected by factors such as availability of water and nutrients, pest attack, disease outbreak and weather conditions. These stresses cause physiological changes which alter the optical and thermal properties of the leaves and bring about the changes in canopy geometry and reflectance / emission. Monitoring and assessment of crop condition at regular intervals during the crop growth cycle is essential to take appropriate curative measures and to assess the probable loss in production.

The variations in the progression of NDVI, in terms of the magnitude and rate of progression, in relation to its respective normal NDVI provide information of the prevailing status of the vegetation. Exclusion of the permanent non-agricultural features like forests, wastelands, water bodies and settlements, reveal the status of the agricultural situation. In order to circumvent the problem of non-availability of cloud free optical data, time composited NDVI over an aggregated period of a fortnight or a month is generated, covering the entire crop growth season. In India, National Agricultural Drought Assessment and Monitoring System (NADAMS) was initiated towards the end of 1986, with the participation of National Remote Sensing Agency, Dept. of Space, Government of India, as nodal agency for execution, with the support of India Meteorological Department (IMD) and various state departments of agriculture.

NADAMS was made operational in 1990 and has been providing agricultural drought information in terms of prevalence, severity and persistence at state, district and sub-district level. In Andhra Pradesh, the Integrated Seasonal Crop Monitoring Systems is based on the analysis on Fourteen year historical NDVI, NDWI, VCI and Rainfall and daily Soil Moisture derived from soil water balance model. The project aims at concurrent monitoring of seasonal conditions using remote sensing, extensive weather network data and continuous ground truth. Using the combination of rainfall deviation, NDVI, NDWI and the duration of the dryspell, the mandals prone for drought are being identified in near real time (Annonymous, 2018a).

17.11 Remote Sensing and GIS in Crop Suitability Studies:

The sustainable crop production in any area depends on its climate, soil and site characteristics of the area. This can be achieved through evaluation of soils of a given area for their suitability to different crops considering the inherent soil properties, topographical features and climatic parameters independently as well as in combination. A study had been carried out at NRSA (1998b) with the objective of assessing soil suitability to groundnut crop through GIS approach. The test site for the study was Tettavai vagu watershed in Tungaturthi mandal of Nalgonda district of AP. The soil maps for the study area was prepared using IRS-1B LISS-II data at 1:50,000 scale. Suitability criteria for groundnut crop in terms of climate, soil and site parameters were developed following FAO approach and incorporated as decision rules in GIS environment. The study revealed that in the test area about 69% of the total geographical area is highly suitable for groundnut crop. Similarly studies were carried out using remote sensing and GIS for sugarcane crop suitability in Puddukottai district, Tamilnadu and upland rice in Koraput district. Orissa. Similarly larger scale soil maps of Mohammadabad village, Nalgonda were used in similar lines as mentioned above to assess the suitability of the village for various crops (Figure 17.4).

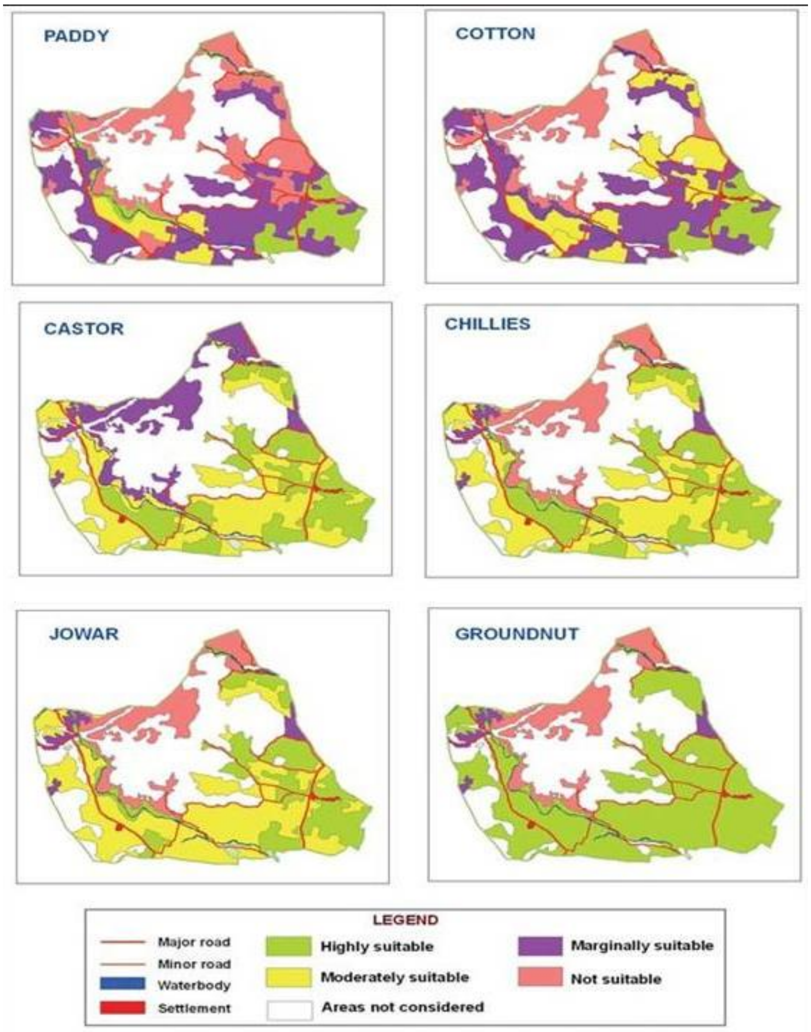

Figure 17.4: Land Suitability of Soils of Mohammadabad Village for Various Crops

17.12 Remote Sensing and GIS in Irrigation Scheduling:

Quantitatively, irrigation system planning strategies depend on three methodologies; to be specific, crop observing, soil checking and water balance strategy. Scheduling irrigation will bring about effective use of the water, and it becomes vital if the monetary and natural supportability of farming is to be guaranteed. The relationship between soil moisture content and soil temperature is utilized by infrared remote sensors, while noticeable or close to infrared sensors utilize the interaction between moisture content and chlorophyll absorption. These are the reason for using remote sensing technique for irrigation scheduling. Three methodologies can be utilized to appraise when the crop needs water. These methodologies are soil moisture monitoring, plant moisture stress, and weather-based water use forecasts system. Remote detecting can give both plant-based, climate based and the soil-based data. Generally, thermal infrared, visible and near-infrared remote sensing are commonly used for irrigation scheduling.

17.13 Remotes Ensign and GIS in Precision Agriculture:

As scientists, engineers and large-scale crop growers increasingly use remote sensing technology for precision farming (Liaghat and Balasundram 2010), it is becoming a key component of the same. With the help of the sensors fitted in farm machines, precision farming aims to reduce the cost of cultivation, improve control, and improve resource utilization efficiency. One of the most advanced components of precision farming is variable rate technology (VRT). The moving farm machines contain sensors with a computer that recommends inputs based on GPS data. This allows the application of inputs to be controlled based on input recommendation maps (NRC, 1997). Using precision farming, you can make management decisions based on information acquired at frequent intervals and at high spatial resolutions. In order to provide such information, remote sensing is undoubtedly an important tool. Multispectral remote sensing was used by Bagheri et al (2013) to manage nitrogen fertilizer at specific sites. An Iranian corn-planting area measuring 23 ha was imaged with the advanced spaceborne thermal emission and reflection radiometer (ASTER).

17.14 Conclusion:

Satellite Remote sensing techniques are being operationally used to provide information on the spatial distribution of soils and crops at different levels. Analysis of satellite data for crops along with the information on other natural resources in GIS environment provides valuable information towards sustainable agriculture. The continuous improvements in the satellite technology in terms of providing improved spatial and spectral resolutions and re-visit periods will greatly enhance the capabilities of mapping and monitoring of crop – type and condition, problematic soils and environmental pollution etc. The discussion in this chapter has showed how remote sensing data from various sources, in combination with other ancillary data, have been successfully used for operational assessment of agriculture in the country. The recent advancement in high resolution field level image processing obtained through drones compiled with the satellite derived knowledge is quite promising.

Though the remote sensing applications have a lot of theoretical consideration and backdrops, it has a huge scope in agricultural sciences to serve the humanity with higher production, vulnerability prediction and impact assessment under the context of rapid climate change. However, there is a need to further extend the area of activity. Following future developments are envisaged in this field are (a) Developing spectral yield models for all crops, (b) assessing biotic and abiotic disaster impact on agriculture, (c) Monitoring the impact of agricultural development programmes of the country, (d) Horticultural assessment, and (e) Agricultural resources management.

17.15 References:

1. Annonymous (2018a). Integrated Seasonal Condition Monitoring System Andhra Pradesh - Technical
2. Annonymous (2018b). Land Degradation Report (2nd Cycle) using three seasons satellite of 2015-16: Andhra Pradesh. November, 2018 (http:// apsac.ap.gov.in/downloads/ Land%20degradation %2050K% 20Report%202018.pdf)

3. Bagheri, N., Ahmadi, H., Alavipanah, S.K. & Omid, M. (2013). Multispectral remote sensing for site-specific nitrogen fertilizer management. International Agrophysics. 26:103-108
4. Baumgardner, M. F., Kristof, S. J., Johannsen, C. J, & Zachery, A. L. (1970). Effects of organic matter on the multispectral properties of soils Proceedings of Indiana Academy of science, Vol. 79, pp. 413 – 422
5. Chakraborty, M., Manjunath, K.R, Panigrahy, S., Kundu, N. & Parihar, J. S. (2005). Rice crop parameter retrieval using multi-temporal, multi-incidence angle Radarsat SAR data. ISPRS Journal of Photogrammetry and Remote Sensing. 59(5): 310–322
6. Choudhary, K., Goel, Inka, Bisen, P. K., Mamatha, S., Ray, S. S., Chandrasekar, K., Murthy, C. S. & Sesha Sai, M.V.R. (2014) Use of Remote Sensing Data for Drought Assessment: A Case Study for Bihar State of India during Kharif, 2013. In: High Impact Weather Events over the SAARC Region (Eds. Kamaljit Ray, M. Mohapatra, B. K. Bandyopadhyay & L. S. Rathore). Capital Publishers & Springer India, New Delhi. pp. 378-385.
7. DAC (2009) Manual for Drought Management. Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, New Delhi, 192 p.
8. Dadhwal, V. K. (1999) Remote sensing and GIS for agricultural crop acreage and yield estimation,pp. 58-67, International Archives of Photogrammetry and Remote Sensing, XXXII, 7-W9, (ISPRS Commission VII/ WG 2 Symposium on Application of Remote Sensing and GIS for Sustainable Development), March 11, Dehradun, India.
9. Dadhwal, V. K., Singh, R. P., Dutta, S. and Parihar, J. S. (2002) Remote sensing based crop inventory: A review of Indian experience. Tropical Ecology 43(1): 107-122.
10. De Beurs, K, & Townsend, P. (2008). Estimating the effect of gypsy moth defoliation using MODIS. Remote Sensing of Environment. 112:3983-3990.
11. Dwivedi, R. S., Ramana, K. V and Sreenivas, K. (2000). Mapping soil resources in part of Northern India using spaceborne multispectral data. Geocarto International. 15(1):77-82p
12. Dwivedi, R. S., Ramana, K. V, Thammappa, S. S & Singh, A. N. (2001). The utility of IRS-1C LISS-III and PAN merged data for mapping salt-affected soils. Photogrammetric Engineering and Remote Sensing. 67(10):1167-1175p
13. Franke, J. & Menz, G. (2007). Multi temporal wheat disease detection by multi spectral remote sensing. Precision Agriculture. 8:161-172
14. Justice, C.O,, Townshend, J.R.G, Vermata, E.F, Masuoka, E, Wolfe, R.E & Saleons N, (2002). An overview of MODISL and at a processing and product status. Remote Sensing of Environment. 83:3-15
15. Kogan, F.N. (1995). Application of vegetation index and brightness temperature for drought detection. Advances in Space Research. 15(11): 91–100.
16. Lee, W., Alchanatis, V., Yang, C., Hirafuji, M., Moshou, D & Li, C.(2010). Sensing technologies for precision specialty crop production. Computer and Electronic inAgriculture. 74:2-33
17. Liaghat, S. & Balasundram, S.K. (2010). A review: The role of remote sensing in precision agriculture. American Journal of Agricultural and Biological Sciences. 5(1):50-55.
18. Manthira, Moorthi, S., Oza, M.P., Misra, Indranil, Gambhir, Rajdeep K., Darji, N.P., Sharma, Shikha, Jain, D.K., Dhar, D., Padia, Kirti, Ramakrishnan, R., Chowdhury, S. & Parihar, J.S. (2014). FASALSoft - An ISRO software framework for crop production forecast using remote sensing data analysis. Journal of Geomatics. 8(1):27-33.

19. Mirik,M.(2013). Remote monitoring of wheat streak mosaic progression using sub-pixel classification of Landsat 5 TM imagery for site specific disease Management in Winter Wheat. Advances in Remote Sensing. 2:16-28.
20. Murthy, C.S. & Sesha Sai, M.V. R. (2011). Agricultural Drought Monitoring and Assessment. In: 'Remote Sensing Applications' (Eds.) P. S. Roy, R. S. Dwivedi and D. Vijayan, NRSC, Hyderabad.
21. Myers, A.L. (1983). Activity coefficients of mixtures adsorbed on heterogeneous surfaces. https://doi.org/10.1002/aic.690290428
22. Navalgund, R. R., Parihar, J. S., Ajai & Nageshwar Rao, P. P. (1991). Crop inventory using remotely sensed data, Current Science, 61: 162–171.
23. Navalgund, R. R. & Ray, S. S. (2000). Geomatics in natural resources management. In Proceedings of Geomatics-2000. 21-22 January, 2000, Pune, pp. NR1-NR14.
24. Nigam, R., Bhattacharya, B. K., Gunjal, K. R., Padmanabhan, N. & Patel, N. K. (2011). Continental scale vegetation index from Indian geostationary satellite: algorithm definition and validation. Current Science, 100(8): 1184-1192.
25. NRC (1997). Precision Agriculture in the 21st Century Geospatial and Information Techniques in Crop Management. Washington, DC: National Academy Press; p. 149
26. NRSA (1998). Soil suitability to crops: A GIS approach - (A case study on groundnut), Project report.
27. Panigrahy, S. & Ray, S. S. (2006) Remote Sensing. In: Environment and Agriculture. (Eds. K. L. Chadha & M. S. Swaminathan). Malhotra Publishing House, New Delhi. pp. 361-375.
28. Parihar, J.S. & M.P. Oza (2006). FASAL: an integrated approach for crop assessment and production forecasting. Proc. of SPIE Vol. 6411641101 Agriculture and Hydrology Applications of Remote Sensing, edited by Kuligowski, R.J., Parihar,J.S. and Saito, G. (doi: 10.1117/12.713157).
29. Ramana, K. V., Srikanth, P., Sesha Sai, M. V. R, Annapurna, G., Das, P. K., Ramani, A. V., Aparna, N., Rao, B. R. M., Fyzee, M. A., Thammappa, S. S. & Ramana, K. V. (2001). Utility of space borne multispectral data for soil and land irrigability assessment – A case study from Southern part of India. Geocarto International Journal, Vol. 16 (2) pp31 – 36.
30. Ravisankar, T. (2001). Soil Information System for optimum land use planning, Ph.D.Thesis, JNTU, Hyderabad
31. Riedell, W.E., Osborne, S.L & Hesler, L.S. (2004). Insect pest and disease detection using remote sensing techniques. In: Proceedings of 7th International Conference on Precision Agriculture. Minneapolis, MNUSA;
32. Riquier, J., Luis Bramao, D & Cornet, J.P. (1970). A new system for soil appraisal in terms of actual and potential productivity (first approximation), F.A.O. Bulletin Agriculture Tesr. /70 /6.
33. Sehgal, J. L., Sharma, P. K & Karale, R. L. (1985). Soil resource inventory of Punjab using remote sensing technology. Proc. Of the sixth asian Conference on remote sensing, NRSA, Hyderabad, pp298-301.
34. Sesha Sai, M.V.R., Ramana, K.V & Hebbar, K. R. (2010). Remote Sensing for Agricultural Applications- In Remote Sensing Applications – Compiled and Ed. P.S Roy, R.S.Dwivedi and D Vijayan. NRSC. p. 1-21
35. Singh, A. N & Dwivedi, R. S. (1989). Delineation of salt affected soils through digital analysis of Landsat-MSS data. . International Journal of Remote Sensing.10 (1):83-92.

36. Stoner, E. R., Baumgardner, M. F., Weismiller, R. A., Biehl, L. I & Robinson, B. F. (1980). Extension of laboratory measured soil spectra to field conditions. Soil science Soc. Am. J. 44: 572-574
37. Tripathy, R. Chaudhari, K. N., Mukherjee, J., Ray, S. S., Patel, N.K., Panigrahy, S. and Parihar, J. S. (2013). Forecasting wheat yield in Punjab state of India by combining crop simulation model WOFOST and remotely sensed inputs. Remote Sensing Letters 4 (1), 19-28.
38. U N E P, (1993). Environmental report 1993-1994. Blackwell Oxford, U.S.A, Cambridge, UK.
39. Vyas Swapnil, Nigam, Rahul, Patel, N. K., Panigrahy, S. & Parihar, J. S. (2011). Monitoring of rabi crop progress using geostationary satellite INSAT 3A CCD data. SAC, Scientific note: ABHG/ SAC/SN/03/2011. Space Applicatiosn Centre, Ahmedabad.
40. Williams, D., Stauffer, M & Leung, K. (1979). A forester's look at the application of image manipulation techniques to lands at data. In: Symposium on Remote Sensing for Vegetation Damage Assessment, February 14–16. Falls Church, VA: Washington The Society; 1979. pp. 221-229.