SATELLITE-BASED AGRO-ADVISORY SERVICE

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Abstract : Remote sensing techniques have been operationally used in many countries to provide basic information on crops, soils, water resources and the impact of drought and flood on agriculture. Procedures for pre-harvest acreage estimation of major crops such as wheat, rice and sorghum, using sampling and digital techniques based on remotely sensed data have improved greatly. Remote sensing can also provide data related to ocean and coastal zones like identifying potential area of fish concentration, environmental degradation that takes place in coastal zones due to over exploitation, etc. Other promising areas of applications include, disaster assessment, drought monitoring, environmental monitoring, forestry information, etc. all of which have advanced significantly.

The main users of crop maps and yield forecasts are governments and agribusiness who use them to assess demand, anticipate prices and plan the use of resources. Farmers do have a considerable interest, in knowing about problems in crops, and developments of the vegetation index concept could provide valuable information in stress management, for example in assessing irrigation demand, disease, pest and weed control, and crop nutrition. This information must be delivered or made accessible in sufficient time for the user to make professional sense and use these advisories appropriately in the management process.

INTRODUCTION

Ever since satellite remotely sensed data was available in digital format, the use of computers for analysis and interpretation of the data took roots. As the data actually depicted the state of the land as it existed at the time of observation, it was like bringing the ground to the office in the form of a picture to be studied by the various specialists. Data sets available from a variety of satellites have opened up tremendous possibilities of extracting a variety of information. In several cases of resources studies, the technique is operational, catering to several varied needs in the area of management of natural resources.

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The major advantage in using satellite remotely sensed data is that it is the latest available at any given time.

Remote sensing techniques have been operationally used in many countries to provide basic information on crops, soils, water resources and the impact of drought and flood on agriculture. Integrated studies on soil and water conservation using remote sensing and GIS have been progressing with a view to raising agricultural production. In India procedures for pre-harvest acreage estimation of major crops such as wheat, rice and sorghum, using sampling and digital techniques based on remotely sensed data have improved greatly.

The question that arises is in what respect can remote sensing be used in agricultural information systems. In fact agricultural production encompasses myriad activities related to crops, soils, water resources, climate and local weather of the region. For some of the specific themes of these disciplines, remote sensing technology has been observed to be operational and in some others some more research may be needed to enable integration into the total agricultural information system.

Mainly, an agricultural resources inventory may need some knowledge of geology and geomorphology, forestry and vegetation, land use, and land degradation information, agricultural crops, water resources and agro-meteorology. The use of remote sensing data to obtain information and produce maps on a 1:50 000 scale is almost operational in all the aspects as mentioned above.

Agro-meteorological Information based on Remote Sensing data

Application potentials of remote sensing techniques on resources related to some important agrometeorological services are mentioned here :

- Agriculture (crops): One basic information that remote sensing can provide to agriculture is data related to crop identification and area measurement under different types of crops, or acreage estimation. This enables us to somewhat estimate the total production by understanding the yield per unit area. Such information has far-reaching consequences in providing adequate food security.

- Forestry and vegetation mapping: Remote sensing can aid in providing a) information about the extent of forest cover and give a general idea of the types of forest cover; b) forest canopy density condition ; c) detection of forest hazards like fire, disease and excessive felling.

- Water resources : Understanding water resources is important from agricultural point of view. Water supply to agriculturally related sectors depends upon the available resources, both in terms of quantity and quality. Remote sensing data is useful in assessing water resources, irrigated area studies and its monitoring and determining potential ground water zones.

Remote sensing can also provide data related to ocean and coastal zones like identifying potential area of fish concentration, environmental degradation that takes place in coastal zones due to over exploitation, etc. Other promising areas of applications include, disaster assessment, drought monitoring, environmental monitoring, etc. all of which have advanced significantly.

Assessment of Crop Condition and Estimation of Yields by Remote Sensing technique

The use of remote sensing data for estimating crop acreage estimation has reached a stage near operational level. Studies carried out for estimating acreage under different crops in many countries show a near 90 percent accuracy level. In many countries, production forecasting of certain crops, crop yield modeling and crop stress detection are done using remote sensing data. Yield is influenced by many factors, such as crop genotype, soil characteristics, cultural practices adopted, meteorological conditions and influences of diseases and pests. Many approaches have been followed to determine the integrated effects of various parameters that affect crop growth and crop yield. Several yield models have been developed in which data obtained from various types of satellites to cover some of the parameters have been used (Gupta, 1993; Doraiswamy *et al.,* 1996).

A major constraint however is a cloudy sky during the cropping season when normal optical remote sensing cannot give good data. However with the emergence of microwave remote sensed data, this can be overcome as such instruments can penetrate through clouds. To ensure complete success in predicting yields, some more research experiments may be needed to evolve a foolproof system.

Many countries have developed methods to assess crop growth and development from several sources of information such as, surveys of farm operators, crop condition reports from field surveys and local weather information. Remote sensing technology can provide supplemental spatial data to provide timely information on crop condition and potential yields. The timely evaluation of potential yields is increasingly important because of the growing economic impact of agricultural production on world markets. The use of the NDVI parameter to estimate crop yields is a specific extension of the above general concept. The seasonal accumulated NDVI values correlate well with the reported crop yields in semi-arid regions (Groten, 1993).

Crop growth simulation models have been successfully used for predicting crop yields at the field level. However, numerous input requirements that are specific to the crop type, soil characteristics and management practices limit their applicability for regional studies. Integrating parameters derived from remotely sensed data with a growth model provides spatial integrity and near real time “calibration” of crop growth simulations. Remotely sensed data are incorporated in simulations of agricultural crop yields to calibrate or adjust model parameters during the simulation period to ensure agreement between the modeled and satellite observed parameters (Maulin *et al.,* 1995).

Real time Forestry Information from Satellite data

The use of satellite remote sensing data has been found to be a reliable and useful tool for gathering forest information. Gathering of real time forestry information enables us to compile gross forest vegetation resources data in a single format and monitor the changes in the areal coverage of the forest.

Since remote sensing satellites re-observe the same areas at periodic intervals, we have the added advantage of monitoring changes that occur in the area of coverage, to plan for remedial measures for any adverse happening, much sooner than what we were able to do in the past, when the facility of remote sensing from space altitudes was not available. It is in this context that we could view forest cover or vegetation cover of a large area, and the changes that occur to it, as the forest is a renewable natural resource which is very vital for human survival. The type of exercise also gives us the approximate rate at which the forest cover is changing and focusses attention on what should be done to ensure sustainability.

Identification of Fishing zone by Remote Sensing

Remote sensing methods have helped greatly in the optimisation of ocean resources. As 60 to 70 per cent of the world’s population live within 20-30 km of the coastline, coastal zone management and optimisation of ocean resources have grown in importance. With the advent of remote sensing methods using satellite and aerial survey, the data coverage and accessibility have increased. Several parameters relating to the oceans including fisheries can be studied using satellite and aircraft data.

While other ocean related applications have become possible on remotely sensed data from satellites, on a near real-time basis, here, it has been shown how a particular satellite and the sensor mounted on it have been used to obtain sea surface temperature and map it, on a regular basis, and pass it on to the fishermen who could concentrate on high potential areas and improve the catch.

The ocean colour as measured by the sensor is found to bear a direct relationship with the suspended material of the water, thermal characteristics and the location of greenish biological matter. One of the important parameters that can be measured with sufficient accuracy is the Sea Surface Temperature (SST), which has related to the concentration of fish population. This is an example of how a high technology has been applied at the grass-root level increasing the earning capacity by increased fish catches.

Fishing Zone Maps

SST derived from NOAA-AVHRR satellite serves as a very useful indicator of prevailing and changing environmental conditions and is one of the important parameters which decides suitable environmental conditions for fish aggregation. SST images obtained from satellite imagery over three or four days are composited and the minimum and maximum temperatures are noted down. These values are processed to obtain maximum contrast of the thermal information. This information is used to prepare relative thermal gradient images.

From these images, features such as thermal boundaries, relative temperature gradients to a level of 1 degree centigrade, level contour zones, eddies and upwelling zones are identified. These features are transferred using optical instruments to corresponding sectors of the coastal maps prepared with the help of Naval Hydrograph charts. Later, the location of the Potential Fishing Zone (PFZ) with reference to a particular fishing centre is drawn by identifying the nearest point of the thermal feature to that fishing centre. The information extracted consists of distance in kilometres, depth (for position fixing) in metres and bearing in degrees with reference to the North for a particular fishing centre.

Monitoring Natural Disasters by Remote Sensing

While aerial remotely sensed data were used for a long time, it is the satellite based remote sensing data which, because of its continuous availability and capacity to observe large areas, is considered a powerful medium to monitor the changes in the Earth's environment and take timely action. Remote sensing satellite information helps minimise damages e.g. the death of cattle, humans etc. and the damage of agricultural production in time of natural calamities by early warning system.

Floods occur mainly due to heavy rainfall in association with low pressure, depressions and cyclones. While floods and cyclones cannot be totally eliminated, careful monitoring and planning can certainly mitigate the destruction and help in evolving suitable rehabilitation measures based on remotely sensed data.

Attempts are being made to evolve a drought prediction system using remotely sensed data, but drought prediction is difficult, and a foolproof mechanism will probably take time. However, the severity of droughts can easily be assessed, thus providing information to the authorities for implementing relief measures.

Forest fires are considered a potential hazard with physical, biological, ecological and environmental consequences. Forest fires occur frequently in tropical countries particularly in the dry and hot seasons causing serious damage to the forest resources and agricultural production. Since the number of forest fires are increasing every year, continuous monitoring is of great importance, not only to understand present trends but also to devise a model to predict the possibility of fires in future. In a recent fire in the Rajiv Gandhi National Park situated in South Karnataka (India), remote sensing data was used for studying environmental aspects and the results were very encouraging.

Monitoring Pests and Disease from Satellite data

Various factors such as intensive cultivation, monocropping, changing weather conditions and indiscriminate use of pesticides have resulted in frequent outbreaks of crop pests and diseases causing huge crop losses. Minimising these losses is one way of enhancing grain production and remote sensing tool has been found very useful in monitoring large areas frequently. The Earth observing systems are useful in monitoring weather and ecological conditions favourable for crop pests and diseases. Weather conditions such as temperature, humidity (moisture), sunshine hours (light) and wind play major influence on the densities of pest population and their natural enemies. Among the weather parameters that can be remotely sensed, type of cloud, extent of cloud cover, cold cloud duration (a surrogate for rainfall) are the most easily retrievable. Such information was used by phytopathologists to study rust diseases of wheat crop.

An aircraft fitted with a camera loaded with colour infrared films and flown over Kerala state (India), identified coconut areas severely affected by 'wilt' which could not be easily detected from the ground. This gave a clue to the area that could be viewed from satellite altitude.

Understanding the magnitude of crop losses is necessary to appreciate the importance of plant protection in crop production programmes. Losses can be due to biotic factors such as pests/diseases/weeds and abiotic factors such as drought, floods, cyclones and hailstorms. Damage caused by pests may be quantitative (overall reduction in yield), or qualitative such as change in colour and offensive odour. The regional disparities in crop condition assessment, the complex Centre-State relationships in handling relief measures and the introduction of crop insurance scheme, call for an unbiased, objective and timely information system to give early warning, to indicate the intensity of such hazards and to assess the loss.

FAO had organized an international training programme at National Remote Sensing Agency (NRSA) in India a decade ago, involving countries like India, Pakistan and Tanzania in the use of various remote sensing data to identify locust-breeding areas. The directorate of plant protection handles such issues. There is no proper information about the area affected by pests and diseases and other yield reducing factors on an all-India basis.

It is stated that the brown plant hopper (BPH) of rice is one of the dreaded insect pests in Asia. BPH is stated to be associated with synoptic weather conditions (depressions). Double cropping, extensive rice cultivation in the command area and indiscriminate use of fertilizers and pesticides aid the occurrence of BPH.

Desert Locust Forecasting

Desert locust plagues affect about 20 percent of the earth's surface spreading across Africa, the middle east and south-west Asia. They breed in areas that have sufficient soil moisture and vegetation to support the early stages of this insect (viz. egg laying and hopper development). They migrate from west to east along with the passage of troughs moving in the westerlies and northward and southward along with the Inter-tropical Convergence Zone (ITCZ). The main weather systems bringing rainfall favourable for the development of desert locust are western disturbances, depressions over Arabian Sea and a few depressions developed over land.

Remotely sensed vegetation indices and rainfall estimates based on cold cloud duration and other cloud indexing techniques are the only cost-effective methods to survey the vast stretches of desert locust habitat.

A few studies have focussed on the collection of historical data on weather and habitat conditions with the dynamics of locust development stages, and synthesis of the data using Geographical Information System (GIS) and evolving decision support systems (Healey *et al.*, 1996). This system integrates remotely sensed landform soil texture, soil moisture and vegetation density with the daily weather data to forecast the suitable breeding sites and time of onset of locust upsurge in and around the study area.

Remote Sensing and Drought Monitoring

One of the natural calamities that affects us is lack of normal rainfall and consequent drought conditions which in turn affect agricultural productivity. Drought conditions can be monitored using data obtained from satellite. This system provides efficient and timely monitoring capability by integrating the timeliness and objectivity of space observations with details of ground perceptions.

During drought, physiognomic changes of vegetation may become apparent. Satellite sensors are capable of discerning many such changes through spectral radiance measures and manipulation of such measures into vegetation indices, which are sensitive to the rate of plant growth as well as to the amount of growth. Such indices are also sensitive to the changes in vegetation affected by moisture stress. The visible and near infrared bands on the satellite multi-spectral sensors allow monitoring of the greenness of vegetation. This property is used in the case of monitoring drought, as the stressed vegetation and other bare ground, water, etc. reflect differently. Besides, moisture stress in vegetation, resulting from prolonged rainfall deficiency, is reflected by lowering of vegetation index values. Such decrease could also be caused by other stresses such as pest/disease attack, nutrient deficiency or soil geo-chemical effects. But this does not show up well in coarse resolution data which covers very large areas at a time.

Reliable drought interpretation requires a Geographical Information System (GIS) based approach, since the topography, soil type, spatial rainfall variability, crop type and variety, irrigation support and management practices are all relevant parameters.

In recent years, many investigations have demonstrated the capability of satellite-borne sensors to provide information on various drought indicators, which helps to monitor drought more effectively. The following paragraphs discuss remote sensing of rainfall, soil moisture, and vegetation/crop conditions, which are helpful in delineating agricultural drought.

Rainfall Estimation by Remote Sensing

Satellite estimation of rainfall is not likely to be better than rainfall measured through conventional rain gauges, but nevertheless is useful to fill in spatial and temporal gaps in ground reports. Nageswara Rao and Rao (1984) demonstrated an approach for preparing an indicative drought map based on NOAA AVHRR derived rainfall estimation at the seedling stage of crop growth. For drought monitoring, quantitative point-specific rainfall estimates on the daily basis all over the country may not be required. What is needed, however, is a capability to spatially distribute the point rainfall observations over the areal unit in a qualitative manner.

Remote Sensing of Soil Moisture

Microwave sensors are probably the best soil moisture sensors, considering the strong physical relationship between the microwave response and soil moisture and the capability of microwaves to penetrate clouds, precipitation, and herbaceous vegetation. The principle advantage of active microwave sensors is that high spatial resolution can be obtained even at satellite altitudes.

Microwave sensors can provide estimates of soil moisture only in surface layers up to 10 cm thick. This depth is too shallow, compared to the 1-2 m root zone of many field crops in the tropics. Using the water content in the top 10 cm of the surface layer, the moisture content can be calculated within acceptable limits and with minimum error when the surface soil moisture estimation is made just before dawn.

Some investigations are under way at the National Remote Sensing Agency, Space Application Centre, and elsewhere to evaluate ERS- ISAR data for soil moisture estimates in the surface layers.

Remote Sensing of Vegetation status

During periods of drought conditions, physiological changes within vegetation may become apparent. Satellite sensors are capable of discerning many such changes through spectral radiance measurements and manipulation of this information into vegetation indices, which are sensitive to the rate of plant growth as well as to the amount of growth. Such indices are also sensitive to the changes in vegetation affected by moisture stress (Das, 2000).

The visible and near infrared (IR) bands on the satellite multispectral sensors allow monitoring of the greenness of vegetation. Stressed vegetation is less reflective in the near IR channel than nonstressed vegetation and also absorbs less energy in the visible band. Thus the discrimination between moisture stressed and normal crops in these wavelengths is more suitable for monitoring the impact of drought on vegetation.

The NDVI varies with the magnitude of green foliage (green leaf area index, green biomass, or percentage green foliage ground cover) brought about phenological changes or environmental stresses. The temporal pattern of NDVI is useful in diagnosing vegetation conditions

Moisture stress in vegetation, resulting from prolonged rainfall deficiency is reflected by lower NDVI values. Such a decrease could also be caused by other stresses, such as pest/disease infestation, nutrient deficiency, or soil geochemical effects. Discrimination of moisture stress from other effects does not present a problem in coarse resolution data over large areal units, as neither pest/disease attack nor nutrient stress is selected in terms of area or crop type.

National Agricultural Drought Assessment and Monitoring System (NADAMS)

Since 1989, National Agricultural Drought Assessment and Monitoring System (NADAMS) in India has been providing biweekly drought bulletins through the kharif season (June to December) for 246 districts in most of the peninsular and northern India. The bulletins, which describe prevalence, relative severity level, and persistence of drought through the season at the district level, are being sent to the concerned state and central administrators as well as to district-level officers. The drought assessment is based on a comparative evaluation of satellite observed green vegetation cover (both area and greenness) of a district in any specific time period to cover in similar periods in the previous year. The trend of seasonal vegetation development until the reporting period is also compared with trends of previous years. The drought interpretation takes into account rainfall and aridity anomaly trends. This nationwide early warning services has been found to be useful for providing early assessment of drought conditions.

Dissemination of the Information through Agro-met Advisory service

Agrometeorological information is rarely provided as a finished product to the clients. Often it is used to complement the purely meteorological products, or delivered in combination with other remotely sensed products, such as information in soil wetness, land or vegetation cover (NDVI), likely presence of pests and/or diseases, estimates of the areal coverage of irrigated or flood-retreat crops, incidence of bush fires, etc. By the nature of their capacity to indicate the probable areal extent of a condition, and of the still very rapid evolution of the parameters that can be measured or derived, remotely-sensed data and their derived products will be a growing resource for the supply of agrometeorological products to clients.

How information is delivered to the users of the product is, finally, of extreme importance. There are a number of issues that fall into information delivery. These include clearly defined users, user-friendly information, cooperation and coordination between producers and users of the product, proper training, and timeliness of information delivery. Hard copy publication sent via mail allows detailed text and graphics, but its effectiveness may be hampered by the timeliness of receipt. Delivery by radio allows rapid dissemination but limits the amount of information that may be provided. Internet technology combines the strengths of detailed information and rapid delivery but is definitely constrained by lack of Internet access in many developing countries.

The product must be delivered or made accessible in sufficient time for the user to make professional sense from the information and use it appropriately in the management process. Formal lines of communication can be developed through user surveys and open forums. Information mechanisms, such as telephone, facsimile, or email exchange should also be encouraged.

Once established, such mechanisms for communication should become a routine occurrence to accommodate changing user needs, new technological innovations, and more efficient distribution procedures. Constructive feedback mechanisms promote an active dialogue to encourage improvements that not only technically enhance the bulletin but also increase its usefulness. Information delivery by Internet communication offers great opportunity to move quality products to the decision-maker rapidly. The computer age technology also allows efficient feedback mechanisms, which in turn may increase the demand for additional information (Motha, 2001).

CONCLUSIONS

The use of satellite based remote sensing has proved itself as a strong and unbiased information system at regular intervals of time. While agricultural scientists have shown some interest in developing its usage, there is still a long way to go, as it is only the agricultural scientists who can clearly define what information is actually needed. Besides, they should integrate the remotely sensed information system with their agricultural information system to derive optimum usage, timely recovery of degraded land and refrain from unsustainable activities by use of other advanced technologies to their benefit and to enable increasing productivity through alternate farming system.

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