INTRODUCTION

1.1 General

Rice \textit{Oryza sativa} L., a semi aquatic annual cereal, is grown in more than 100 countries (planted in 11% of the world's cultivated land), in a wide range of climatic, soil and hydrological regimes—from a wet tropical to semi-arid and warm temperate regions, from heavy clay to poor sandy soils and from a prolonged period of flooding in deep water to dry land on hilly slopes. Geographically rice is grown between 53°N latitude and 40°S longitude and from sea level to an altitude over 3000 meters (Bor Luh, 1994).

1.2 World scenario in rice production

Rice is the world's single most important crop and staple diet for more than a third of the world's population. 90% of the world's total rice is produced and consumed in Asia, where about 60% of the earth's people live (Gurudev Kush, 1994). It supplies 75% or more of the calorie requirement and almost 50% of the protein requirement. India, China and Indonesia are the leading rice producing countries, with India and China accounting for 50% of the world's supply of rice. A complicating factor in the human geography of rice producing areas is the rapid population growth and the resulting increased pressure on the already strained food producing resources.

1.3 Indian scenario in rice production

Archeological records reveal that rice has been cultivated in India since 9/8th millennia B.C. India occupies first position in area with 42.4 million hectares (31%) out of total cultivable area of around 143 million hectares and such a large area is not witnessed in any of the rice growing countries. In India, rice is cultivated mostly during the wet season, coinciding with the period of active monsoon rains. However in some south and southeast regions two to three rice crops are harvested in a year by extending
cultivation to the dry season with the help of irrigation. Regarding production, India is in second position with 112.5 million tones (42%). Apart from providing employment to the largest mass of rural population (70%), rice earns foreign exchange to the tune of Rs.1790 crores.

The success or failure of rice crop is pivotal to the quality of individual life of major segments of world’s population as well as to the political and economic stability of large regions. The socio economic importance of rice combined with urban growth and the requirement of cost-effective monitoring of the rice crop has lead these countries to investigate methods to augment traditional land based monitoring with data obtainable through space born sensors.

1.4 Crop estimates and importance

Crop estimates consist of two major components i) acreage under the crop and ii) crop yield per unit area. Pre harvest estimates of crop production is indispensable for national food security including policy decisions of import/export plans and to estimate the requirement of capital, storage and transport facilities to stabilize the domestic supply and prices under Indian situation, where the agricultural production is highly susceptible to the vagaries of monsoon and vary seasonally and/or annually and the interactions among them are very complex. Crop management practices, such as fertilizer topdressing, irrigation and application of chemical pesticides are made explicitly or implicitly on the basis of assessment of both current crop status and technology effects in terms of final yield.

1.5 Conventional methods of crop estimations

Conventional procedures for crop statistics in India date back to 1884 as eye estimates. Presently, the crop production estimates are compiled by Directorate of Economics and Statistics, Ministry of Agriculture in New Delhi based on the reports
received from State Government authorities which are mainly prepared by the revenue agencies on complete enumeration of area and yield estimates on the basis of crop cutting experiments - conducted jointly/individually by central/state Government authorities. Limitations of the procedure are, the results of crop cutting experiments are received much after the crops are harvested and the crop production estimates are finalized after the season and worked out about six months after the close of the agricultural year. These delayed estimates do not serve towards timely policy development.

Other method of assessing yield is directly monitoring the crops by taking biophysical observations which are associated with yield like crop density, number of ears per plant, number of grains per ear, weight of grains etc. But this method is very expensive where systematic human errors can not be avoided and can be done only for small test areas.

1.6 Remote sensing in agriculture

Remote sensing is the science of deriving information about objects from measurements made at a distance, based on the electronic detecting, recording, and processing of electromagnetic radiation received from target areas. Reflectance/emittance of objects at different wavelengths, constitute spectral signatures of target object under study, enable identification and discrimination of objects. The large area perspective of aerial and space born remote sensing data, their repetivity, the ability to reduce field work and reducing travel cost, and the accuracy and timeliness of cost effective information generation are some of the reasons for the increasing use of remote sensing techniques by resource managers.

Current agricultural uses of remote sensing gleaned from various sources (Pacheco 1980, De jace and Mayer 1980, National Academy of Sciences 1977) include: preparing land use inventories; mapping soils; measuring organic matter and water
content of soils; evaluating biomass; detecting salt water intrusions; locating ground water; detecting diseases and insect pests of crops; determining crop vigour; identifying crops and detecting salt, drought and mineral stresses in crops. The information is more easily explored and modeled when synoptic, wall to wall remotely sensed data is used in conjunction with detailed, finer resolution ground data and spatially located point measurements.

1.7 Remote sensing in crops

Space born remote sensing in the visible, infrared and microwave bands of the electromagnetic spectrum using modern automatic interactive data handling techniques, has shown its effectiveness as a monitoring technique. Assessment of vegetation using remotely sensed data requires understanding of the spectral behavior of vegetation in different parts of the electromagnetic spectrum. Such an understanding of the spectral response helps in interpretation of data collected by various sensors. The identification of agricultural crops is based on the spectral reflectance characteristics of the different crop types. This reflectance however is a function of a number of factors such as phenology, which again depends on the weather situation of a particular year on other growing conditions like soil fertility or on management practices. Another factor relevant for crop identification is the similarity of reflectance values of different crop types. A careful selection of the satellite data acquisition date is necessary, which makes use of different phenological dynamics of the crops in question, provided the crop calendar of the various crops existing in the area is known.

1.8 Remote sensing in rice

Remote sensing has the potential to provide information on many factors related to rice production worldwide. Although production and yield statistics are available, data from many areas, especially those where access is difficult, is open to question.
Moreover, because of differences in sampling methods, comparisons of production figures among different areas may not be valid. When compared with the number of investigations on wheat and maize, the number of remote sensing investigations on rice is meager; thus it is suggested that rice crop has presented investigators with a great array of problems both technical (example: cloud cover during monsoon season) and logistical. The reasons are much higher diversity in growing conditions as well as yield, sensitivity of spectral indices to water background particularly in cases where the rice canopy is poor. If successfully applied, remote sensing of biomass can be important in global predictive estimates of grain production.

1.9 Geographic information systems in rice production modeling

Geographic information system is a decision support system involving the integration of spatially referenced data and non-spatial data where geographical location is the organizing principle. Geographic information system brings about rapid changes in the way that agronomic analysis and management are being conducted and provides the farm manager with a tool to aid in selective field management and also facilitate the evaluation of crop yield influenced by soil, climatic and crop factors, integration of spatial and attribute data and subsequent planning. Geographic information system coupled with Remote sensing and information technologies is providing new vistas for data acquisition, storage, processing, analysis and modeling in rice.

1.10 Rice production modeling - three tier approach

The economic benefits of methods suggested by research can often be investigated and highlighted by a model, thus stimulating the adoption of improved methods of prediction. The development of reliable crop yield with minimal data is a major thrust area by incorporating the spectral information to improve the predictive capability of the remote sensing based crop production estimation (Ajay Verma, 1999). The models are
capable of producing periodic yield estimates using only agronomic data or spectral data in ground-based studies at farm level, satellite data of finer resolution for mandal level studies as well as remote sensing data of medium resolution for district or regional level studies.

1.11 Study objectives

In view of the potential significance of studies in agronomy, remote sensing and Geographic Information System, a research program has been carried out covering three-tier approach, with the broad objective of modeling rice production using agronomic information, remote sensing data and Geographic Information System. The specific objectives of the research program are as follows.

1. To study the in-season spectral behavior of rice crop in relation to internal structure of leaf, growth and yield of rice in ground based field experiment.

2. To bring out the relationship of ground based spectral response of rice to satellite derived spectral response.

3. To estimate the pre-harvest acreage and production of rice using fine resolution remote sensing data at mandal level.

4. To evaluate the utility of fine and medium resolution remote sensing data for acreage and production estimates at mandal level.

5. To estimate the pre-harvest acreage and production of rice using medium resolution remote sensing data at district / region level.

6. Integration of Remote Sensing and GIS to develop suitable yield/ production model for rice, at regional level.

7. To generate rice yield potential zones in the study area using spatial and non-spatial data.
To achieve the above objectives, a ground-based experiment using LI-1800 portable spectro-radiometer was conducted initially in Directorate of Rice Research farm (ICRISAT campus), followed by processing, interpretation and analysis of IRS satellite data as well as necessary ground truth collection in the study area. GIS was used to integrate the agronomic, attribute, and spectral data to develop yield/production model.