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Applications of Remote Sensing and GIS in Crop Surveys: An IASRI Perspective

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SUMMARY

I consider it a great honor to be called upon to prepare a paper on birth centenary of Dr. Daroga Singh, Former Director of the Institute. I am grateful to ISAS and especially Dr. Padam Singh, Executive President, ISAS for giving me this opportunity. I am greatly indebted to Dr. Daroga Singh for his generosity, kindness, guidance and support right from my student days at IASRI and his inspiration and guidance as Chairman of my Advisory Committee for both my M.Sc. Degree and Ph.D Degree at IASRI and in Delhi University. After I joined service at IASRI, Dr. Daroga Singh remained a great inspiration and support for which I will remain indebted to him throughout my life. During 1980's, NATP Programme sponsored by UNDP was implemented at ICAR and its research institutes to give a thrust to application of the new and advanced technologies in different fields of Agricultural research to boost the production and research. During this period, Dr. Prem Narain has been the Director of the Institute. He had a great vision and zest to work and during his time, the research activities of the Institute expanded vastly. He had great belief in the enormous strength of the Remote Sensing technology and hence it was recognized as a new thrust area of research under NATP and I was given the responsibility to initiate research programs in this field. As Dr. D. Singh had been great supporter of new technology therefore, we have therefore decided to present work done at IASRI in the area of Remote Sensing and Geo-Informatics in this paper, which is dedicated to him.

Keywords: Remote sensing; Geographical information system; Spatial sampling; Spatial modeling.

1. INTRODUCTION

Geo-informatics is integrated technology for collection, transformation and generation of information from integrated spatial and non-spatial data bases. Remote sensing, Geographical Information Sciences (GIS), Global Positioning Systems (GPS), Relational Data Base Management Systems (RDBMS) are some of its important constituents. It is a tool for assessment, monitoring, planning and management of agricultural research and development. Management of agricultural resources is a myriad activity of conservation practices and land/water resources aimed at increasing the food production. Substantial increase in crop production could be achieved by bringing additional land under cultivation, improved crop management technology through use of high yielding, input responsive and stress tolerant crop varieties, improved pest control as well as by increasing irrigation and fertilizer inputs. These inputs together with reliable information on existing land use, acreage under various crops, soil type, monitoring of surface water bodies for ground water development management of natural calamities etc. will enable formulation of appropriate strategies to sustain the pace of agricultural development. This in turn calls for a holistic approach, which must combine short-term management of agricultural resources at micro-level with long-term global perspectives, keeping in view of socio-economic and cultural environment of the people. The role of space geo-informatics in finding new resources for agriculture development for optimally managing the already available resources in order to maximize agriculture production is recognized worldwide and is found to be potential.

Remote sensing technology has great potential in different fields of agricultural research and offers numerous advantages in the study of agricultural and

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other resource surveys which include, the potential for accelerated surveys, capability to achieve a synoptic view under relatively uniform lighting conditions, availability of multispectral data for providing intense information, capability of repetitive coverage to depict seasonal and long-term changes and availability of imagery with minimum distortion etc. Therefore, it permits direct measurement of important agro-physical parameters.

Remote sensing of earth resources utilizes electromagnetic waves, which ranges from short wave length ultra violet through visible near infrared and thermal infrared in the longer wave length, active radar and passive microwave systems. A great advancement in applications of computers to this science is the development of capability of storing vast and varied information, ranging from historical information and aerial photography to spacecraft data, ground reference, and other forms of ancillary data. All these information is stored in the form of highly useful database/information system. Thus, remotely sensed data and its derived information have become an integral component of agricultural management system in the country.

Applications of space borne remote sensing data for large area crop survey was explored in USA under Corn Blight Watch Experiment (CBWE) in 1971 which was followed by large number of experiments/large-scale remote sensing program. In a country like India, with vast geographic spread and great diversity in its set up, the need to apply remote sensing technology for national development was recognized during early 70's. The pioneering experiment was of coconut root–wilt disease using colour-infrared aerial photography. Numbers of studies were conducted for methodological development in this area.

Remote sensing activities in India received a tremendous boost with the launch of Indian Remote Sensing Satellite-1A (IRS 1A) in March 1988. India is moving fast in development of new satellite systems and recently launched number of satellites dedicated to specific area of applications such as Oceansat, Cartosat, Resourcesat etc. Radar Imaging Satellite (RISAT), a microwave remote sensing mission with Synthetic Aperture Radar (SAR) operating in C-band and having a 6 x 2-meterplanar active array antenna based on trans-receiver module architecture has been launched recently. Many technological developments, which occurred in 20th century contributed to the development of the concept of precision farming, which includes GPS, GIS and high-resolution remote sensing satellite data. In following sections, contributions of this Institute in the field of GIS and Remote sensing are described in detail.

2. CONTRIBUTIONS OF IASRI

ICAR-Indian Agricultural Statistics Research Institute (IASRI) was established on July 02, 1959 as an Institute of Agricultural Research Statistics. The mandate of the Institute is to undertake basic, applied and adaptive research in Agricultural Statistics, to conduct post graduate and in-service training courses in Agricultural Statistics and Computer Applications, to provide consultancy services, to act as a repository of information on Agricultural Statistics for research. Institute has been identified as an Advanced Centre of Excellence in education and training in Agricultural Statistics and Computer Applications. Apart from this Institute also, liaise with institutions of National Agricultural Research System (NARS), National Agricultural Statistical System (NASS), Department of Space (DOS) etc., to assist in the development and strengthening of quality of agricultural research and agricultural statistics through undertaking research and consultancy projects. This Institute also recognized potential of geo-informatics technologies and initiated work in the direction of generation of crop production statistics since early nineties. During these years Institute has undertaken number of research projects / studies and made significant contributions broadly in the areas of (i) Crop yield estimation (ii) Spatial stratification techniques (iii) Small area estimation (iii) Spatial sampling (iv) Spatial modeling (v) Classification techniques (vi) Integrated surveys for hilly regions and (vii) Web GIS. Some of important contributions of the Institute are briefly described in following sub-sections:

2.1 Crop yield estimation

After the end of Second World War and in the aftermath of severe Bengal famine in 1943 an urgent need for reliable estimates of food grain production was recognised by the Institute. After conducting several studies, the important methodology for estimation of crop yield based on crop cutting experiments on a random sample of crop plots selected through a multi-stage sampling design was developed which is being used very successfully in the country and in several other countries also Panse (1946, 1947, 1954).

Therefore, our first attempt was to make use of remote sensing satellite data to improve the efficiency of our crop yield estimation methodology. Further, we also studied how without increasing the number of crop cutting experiments, we can obtain reliable estimates of crop yield at small area like Blocks or Tehsil level and also how to utilize satellite data for improving crop yield forecasting models.

Goyal (1990) demonstrated that remotely sensed satellite spectral data in the form of vegetation indices has been used to post- stratify the cropped area into area of homogeneous crop vigor and consequently improved estimators are proposed to estimate the crop yield using remote sensing data along with the ground enumerated yield estimation survey data. The usefulness of the suggested procedure has been demonstrated by using the Landsat (TM) satellite data and the crop yield data from yield estimation survey based on crop cutting experiments from Sultanpur district of Uttar Pradesh. Further, it has been observed that Normalized Difference Vegetation Index (NDVI) as compared to Ratio Vegetation Index (RVI) has higher potential to discriminate vegetation vigor and hence has the higher potential to be used in crop yield estimation surveys. An attempt was also made to quantify the effect of misclassification of units on the size of post-strata and the post-stratified estimator of the crop yield. The expressions for the bias and variance of the post-stratified estimator have been derived in terms of the extent of misclassification.

Singh and Goyal (1993), Singh *et al.* (2000) and Singh and Goyal (2000) extended the earlier results for estimation of wheat crop yield for district Rohtak, Haryana using crop cutting experiments data for the year 1995-96 and satellite spectral data from the Indian Remote Sensing Satellite IRS-1B LISS II data for February 17, 1996. Post stratified estimator of crop yield using spectral data in the form of vegetation indices NDVI and RVI for stratification have been obtained for the district. The efficiency of the post stratified estimator based on NDVI and RVI compared to the usual estimator comes to 1.42 and 1.28 respectively. This study thus almost confirms the findings of the earlier study that the district level estimator of crop yield may be obtained by reducing the number of crop cutting experiments to about 2/3rd without loosing the precision thus resulting in great savings of cost. Further, two small area estimators of crop yield, namely the direct estimator and the synthetic estimator have been developed at tehsil level using post stratification based on NDVI. The standard error of both the direct estimator and the synthetic estimator at tehsil level is within 5 per cent and as expected the synthetic estimator is more efficient as compared to the direct estimator.

Ibrahim (1992) investigated the utility of the multi-date spectral data taken at selected intermediate times in the growing season, in a Markov chain model to forecast crop yield. A hand-held spectral radiometer has been used for collecting the spectral responses from the experimental plots of wheat crop at fortnightly intervals during the growth of the crop. The spectral parameters observed at the different growth stages as well as the observed yield have been utilized to simulate a spectral population along with the corresponding yield based on a stochastic model.

Das (2004) proposed alternative approach of crop yield estimation using multi resolution satellite data. The attempts were made to make use of satellite spectral data and spatial sampling technique for crop acreage estimation, crop yield estimation and crop yield forecasting, which involves use of satellite data of coarse spatial resolution, which is cheaper with larger aerial coverage. It was shown that remotely sensed satellite data can be used effectively as area frame for conducting crop yield estimation surveys.

Das *et al.* (2013) proposed an estimator for the average yield of wheat for the state of Haryana, India. This estimator uses information from Wide Field Sensor (WiFS) and Linear Imaging Self Scanner (LISS-III) data from the Indian Remote Sensing (IRS-1D) satellite and crop-cutting experiment data collected by probability sampling design from a list frame of villages. The authors found that relative efficiencies of multiple-frame estimators are high in comparison to single-frame estimators.

2.2 Spatial Sampling

In agricultural surveys often the parameter of interest is geographical in nature *i.e.,* the observations are dependent through space thus classical statistics cannot be applied as such. Dependence implies correlation and spatial dependence implies the presence of spatial autocorrelation. Since, in geographical data ‘adjacent units are often more alike than units that are far apart', it is desirable to exploit this information in the sampling designs. In this way duplicate information partly contained in areas already sampled can be avoided. Another advantage is that the sampling cost can be economized without loosing the reliability of the estimates. An attempt by Misra (2001) was made to improve the conventional survey methodology for agricultural surveys with the help of spatial sampling procedures. The potential of GIS to handle various kinds of information through their geographic coordinates and Remote Sensing with its advantage of wide area coverage, repetitive coverage and synoptic view have been exploited for the study. An improved spatial sampling technique known as Contiguous Unit Based Spatial Sampling (CUBSS) Technique is proposed in this study (Sahoo *et al.*, 2006). The technique incorporates size measure along with spatial contiguity of the units in the population. The spatial correlation is estimated for auxiliary character which is used along with size measure in assigning weights for selection of the sampling units. The probability of selection of any unit is governed by these weights. The principle of sample selection is that the probability of selection of any unit increases as the distance from the units (area) already selected increases. The sample selection criterion is based on the weights, accounting for spatial variability and the size measure accounting for areal extent. Further, a suitable unbiased estimator which takes into account the order of the draw is suggested for this situation. The study was carried out for regular lattice i.e., assuming the area to consist of regular units. In order to tackle the problem of irregularity of the sampling units, application of distance-based neighbors were suggested. Based on these neighbors the modified formula for spatial correlation is also suggested in this study. For defining these neighbors, the concept of lagged variable and lagged series is being used. A spatial sampling technique termed as Distance Unit Based Spatial Sampling (DUBSS) is also proposed in this study and its efficiency is compared with the existing ones and CUBBS technique by carrying out a suitable simulation study. The proposed technique performs considerably better than all the other techniques.

Kankure (2007) made an attempt to develop spatial ranked set sampling methodology for the estimation of finite population mean. Four sampling designs were proposed which takes into account the spatial relationships of the areal sampling units in the population while selecting a sample. The proposed Spatial Ranked Set Sampling (SRSS) procedures involve the selection of ultimate sampling units in two stages. In the first stage Random Spatial Clusters (RSC) of sampling units in the population are formed and in the second stage ranked set sample of specified size is being selected. Sample selection at the first stage is done by applying Dependent Areal-Unit Sequential Technique (DUST). This technique is based on giving different probabilities of selection to the sampling units in such a way that nearer units, or already selected units in the sample, get lesser probability of selection, while farther units get higher probability of selection. It is one of the desirable characteristics of a sampling design in spatially correlated population. The spatial component of the data is incorporated at this stage by dividing the entire population into Random Spatial Clusters (RSCs) by considering first phase units as the key units. The spatial clusters are formed on the basis of nearest neighborhood approach with respect to randomly selected units. Any particular unit will fall exclusively in a single spatial cluster, which has been formed by the key unit nearest to it on the basis of Cartesian distances calculated using latitudes (La) and longitudes (Lo) of the locations. Having selected the RSC, RSS was carried out using two approaches i.e. (i) the entire ranked set sample was selected independently from each RSC and (ii) different sets of the RSS are selected independently from different RSC. Thus, in this study some new and more efficient sampling techniques have been proposed which take into account the spatial correlation present in the geographical units. The results of the study point out that, in spatial surveys, a considerable gain in efficiency of the estimators could be achieved by using distance-based sample selection strategies even when applying these for complex sampling schemes such as RSS. The complex algorithms involved in the selection procedure of distance-based sampling strategies could be solved with the use of advanced computing and software. Biswas (2014) and Biswas *et al.* (2017) proposed a Spatial Estimator (SE) to estimate the population mean of a spatially correlated finite population by incorporating spatial dependencies among the sampling units. The author also developed two Rescaled Spatial Bootstrap (RSB) methods for estimating the variance of the proposed spatial estimator. The properties of the proposed spatial estimators and its corresponding RSB methods were studied empirically through spatial simulation study.

2.3 Crop Acreage Estimation in Hilly region where Cadastral survey data is not available

It is well known fact that there is no objective methodology for estimation of area under different crops in North-Eastern states due to typical problems existing in these regions. The north-eastern states particularly Meghalaya, mainly consists of hilly region with thick forest cover. Besides this, the main problem is its undulating topography and non-accessibility of vast area. Further, the relative percentage area under the crops is very less. Mostly terraced farming and Jhum cultivation is practiced in these regions. Moreover, these areas particularly Meghalaya, are covered by clouds most of the time in a year. Thus, it is difficult to get cloud free images of these areas. Therefore, use of remote sensing satellite data alone may not be able to provide reliable information. Further, there are no cadastral maps and village boundary maps existing for these regions. In contrary to other states, in north-eastern regions reliable information regarding total number of villages in each district/block is not available. Further, within a village's total number of farmers, number of fields owned by each farmer, crops grown by the framers etc. are also not available in village records. Thus, the traditional methodology of area estimation is not applicable in these regions. Keeping all this in view, a study (Sahoo *et al.,* 2008) was taken up by Indian Agricultural Statistics Research Institute (IASRI), New Delhi in collaboration with North- Eastern Space Applications Center (NESAC) Shillong and Space Applications Center (SAC) Ahmedabad in which methodology was developed using integrated approach of remote sensing, GIS and ground survey for estimation of area under winter paddy crop in Meghalaya. The satellite data of IRS 1D, LISS III sensor has been used for this study. Under this approach the area under paddy has been obtained by usual classification method. There are two major factors affecting the accuracy of the crop area as obtained from the classified satellite image in the hilly regions: (i) Due to undulating topography of the region, misclassification and topographic geometry, there may be large differences of area under crop in the image and actual area under crop on the ground which may also result in larger extent of misclassification errors (ii) The area under paddy crop falling under hill shades or valleys may not be exposed to the satellite sensor, as satellite sensors are sun-synchronous. Further, small paddy fields are not detectable due to lower spatial resolution of the LISS-III sensors. In order to rectify the area under paddy crop due to undulating topography and misclassification errors, relationship between area under paddy in the classified image and actual area under paddy crop on the ground has been established. The area under paddy which has not been captured by satellite sensor due to hill shades and limitations of spatial resolution of the sensor has been rectified by a suitable sample survey in the buffer created along the National Highway/State roads in GIS environment. Suitable estimators were developed to estimate the area under paddy in this buffer zone. The vector layer of this buffer was overlaid on the satellite-classified image and the corresponding area from the image was extracted. Using these estimates, the area under paddy in the entire district was estimated.

A study was undertaken in Yamunanagar district of Haryana State (Ahmad *et al.,* 2003), to develop a GIS based technique for identification of potential agro-forestry areas. In this study, important factors responsible for growth of agro-forestry were identified, suitability index using Spatial-Analytic Hierarchy Process was constructed and was compared with the Composite development index. A new Objective Analytic Hierarchy Process (OAHP) procedure was used to develop suitability index for agro-forestry of each village.

Ahmad *et al.* (2015) developed a methodology for acreage estimation under agro-forestry using LISS-IV (Spatial resolution- 5.8 m) data in Ludhiana district of Punjab State. In this study supervised classification, MLC was applied and overall accuracy of 94.28% was achieved. Area under agroforestry at district level was again classified into different classes such as area under *Populous trichocarpa*, *Eucalyptus globus* and *Melia azedarach*.

Paul (2016) studied acreage estimation of mango using EO-1 Hyperion sensor hyperspectral data. Statistical techniques like Analysis of Variance (ANOVA), Classification and Regression Tree (CART), JafrriesMatusita (J-M) distance and Linear Discriminant Analysis (LDA) were used for identifying most suitable bands for discriminating fruit crops. The study has been conducted in Sabour district of Bihar, Meerut in Uttar Pradesh and IARI, New Delhi. Pixel counting method was used for area estimation of mango orchards.

Udgata (2017) studied acreage estimation of mango using sentinel 2 multispectral satellite data for West Godavari district of Andhra Pradesh. In this study three supervised classification techniques such as Maximum Likelihood Classification, Support Vector Machine (SVM) and Artificial Neural Network (ANN) were used for discrimination of mango crops from other fields. The area under mango was calculated from satellite data which was further integrated with survey data to calculate final mango area.

Paul *et al.* (2018) gave an estimate of acreage under mango orchard using hyperspectral satellite data. The study was conducted for Meerut district of Uttar Pradesh. The hyperion hyperspectral satellite data was evaluated to estimate the area under all mango orchards. These estimates were compared with actual area under mango orchards measured using Global Positioning System (GPS) and the total area under mango was predicted as 961.88 ha which was 92% close to ground data 889.65 ha. The results indicated the scope of hyperspectral remote sensing in acreage estimation of fruit crops.

Udgata *et al.* (2020) gave acreage estimation of mango (Mangifera indica) using remote sensing and machine learning techniques for West Godavari district of Andhra Pradesh. In this study four satellite images of sentinel 2 was acquired during December 2016. Three supervised classification techniques, viz. Maximum Likelihood Classification (MLC), Support Vector Machine (SVM) and Artificial Neural Network (ANN) were used for land use and land cover map preparation. Support Vector Machine using three different kernel functions, viz. Radial Basis Function (RBF), Sigmoid kernel and Polynomial kernel were used to improve the classification accuracy. SVMRBF was found to be the best classification technique with overall accuracy of 94.44 and kappa coefficient 0.9218.

Anjoy *et al.* (2020) proposed small area estimation (SAE) methodology to estimate proportion of indebted households in rural areas for the two major occupation categories- rural cultivator and rural non-cultivator as well as for both categories combined together across all the 30 districts of Karnataka state in India using the data of All India Debt and Investment Survey 2012-13 and population census 2011.

2.4 Spatial Prediction and Modeling

Agricultural fields are Spatial in nature. If we consider productivity of the field with respect to certain crop provided other factors as constant. It does not change abruptly from one field to another. The change is very gradual and the neighboring fields have more or less same structure. In general crop-cutting experiments (CCE) are carried out for yield estimation in selected villages. It may be noted that from crop cutting experiment the estimation of production at lower level like Tehsil's, villages etc. is difficult and prone to large error due to small sample size. The application of spatial statistics in agriculture to improve the prediction and estimation may be a useful attempt for small area levels. Spatial characteristics and CCE will help us in giving the better estimate and at lower level also. With the help of available literature in the field of spatial statistics, it is possible to apply suitable spatial models to predict the production surfaces i.e., values of production at each point of the map, of the target region. Field sizes of our country are fairly small; therefore it is more appropriate to utilize the spectral data as auxiliary information. A study was undertaken by Gupta (2002) to develop an integrated methodology for wheat crop yield estimation using the survey data on wheat crop yield from CCE along with the satellite spectral data in the form of vegetation indices i.e., Normalized Difference Vegetation index (NDVI). The use of remote sensing satellite data along with the crop yield data based on CCE can greatly improve the efficiency of crop yield estimators at small area level.

Gupta (2007) made an attempt to develop spatial prediction model under four different situations i.e. (i) using prior information about parameters which is non-informative for known and unknown variance (ii) using prior information about parameters which is informative for known and unknown variance, (iii) using prior information about parameters as natural conjugate prior for known and unknown variance and (iv) using fuzzy approach for linear interval model for vague characters under study. It was shown in this study through simulation that Bayesian regression analysis is always better than simple regression analysis. This may be due to the fact that information contained in the sample as well as about the parameter of the model has been utilized in the estimation procedure. Further, there is significant gain in the precision in case of geographical variables when spatial effects were taken in to account in the estimation procedure under Bayesian framework. It can be seen that variogram models plays significant role in capturing the spatial effect. Spatial Bayesian regression model performs better when spatial effects are incorporated through variogram models. The results obtained through exponential and spherical variogram models were found to be encouraging as compared to other models. Rai *et al.* (2007) showed the great potential of spatial models based on geo-statistical techniques of variogram and kriging for estimation of crop production at small area level *i.e.,* at low administrative level, through generation of production surface which was found to be comparable to the estimated production of wheat crop through large-scale survey data.

A study was undertaken by Rai *et al.* (2004) in district of Lalitpur in UP due to the fact that this district has been observed to have considerable area under most of the land use classification categories. It has been observed in this study that quality of revenue records in the study area i.e., Lalitpur district is quite reliable for most of the usual nine-fold classified land use classes. The statistics of land use classes were restricted to five broader classes, which can be identified by using single time digital data of Remote Sensing out of the above nine-fold classification can be easily obtained using RS. These statistics of land use classes obtained through RS could be used as auxiliary information in spatial / non-spatial models to get reliable statistics of different classes. The above models can be used to predict the statistics related to these classes for non-surveyed area/villages of the districts. Hence, it is possible to develop reliable land use statistics at any smaller level i.e., panchayat/block/tehsils using above models. In order to take into account of spatial dependence of the neighboring units, the classical sampling technique approach is being modified such that the probabilities of selecting neighboring units, once a particular unit is selected in the sample, becomes less as compared to distant areal units. The best fitted spatial model for each class of land use was found to be different, depending on the spatial distribution of the land use class patches of land in the district. The prediction of area under different land use categories covered under nine-fold classification based on satellite data using spatial model seems to be quite satisfactory.

Chandra *et al.* (2012) proposed geographical weighted empirical best linear unbiased predictor (GWEBLUP) for a small area average and also developed an estimator, its conditional mean squared error. The author also obtained empirical best linear unbiased predictor under the linear mixed model as a special case of the GWEBLUP. It was found from the empirical study that the proposed GWEBLUP predictor can lead to efficiency gain when spatial non-stationarity is present in the data.

Gharde *et al.* (2013) developed a small area estimator based on GWR technique to incorporate spatial information in the random area effect present in the unit level small area model and also suggested a method for finding MSE using this model. Furthermore, she has made a comparison of developed estimator with non-spatial estimators.

Chandra *et al.* (2017) developed a geographically weighted regression extension of the generalized linear mixed model (GLMM) and extended this model to allow for spatial non-stationarity under small area estimation and an empirical predictor for small area counts under an area level model was proposed.

Barman (2017) and Barman *et al.* (2020) proposed estimators for finite population total which incorporates spatial information that has smaller bias and better efficiency as compared to existing estimators.

Moury (2020) and Moury *et al.* (2020) proposed two outlier robust geographically weighted regression (RGWR) estimators to estimate finite population total under spatial non-stationarity condition. The author found that the proposed estimators performed fairly well under spatial non-stationarity condition when survey data contain outliers.

Paul *et al.* (2022) proposed a Proportional Spatial Bootstrap (PSB) variance estimation method for the spatially integrated estimator of finite population total in presence of missing observations. The statistical properties of different spatial imputation techniques under the proposed PSB method of variance estimation were studied empirically through a spatial simulation study. The empirical results reveals that the proposed PSB method is quite efficient for variance estimation while dealing with missing observations.

Apart from these studies, numbers of research papers were published in national and international journals by the researchers of this Institute. Some of the important contributions in this regard are Singh *et al.* (1992), Singh and Ibrahim (1996), Singh *et al.* (2002), Sahoo *et al.* (2005), Sahoo *et al.* (2006), Sahoo *et al.* (2010), Sahoo *et al.* (2012), Sahoo *et al.* (2013), Ahmad *et al.* (2007), Kankure and Rai (2008), Karmakar (2018), Krishna *et al.* (2018), Paul *et al.* (2018), Udgata *et al.* (2020) etc.

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