

Use of Remote Sensing and GIS Technology in Agricultural Surveys

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Abstract

The advent of remote sensing technology and its potential in the field of agriculture has given new opportunities for improving agricultural statistics. In the present study a suitable methodology is developed for estimating crop area by integrating remote sensing and GIS based spatial sampling approach. An empirical study to estimate the area under wheat crop for district Rohtak, Haryana for the year 1995-96 using IRS-1B, LISS-II data has been conducted. Improved estimators of crop acreage using spatial sampling as suggested by Prachi (2002) by using average NDVI of the village as an auxiliary character have been developed. Further, the estimates obtained from this approach are compared with those obtained from usual remote sensing method based on supervised classification. The results of the study show that inclusion of remote sensing parameter in GIS assisted spatial sampling techniques considerably enhance the performance of the estimators.

1 Introduction

The crop production of principal agricultural crops in the country is usually estimated as a product of area under the crop and the average yield per unit area of the crop. The estimates of the crop acreage at a district level are obtained through complete enumeration, whereas, the average yield is estimated through General Crop Estimation Surveys (GCES), on the basis of crop cutting experiments conducted on a number of randomly selected fields in sampled villages of the district. However, the traditional system of estimation of crop production is facing several problems, viz. lack of timely information, reliability of records maintained by the *patwaris* due to heavy burden of their work etc.

Advent of remote sensing technology and its great potential in the field of agriculture have opened newer possibilities of improving agricultural statistic system as it offers accelerated, repetitive and spatial – temporal synoptic view in different windows of the electromagnetic

spectrum from its vantage point in space. In the last few years, remote sensing technology has been increasingly considered for evolving an objective, standardized and possibly cheaper and faster methodology for crop production estimation (Bauman, 1992). The acreage estimation procedure using remote sensing technique broadly consists of identifying representative sites of various crops (called training sites) on the image based on the ground truth collected, generation of signatures for different training sites and classifying the image using these training statistics. Depending upon the study area, broadly two procedures namely, (i) sample segment approach and (ii) administrative-boundary-overlaying approach have been studied

Further, as remote sensing methods regularize continuous landscapes into a grid of equal sized and regularly spaced data in the form of pixels (Fisher, 1997), it is anticipated that there will be some degree of dependency between pixels, most likely in the form of positive spatial autocorrelation. Such dependence has potentially a dual impact on the analysis of image data. On the one hand it is a source of nuisance and error, when traditional statistical techniques involving assumption of independence of sampling units are applied, while on the other hand it represents a valuable information, which may be exploited as an image characteristic. Hence, use of satellite data for estimation of crop acreage, considering spatial variability of crop area distribution needs to be considered. GIS is a potential tool for handling voluminous remotely sensed data and has capability to support spatial statistical analysis. Thus there is a great scope to improve the accuracy of crop area estimates by incorporating the effect of spatial dependency through integrated application of remote sensing technology and GIS.

Keeping in view the above facts, in the present study, an attempt has been made to estimate area under wheat crop for the year 1995-96 in Rohtak district of Haryana by following three approaches namely (i) through simple random sampling of villages (ii) using remote sensing technique of boundary overlaying approach and (iii) through spatial sampling approach namely Stratified CUBSS and Stratified DUBSS (Prachi et al 2002).

2 Study Area

This study has been carried out for Rohtak district of Haryana State for wheat acreage estimation, during Rabi season of the year 1995-96. During the year 1995-96, Rohtak district was reconstituted with four tehsils namely Rohtak, Jajjar, Bahadurgarh and Maham, altogether consisting of 402 villages. The digitized map of Rohtak district having 402 villages is shown in the Fig. 5.1. (Gohana tehsil containing 90 villages,

which was earlier a part of Rohtak district during the year 1991-92, has been included in Sonapat district of Haryana. Hence, from this map, which is based on digital data of 1996, Gohana tehsil has been excluded.). Rohtak district is covered in twelve Survey of India Toposheets of scale 1: 50,000.

3 Data Used in the Study

Three types of data have been used in this study, satellite data obtained through remote sensing of Rohtak district of IRS 1B- LISS II for February 17, 1996 , spatial data in the form of digitized maps of all the 402 villages in the district obtained through GIS and cop acreage data of selected villages from the *girdawari* records maintained by the village *patwaris*.

4. Estimation Procedures

The area under wheat for the district was estimated by using three methods namely (i) simple random sampling technique, (ii) usual remote sensing technique and (iii) the proposed spatial sampling technique using remote sensing and GIS.

4.1 Estimation by Simple Random Sampling

A sample of 100 villages was selected from the entire population of 402 villages by the method of simple random sampling. The data for area under wheat crop, of these selected villages were obtained from *patwari* records. The usual estimator of simple random sampling was applied to obtain the estimate for area under wheat crop and its standard error.

4.2 Estimation by Usual Remote Sensing Technique using Administrative-Boundary-Overlay Approach

In this approach, the district administrative boundary of Rohtak district was overlaid over the remote sensing image to extract the image of Rohtak district in all four bands. Then wheat crop area was identified and estimated by following supervised maximum likelihood classification.

4.3 Spatial Sampling Technique Using Remote Sensing and GIS

In this approach, remote sensing digital data, in the form of NDVI has been used as an auxiliary character for the spatial sampling technique. Prachi (2002) proposed improved spatial sampling schemes and suitable unbiased estimators, which take into account the order of the draw. On the

basis of the method of sample selection and estimation four spatial sampling methods have been suggested. These are (i) Contiguous Unit Based Spatial Sampling (CUBSS) Technique (ii) Stratified Contiguous Unit Based Spatial Sampling Technique (iii) Modified Contiguous Unit Based Spatial Sampling Technique (iv) Stratified Modified Contiguous Unit Based Spatial Sampling Technique.

The spectral response of vegetation in the red band is strongly correlated with chlorophyll concentration while the spectral response in the near infrared band is controlled by the leaf area index and green vegetation density (Major *et. al.*, (1990). The differential vegetation responses at these two spectral regions have been used to develop Normalized Difference Vegetation Index (NDVI), which is defined as

$$NDVI = \frac{(B4 - B3)}{(B4 + B3)}$$

where, B4 is mean reflectance (digital number) in near infrared band and B3 is mean reflectance (digital number) in the red band.

NDVI image was prepared from unstretched corrected B4 and B3 bands of IRS 1B, LISS -II sensor to represent quantitatively the vegetation coverage over the area. The value of the prepared NDVI image was ranging from -0.31 to 0.62. Higher the positive value of NDVI, higher is the vegetation cover and its vigour. This NDVI image was further linearly stretched to have values between 0-255 digital numbers for better display and interpretation. In case of district Rohtak, the wheat is one of the major crops during *Rabi* season. Hence, major part of cultivated area was under wheat crop. Due to this fact the correlation between mean NDVI and area under wheat in a village is expected to be high. Hence It is expected that greater the value of mean NDVI of the village, larger is the area under cultivation

Two spatial sampling techniques - Stratified CUBSS, for the regular area units using contiguity based and stratified DUBSS, a modified technique for irregular area units using distance based neighbour approaches respectively, have been used here for selecting a representative sample of villages. The mean NDVI of each village was used as the auxiliary character for estimating spatial correlation using both the approaches. The spatial correlation was further used for obtaining weights for selecting the villages in the sample for better representation. The calculated values of spatial correlation for stratified CUBSS and stratified DUBSS were 0.48 and 0.57 respectively. Based on these values, weights were obtained for the sample selection.

A sample of 100 villages was selected for estimating area under wheat crop for Rabi season of 1995-96 for district Rohtak by two sampling techniques namely (i) Stratified CUBSS and (ii) Stratified DUBBS. The first unit was selected by probability proportional to size sampling. The rest of the units were selected according to the weights assigned to each unit according to stratified CUBBS and stratified DUBSS technique.

5. Results

To examine the performance of different estimators, percentage relative bias for mean (RB) for different estimators were computed using the following formula.

$$RB = \left(\frac{\bar{Y}_C - \bar{Y}_A}{\bar{Y}_A} \right) \times 100, \text{ Where, } \bar{Y}_C \text{ is the estimated and } \bar{Y}_A \text{ is true value.}$$

The results of the study are given in the table 1. The table shows the estimates of the area under wheat crop in the district by the four methods *viz.* simple random sampling (SRS), Remote sensing technique, Stratified CUBSS and Stratified DUBSS. The true value of the total area under wheat in the district based on *patwari* records is also obtained and is given in the table. This was used for calculating relative bias for each estimator. Since, exact

Table 1 Comparison of different estimators of area under wheat for district Rohtak during *Rabi* 1995-96 ('000 ha)

Estimator	Area under wheat	Relative Bias (%)
SRS	132.57	7.52
Remote Sensing Technique	137.01	2.97
Stratified CUBBS	135.73	3.87
Stratified DUBBS	139.76	1.02

* True value is 141.20 ('000) ha.

On the basis of this investigation, it has been observed that stratified DUBBS is superior in terms of relative bias followed by remote sensing estimate and stratified CUBSS. Thus it has

been observed that the traditional sampling techniques can be improved upon using GIS assisted spatial sampling technique. Further, when remote sensing parameter, NDVI was used as an auxiliary character for the GIS assisted spatial sampling technique its performance was enhanced. The study demonstrated that the two technologies are mutually complementary and should be used simultaneously to achieve the best results.

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