J. Ind. Soc. Agril. Statist.
59(2), 2005 : 151–160

Integrated Approach Based on Remote Sensing and GIS for Estimation of Area under Paddy Crop in North-Eastern Hilly Region

Prachi Misra Sahoo, Anil Rai, Randhir Singh, B.K. Handique[1] and C.S. Rao
Indian Agricultural Statistics Research Institute, New Delhi
(Received : June, 2005)

SUMMARY

At present the states belonging to north-eastern region do not have any objective approach for collection of agricultural statistics. The north-eastern states particularly Meghalaya, mainly consists of hilly region with thick forest cover and mostly terraced farming and Jhum cultivation is practiced in these regions. The main problem of this region is its undulating topography and non-accessibility of vast area and very less percentage of area under agriculture, scattered throughout the state. Meghalaya, remain covered by clouds most of the time during the year. Therefore, use of remote sensing satellite data alone may not be able to provide reliable information regarding crop acreages. Therefore, in the present study sampling methodology for collection of agricultural statistics using remote sensing satellite data combined with ground survey has been proposed.

Key words : Crop area estimation, Remote sensing, GIS, Hilly region.

1. INTRODUCTION

India is predominantly an agrarian economy both from the point of view of employment as well as contribution to the national income. Availability of reliable and timely agricultural statistics is hence of paramount importance for policy decisions regarding production, pricing, procurement, marketing, export/import, public distribution etc.

The Directorate of Economics & Statistics in the Department of Agriculture & Cooperation is the nodal official agency for collection, compilation and publication of major agricultural statistics like area and production of principal crops. The area statistics are collected on complete enumeration basis in respect of temporary settled states and a scheme for Establishment of Agency for Reporting of Agricultural Statistics (EARAS) has been introduced in permanently settled states i.e. Kerala, Orissa and West Bengal. But area statistics in the North-Eastern Region, Sikkim, Goa, UTs of Andaman Islands, Daman & Diu and Lakshwadeep are collected on the basis of ad-hoc methods based on impressionistic approach from the village headman. These estimates are quite subjective and unreliable. Therefore, there is need to develop a scientific methodology with strong statistical background which is capable of providing reliable estimates of area under different crops in these regions.

The advent of remote sensing technology supported by Geographic Information System (GIS) has opened new vistas of improving agricultural statistics systems all over the world. The applications of Remote Sensing (RS) in the field of agriculture are wide and varied, ranging from crop discrimination, inventory, assessment and parameter retrieval on one hand to assessing long-term changes and short-term characterization of the crop environment. The use of remote sensing for crop acreage and yield estimation has been well demonstrated through various studies all over the world, and has gained importance in recent years as a means of achieving these estimates possibly in a faster mode and at a cheaper cost (Murthy *et al.* (1996)). It is therefore required to explore

[1] *North Eastern Space Application Centre, Dept. of Space, Umiam, Shillong*

the possibility of use of satellite Remote Sensing for collecting agricultural statistics on a regular basis in north-eastern regions.

A major project Crop Acreage and Production Estimation (CAPE) by Department of Space has been in vogue since 1988 for developing methodologies for various major crops like paddy, wheat, maize using spectral data (Dadhwal and Parihar (1985); Dadhwal *et al.* (1991)). Recently a project "Forecasting Agricultural Output Using Space, Agro-meteorology and Land-based Observations (FASAL)" has been launched under the National Crop Forecasting Centre (NCFC) set up in the Ministry of Agriculture to meet the stringent requirements of timely, nation-wide and multi-crop reliable forecasts.

Singh and Goyal (2000) developed an integrated methodology for providing area and yield estimation and yield forecasting models using satellite data. The crop yield data from general crop yield estimation surveys based on crop cutting experiments (CCE) have been utilized for this purpose. Singh *et al.* (2002) developed small area estimates at the block level using satellite digital data along with yield data obtained from CCE.

The north-eastern states particularly Meghalaya, mainly consists of hilly region with thick forest cover. Mostly terraced farming and Jhum cultivation is practiced in these regions. The main problem of this region is its undulating topography and non-accessibility of vast area. Further, the relative percentage area under the crops is very small. These areas particularly Meghalaya, remain covered by clouds most of the time during the year. Therefore, use of remote sensing satellite data alone may not be able to provide reliable information regarding crop acreages. As there are no cadastral maps and well-defined village boundary maps for these regions, therefore reliable information regarding total number of villages in each district/block is not available. Also information on total number of farmers in a village, number of fields owned by each farmer, crops grown by the framer etc. are not available in the records.

Keeping all this in view, it was considered that the use of satellite data along with the ground survey data in GIS environment may be useful to obtain the reliable estimates for the area under crops in north-eastern states. In order to study the feasibility of this approach for estimation of area under winter paddy crop in Meghalaya, a pilot study was taken up in Ri-Bhoi district of the state. Indian Agricultural Statistics Research Institute (IASRI), New Delhi and North-Eastern Space Application Center (NESAC), Shillong jointly conducted the study with the support from Space Application Center (SAC), Ahmedabad.

2. STUDY AREA

Ri-Bhoi district is one of the seven districts of Meghalaya. The district has an area of 2448 sq. kms with a population of 1,92,795 (2001 Census). Its head-quarter is at Nongpoh, which is about 53 kms from the State Capital, Shillong. There are 3 blocks in the district. The district is bounded on the north by Kamrup district on the east by Jaintia Hills and Karbi Anglong district of Assam and on the west by West Khasi Hills district. The National Highway No. 37 passes through the district from Jorabad to Shillong. Ri-Bhoi district essentially consists of hilly areas. In the centre lies the central uplands known as Lum Raitong and in the south-east lies U Lum Sohpetbneng. Forest covers a large part of the geographical area of Ri-Bhoi district. Soil in the district may broadly be classified into hill and plain soils. The district experiences different types of climate ranging from tropical climate in the areas bordering Assam to the temperate climate adjoining the East Khasi Hills district. The Ri-Bhoi district is the rice bowl of Meghalaya. The major crop of the district is paddy followed by maize. Though there are three paddy seasons in the district namely Autumn(Ahu), Winter (Sali) and Spring (Boro) but the winter paddy crop accounts for major area (90%) of the total area under paddy. Important vegetable crops grown in the district are potato, ginger, and tomato. Banana, papaya and pineapple are the important fruit crops of the district. Besides this tea is the important plantation crop in the district.

3. DATA USED IN THE STUDY

Satellite Data

The satellite data used in the study is given in Table-1 along with the sensors and date of pass of the satellite.

Table 1 : Details of satellite data used in the study

S. No.	Name of Satellite	Date of Pass	Path & Row	Sensor
1	IRS-1D	8 September 2002	111_53	LISS-III
2	IRS-1D	22 November 2002	111_53	LISS-III
3	IRS P6	18 October 2004	110 & 53	LISS III
4	IRS P6	23 October 2004	111 & 53	LISS III

Collateral Data

1. List of villages obtained from DES (Directorate of Economics and Statistics), Meghalaya
2. Boundary map of Ri-Bhoi district
3. Road map of Ri-Bhoi district
4. Topographic maps of 1:20,000 scale for the entire district (78 N/12, 78 N/16, 78 O/5, 78 O/9, 78 O/13, 78 O/10, 78 O/14, 83 B/4, 83 C/1, 83 O/2) from Survey of India (SOI)

5) Crop calendar followed in the district

4. METHODOLOGY

There are three major problems faced in the application of remote sensing technology in the hilly regions. (i) The area especially Meghalaya state (the abode of clouds) is covered with clouds during most of the year and thus obtaining the cloud free spectral image is very difficult. (ii) Due to undulating topography of the region, topographic geometry and misclassification there may be large differences of area under crop in the image and actual area under crop. In order to rectify the estimate of area under paddy crop affected by these factors a relationship between area under paddy in the classified image and actual area under paddy crop on the ground has been developed. (iii) The area under paddy crop falling under hill shades or deep valleys may not be exposed to the satellite sensors, which are sun-synchronous. Further, smaller paddy fields may also not be detectable due to lower spatial resolution of the sensors. The extent of errors in the estimate due to the loss of 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 a buffer created along the National Highway/State Roads in GIS environment.

4.1 Estimation of Area under Winter Paddy during 2004 by Digital Classification and Handling the Problem of Cloud Cover

The digital data of IRS-1D, LISS-III sensor pertaining to 8 September 2002 was used for creation of base image for the study. The paddy field signatures are visually distinguishable/identifiable on the satellite image in September image, as in this period paddy is in puddling stage. In the month of October-November, paddy is in vegetative stage and during this period the signature of paddy class may mix with forest and grasslands. Further, in the month of November-December when paddy is in maturity and harvesting stage, the signatures of paddy class may mix with built-up lands. Therefore, the September date image has been considered most suitable for the estimation of area under winter paddy by digital classification. Since cloud free image of September 2004 was not available so the nearest cloud free September image for September 8, 2002 has been used.

The classification is done using maximum likelihood classifier. In this supervised classification technique information of training sites of the ground survey has been utilized. However, this image also had some clouds/ cloud shades over the study area. In order to make this classified image cloud free, the digital data of the corresponding satellite image dated November 22, 2002 was also classified using same set of training sites and number of classes. The regions of cloud patches and their shades in September 2002 classified image have been replaced by corresponding classified image from November 22, 2002 image. The modified September 2002 classified image has been used as a base image for estimation of area under paddy crop. Further, images of October 18 and October 23, 2004 have been used for recoding/updating of the base image for estimation of area under winter paddy for the year 2004.

4.2 Relation Between Area under Paddy Crop in the Image and Actual Area under Paddy on the Ground for Correcting Errors due to Undulating Topography

To develop a relationship between area under paddy in the image and actual area under paddy on the ground a suitable number of paddy patches/ fields, which are clearly visible and demarcable in the standard False Color Composite (FCC) of the study area have been identified. The actual area of these patches/fields was recorded on the ground by using a Global Positioning System (GPS). Further, these patches were extracted from the classified digital image and the corresponding area under paddy was recorded.

Let there be 'n_r' clearly visible paddy patches/ fields, which can be demarcated in the FCC as well as on the ground. Let $Y_{(r)i}$ and $X_{(r)i}$ denote the area under paddy crop as obtained by GPS on the ground and from the classified image for i[th] paddy patch respectively. The linear relationship between area measured by GPS and obtained by classified image can be represented by the model

$$Y_{(r)i} = \alpha_{(r)} + \beta_{(r)} X_{(r)i} + e_{(r)i}, \; i = 1,2,3 \ldots n_r \qquad (1)$$

where

$$E\left(e_{(r)i}\right) = 0 \text{ and } V\left(e_{(r)i}\right) = \sigma^2_{(r)}, \; \forall \; i$$

Using least square technique, following parameter along with their standard errors can be estimated as

$$\hat{\alpha}_{(r)} = \bar{y}_{(r)} - \hat{\beta}_{(r)} \bar{x}_{(r)}$$

where

$$\bar{y}_{(r)} = \frac{1}{n_r} \sum_{i=1}^{n_r} Y_{(r)i}, \quad \bar{x}_{(r)} = \frac{1}{n_r} \sum_{i=1}^{n_r} x_{(r)i} \text{ and}$$

$$\hat{\beta}_{(r)} = \frac{\sum_{i=1}^{n_r} \left(y_{(r)i} - \bar{y}_{(r)}\right)\left(x_{(r)i} - \bar{x}_r\right)}{\sum_{i=1}^{n_r} \left(x_{(r)i} - \bar{x}_r\right)^2}$$

$$S\hat{E}\left(\hat{\alpha}_{(r)}\right) = \sqrt{\hat{\sigma}^2_{(r)} \left[\frac{1}{n} + \frac{\bar{x}^2_{(r)}}{\sum_{i=1}^{n_r} \left(x_{(r)i} - \bar{x}_r\right)^2}\right]} \text{ and}$$

$$S\hat{E}\left(\hat{\beta}_{(r)}\right) = \sqrt{\frac{\hat{\sigma}_{(r)}^2}{\sum_{i=1}^{n_r} \left(x_{(r)i} - \bar{x}_r\right)^2}}$$

$$\text{where } \hat{\sigma}^2_{(r)} = \frac{1}{n_r - 2} \left[\sum_{i=1}^{n_r} \left(y_{(r)i} - \bar{y}_{(r)}\right)^2 - \hat{\beta}^2_{(r)} \sum_{i=1}^{n_r} \left(x_{(r)i} - \bar{x}_{(r)}\right)^2\right] \qquad (2)$$

Then prediction model (1) for correcting the image area can be written as

$$\hat{y}_{(r)i} = \hat{\alpha}_{(r)} + \hat{\beta}_{(r)} X_{(r)i} \qquad (3)$$

Using this model, the area under paddy crop obtained from the classified satellite image can be considerably corrected for undulating topography, miss-classification errors and topographic geometry.

4.3 Estimation of Paddy Area in the Buffer Zone to Account for Area not Captured in the Satellite Image

In order to estimate the extent of area under hill shades and non-visible area due to smaller paddy fields (limitation of spatial resolution of satellite sensors) a field survey has to be conducted. Conducting a field survey in this region has several limitations such as highly undulating topography, inaccessibility of most of the area etc. Keeping in view the above factors it was decided to conduct this survey along the major roads of the district. Further, it has been observed that cultivation of paddy along the road is one of the dominant land uses in this district. Therefore, a buffer zone of 500 meters along the roads has been considered for conducting this survey. The roads of the district were divided into three categories: (i) National Highway, (ii) Primary Roads and (iii) Secondary Roads. Some of the roads from each category were taken for this survey. Each of these roads was conceptually considered to be divided into segments of 500-meter length and buffer zone of 250 meter on both sides of the road was created.

Let there be $N_{(b)h}$, (h=1,...L; L = 3) roads in the h[th] category. Let $M_{(b)hj}$ be the number of grids (each of 500 × 500 sq. meter) on j[th] road of h[th] category and $m_{(b)hj}$ be the number of grids selected randomly from j[th] road of h[th] category; j = 1,2,3......, $N_{(b)h}$.

In each of the selected grids of 500 × 500 m^2 area under paddy crop has been recorded through eye estimates. Further, actual area under paddy crop was measured using GPS for accessible grids only.

Let $Y_{(be)hji}$ and $Y_{(bg)hji}$ denote the area under paddy in i^{th} grid of j^{th} road from h^{th} category as recorded by eye estimate and as measured by GPS respectively; where $i = 1, 2, 3, \ldots m_{(bg)hj}$ and $m_{(bg)hj} \leq m_{(b)hj}$ as the area under paddy has been recorded only for approachable grids.

Define

$$y'_{(bg)hji} / y'_{(be)hji} = \begin{cases} y_{(bg)hji} / y_{(be)hji} & \text{if area under paddy is measured by GPS/ eye estimate in the } i^{th} \text{ segment} \\ 0 & \text{otherwise} \end{cases}$$

Now a linear relationship between area under paddy through eye estimate and actual measurement using a GPS can be represented by the model

$$y'_{(bg)hji} = \alpha_{(b)} + \beta_{(b)} y'_{(be)hji} + e_{(b)hji}$$
$$i = 1,2, \ldots m_{(b)hj} \quad (4)$$

where $E(e_{(b)hji}) = 0$ and $V(e_{(b)hji}) = \sigma^2_{(b)hj}$

Again by using least squares technique, we obtained

$$\hat{\alpha}_{(b)} = \bar{y}_{(bg)} - \hat{\beta}_{(b)} \bar{y}_{(be)}$$

where $$\bar{y}_{(bg)} = \frac{\sum_{h=1}^{L} \sum_{j=1}^{N_{(b)h}} \sum_{i=1}^{m_{(b)hj}} y'_{(bg)hji}}{\sum_{h=1}^{L} \sum_{j=1}^{N_{(b)h}} m_{(bg)hj}}$$

$$\bar{y}_{(be)} = \frac{\sum_{h=1}^{L} \sum_{j=1}^{N_{(b)h}} \sum_{i=1}^{m_{(b)hj}} y'_{(be)hji}}{\sum_{h=1}^{L} \sum_{j=1}^{N_{(b)h}} m_{(be)hj}}$$

and $\hat{\beta}_{(b)}$ is given by

$$\hat{\beta}_{(b)} = \frac{\sum_{h=1}^{L} \sum_{j=1}^{N_{(b)h}} \sum_{i=1}^{m_{b(hj)}} \left(y'_{(bg)hji} - \bar{y}_{(bg)}\right)\left(y'_{(be)hji} - \bar{y}_{(be)}\right)}{\sum_{h=1}^{L} \sum_{j=1}^{N_{(b)h}} \sum_{i=1}^{m_{b(hj)}} \left(y'_{(be)hji} - \bar{y}_{(be)}\right)^2}$$

The area under paddy through eye estimate from those segment, where it is not measured by GPS were corrected by the following model

$$\hat{y}_{(bg)} = \hat{\alpha}_{(b)} + \hat{\beta}_{(b)} * y_{(be)} \quad (5)$$

4.3 Estimate of Total Area under Paddy in the Buffer Zone

The estimate of area under paddy in the buffer zone can be obtained on the basis of all the surveyed grids and also on the basis of grids containing paddy area only. The first approach is better if there are sufficient number of selected grids having area under paddy otherwise second approach may provide better results. Thus, two different methods can be applied for obtaining the estimate of total area under paddy in the buffer zone which are given below

Method I. Estimate of area under paddy in the buffer zone based on all surveyed grids

Let $\hat{Y}_{(b)}$ denotes the estimate of total area under paddy in the buffer zone given by

$$\hat{Y}_{(b)} = \sum_{h=1}^{L} \hat{Y}_{(b)h}$$

where

$$\hat{Y}_{(b)h} = \sum_{j=1}^{N_{(b)h}} \hat{Y}_{(b)hj} \quad \text{and} \quad \hat{Y}_{(b)hj} = \frac{M_{(b)hj}}{m_{(b)hj}} \sum_{i=1}^{m_{(b)hj}} y_{(bg)hji}$$

The variance of the above estimator can be written as

$$V(\hat{Y}_{(b)}) = \sum_{h=1}^{L} \sum_{j=1}^{N_{(b)h}} V(\hat{Y}_{(b)hj})$$

The covariance terms will be zero as independent samples were selected for each road.

Therefore

$$V(\hat{Y}_{(b)}) = \sum_{h=1}^{L} \sum_{j=1}^{N_{(b)h}} M^2_{(b)hj} \left(\frac{1}{m_{(b)hj}} - \frac{1}{M_{(b)hj}} \right) S^2_{(b)hj} \quad (6)$$

where

$$S^2_{(b)hj} = \frac{1}{M_{(b)hj} - 1} \sum_{i=1}^{M_{(b)hj}} \left(\hat{y}_{(bg)hji} - \bar{\hat{Y}}_{(bg)hj} \right)^2 \text{ and}$$

$$\hat{\bar{Y}}_{(bg)hj} = \frac{1}{M_{(b)hj}} \sum_{i=1}^{M_{(b)hj}} \hat{Y}_{(bg)hji}$$

Method II. An alternative estimator of area under paddy in the buffer zone based on survey grids having area under paddy only

In case lesser number of grids having area under paddy crop on a road, a better way of estimation could be based on estimating average area under paddy per grid based on only those surveyed grids which has the area under paddy. The detailed method is given below.

Let $M_{(bc)hj}$ denotes the number of grids having area under paddy on j^{th} road in the h^{th} category. This number is unknown and has to be estimated. Let $m_{(bc)hj}$ be the number of surveyed grids having area under paddy crop on the j^{th} road in h^{th} category. Then an estimated number of grids on the j^{th} road in h^{th} category having paddy crop is given by

$$\hat{M}_{(bc)hj} = \left[\frac{\text{No. of grids having area under paddy on the } j^{th} \text{ road}}{\text{No. of grids surveyed on the } j^{th} \text{ road}}\right] \times \text{total no. of grids on the } j^{th} \text{ road}$$

i.e. $$\hat{M}_{(bc)hj} = \frac{m_{(bc)hj} \times M_{(b)hj}}{m_{(b)hj}}$$

Let

$$y_{(bgc)hji} = \begin{cases} \hat{Y}_{(bg)hji} & \text{if } i^{th} \text{ grid on } j^{th} \text{ road from the } h^{th} \text{ category is having paddy area as obtained by model (5)} \\ 0 & \text{otherwise} \end{cases}$$

Now the total area under paddy in the buffer zone of j^{th} road on h^{th} category can be obtained as $\hat{Y}_{(bc)hj} = \hat{M}_{(bc)hj}\, \hat{\bar{y}}_{(bgc)hj}$]

where $$\hat{\bar{y}}_{(bgc)hj} = \frac{1}{m_{(bc)hj}} \sum_{i=1}^{m_{(bc)hj}} y_{(bgc)hji}$$

The estimated area under paddy in the h^{th} category can be obtained as $\hat{Y}_{(bc)h} = \sum_{j=1}^{N_{(b)h}} \hat{Y}_{(bc)hj}$

Hence, an estimate of the total area under paddy in the buffer zone can be obtained as

$$\hat{Y}_{(bc)} = \sum_{h=1}^{L} \hat{Y}_{(bc)h} \qquad (7)$$

The approximate expression of Mean Square Error (MSE) of $\hat{Y}_{(bc)hj}$ is obtained as

$$\begin{aligned} MSE\left(\hat{Y}_{(bc)hj}\right) &= M^2_{(bc)hj} \cdot V\left(\hat{\bar{Y}}_{(bc)hj}\right) \\ &+ \bar{Y}^2_{(bc)hj} V\left(\hat{M}_{(bc)hj}\right) + 2M_{(bc)hj} \cdot \bar{Y}_{(bc)hj} \\ &\text{Cov}\left(\hat{\bar{y}}_{(bc)hj}, \hat{M}_{(bc)hj}\right) + \text{higher order terms} \end{aligned}$$

4.5 Corrected Estimate of Total Area under Paddy in the District

The total area under paddy in the district is estimated by correcting for the non-detectable area under paddy obtained through remote sensing and the field survey estimator in the buffer zone along the roads.

Let Y_P denote the total area under paddy in the district. Let $\hat{Y}_{(r)}$ denotes the area under paddy in the district as estimated by the classified image. Further, let $\hat{Y}_{(b)}$ be the area under paddy in the buffer zone as estimated by the road survey and $\hat{Y}_{(br)}$ be the corresponding area as obtained through the classified satellite image. Now,

$$\frac{\hat{Y}_{(b)}}{\hat{Y}_{(br)}}$$

provides a ratio of estimated actual area in the buffer to the area obtained through remote sensing in the buffer zone. Assuming this ratio to hold for the entire region we may write

$$\frac{\hat{Y}_P}{\hat{Y}_{(r)}} = \frac{\hat{Y}_{(b)}}{\hat{Y}_{(br)}}$$

From this we can obtain an improved estimate of crop area under paddy in the district as given by

$$\hat{Y}_P = \frac{\hat{Y}_{(b)}}{\hat{Y}_{(br)}} \hat{Y}_{(r)} \qquad (8)$$

The estimate of mean square error of $\hat{Y}_P$ is given by

$$M\hat{S}E(\hat{Y}_p) = \left(\frac{Y_b^2 + Y_p^2}{Y_b^2} \right) \hat{\sigma}^2 + \frac{Y_p^2}{Y_b^2} \hat{V}(\hat{Y}_{(b)}) \qquad (9)$$

where $\hat{\sigma}^2$ is obtained by equation (2) and $\hat{V}\left(\hat{Y}_{(b)}\right)$ is obtained by equation (7) for Method I and equation (8) in case of Method II.

5. RESULTS AND DISCUSSIONS

5.1 Estimation of Area under Paddy by Digital Classification

The Indian Remote Sensing Satellite (IRS) LISS-III data of 8 September 2002 and 22 November 2002 have been used for the classification. The supervised maximum likelihood classification procedure was used to transform the multi-spectral data into land use/ land cover map. The ground information collected during the fieldwork for the sample areas of different vegetation types were defined interactively as training sets.

The total paddy area for the entire district estimated from the satellite image using supervised classification technique is 8006.57 ha and the total paddy area under the buffer zone as estimated by the classified image of the buffer is 1283.37 ha.

5.2 Development of Relationship between Area under Paddy Crop in the Image and Actual Area under Paddy on the Ground

The relationship between area under paddy obtained from the classified image and actual area under paddy on the ground has been developed by identifying 33 paddy patches/ fields which were clearly visible and demarcable in the classified image. The actual areas of these fields were recorded on the ground by using GPS and corresponding area in the image has been obtained by extracting these patches from classified image. Using the relationship as given in equation (1), equation (3) can be written as

$$\hat{y}_{(r)} = 0.213 + 0.837X_{(r)} \text{ with } R^2 = 0.915$$

Using the above relationship the corrected total estimated area under paddy in the entire district has been obtained as 6701.71 ha and in the buffer zone as 1193.67 ha.

5.3 Estimation of Paddy Area in the Buffer Zone

The rock network of the district consists of National highway, and 14 state roads along with the district roads. To obtain a reliable estimate of area under paddy along a buffer of 500 meter, the roads are conceptually divided into segments of 500 meters. The buffer along the roads is shown in Figure 1 within the district boundary of Ri-Bhoi. A sample of segments is selected randomly on each of the road and a grid of 500 × 500 m^2 has been observed for recording the area under paddy as measured by GPS as well as eye estimates.

In some of the selected grids it has not been possible to measure the area through GPS, only eye estimate of crop area in the grid has been recorded. However, to improve the eye estimate, a linear relationship has been developed between the eye estimate of area under paddy in a grid and the actual area as measured by GPS. Using this relationship given by equation (4), equation (5) can be written as

$$\hat{y}_{(bg)hji} = 0.078 + 0.98y_{(be)hji} \text{ with } R^2 = 0.95$$

Thus using the above results the area for the fields obtained through eye estimates only was corrected. The area under paddy was estimated for each road using both the methods of Section 4.4. The estimated total area under paddy for each road is given in Table 2 for Method I and Method II.

5.4 Estimate of Total Paddy Area in the District

Using equation (8) of Section 4.5, an improved estimate of the total area under paddy ($\hat{Y}_P$) may be obtained by substituting the values of estimated area

Table 2. Road-wise estimated paddy area under buffer as obtained by road survey using Method I and Method II

S.No.	Road name	Total no. of grids	No. of surveyed grids	No. of paddy grids among the surveyed grids	Estimated no. of paddy grids	Method I		Method II	
						Estimated average area under paddy per grid	Estimated area under paddy on the road	Estimated average area under paddy per grid	Estimated area under paddy on the road
1	Umling-tasku-Umreit	77	16	9	39	2.19	168.76	4.43	170.63
2	Guwahati-Umreit	41	9	7	32	3.63	149.01	4.72	150.41
3	NH	120	24	14	70	1.60	192.49	2.84	198.54
4	ICAR-Kyrdem	48	10	6	29	3.87	185.84	6.07	174.77
5	Bhoirymbu-Sohilya	30	6	6	30	6.26	187.85	6.27	188.00
6	Kyrdem-Mawbsein	12	3	3	12	0.27	3.29	0.25	2.98
7	Kyrdem-Klew	8	2	2	8	6.64	53.11	6.49	51.90
8	Umsning-Raiting-Mawhati	68	14	9	44	0.55	37.54	1.24	54.42
9	Umsning-Rtiang-Mawreng	47	10	7	33	2.36	110.95	3.61	118.65
10	Nongpoh-maranger-Palaisha	54	11	11	54	2.25	121.49	1.98	107.21
11	Maranger-Umsaa	23	5	5	23	1.80	41.30	1.90	43.77
12	Umden-Pamjri	6	2	2	6	0.32	1.92	0.32	1.92
13	Kyrdemkulai	22	5	5	18	0.86	18.88	0.76	13.36
14	Umran(forest gate)	13	3	3	13	0.38	4.89	0.24	3.10
15	Umsning_Kyrdemkulai	18	4	4	4	0.32	5.82	1.30	5.52
	Total						1283.14		1285.17
					SE	75.53	SE	424.17	
					% SE	5.88	% SE	9.24	

under paddy by the classified image ($\hat{Y}_{(r)}$), estimated area under paddy by the classified image under buffer ($\hat{Y}_{(rb)}$) and estimated area under paddy in the buffer by the road survey. We have

$$\hat{Y}_r = 6701.71 \text{ and } \hat{Y}_{(rb)} = 1193.67$$

$$\hat{Y}_{(b)} = 1283.14 \text{ (Method I)}$$

$$\hat{Y}_{(b)} = 1285.17 \text{ (Method II)}$$

Substituting the values in equation (9), we obtain $\hat{Y}_P$ the estimate of area under paddy in the district as 7204.03 ha with percentage standard error of 5.8 and 7215.43 ha with percentage standard error of 9.2 by Method I and Method II respectively. In this district winter paddy is one of the dominant crop therefore, performance of Method I was found to be better than Method II. But if this methodology is to be extended to other districts where winter rice is not a dominant crop the performance of Method II may be found to be better.

Note: It may be noted that the relationships between area under the paddy fields in the image and actual area of the paddy fields are likely to be stable for each district. Also, the relationship between eye estimates and actual observations are likely to be stable. Further, the estimate of percentage non-detectable paddy area and area of paddy falling under hill shades are also likely to be same for the district. These statistics are likely to change with the changes in the remote sensing sensors technology or changes in cropping pattern of the district. Therefore, after few years say three to five years when these statistics are tested, field surveys may not be required for estimation of area under paddy crop. The area estimates by the paddy may be obtained only through digital classification of remote sensing data for each district. The methodology is independent of type of satellite sensor used to capture the digital data. The accuracy of estimation by this method depends on the satellite sensor and area coverage by the crop under consideration. If the resolution of the sensor is increased the accuracy of the estimates will be improved. Similarly, accuracy of the estimates will depends on extent of area covered by crop i.e. if crop is grown in larger area then the accuracy of the estimates will be better.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial support provided by Space Application Centre, (ISRO) Ahmedabad for this research and support of officials of DES, Shillong in conducting the field survey.

REFERENCES

Dadhwal, V.K. and Parihar, J.S. (1985). Estimation of 1983-84 wheat acreage of Karnal district (Haryana) using Landstat MSS digital data. Technical note, IRS-UP/SAC/CPF/TN/09, Space Application Centre, Ahmedabad.

Dadhwal, V.K., Rahul, D.S., Medhavy, T.T., Jarhal, S.D., Khera, A.P., Singh, J., Sharma, T. and Parihar J.S. (1991). Wheat acreage estimation for Haryana using satellite digital data. *J. Ind. Soc. Rem. Sens.*, **19**, 1-15.

Murthy, C.S., Thiruvengadachari, S., Raju, P.V. and Jonna, S. (1996). Improved ground sampling and crop yield estimation using satellite data. *Int. J. Rem. Sens.*, **17(5)**, 945-956.

Singh, R. and Goyal, R.C. (2000). Use of remote sensing satellite data in crop surveys. Project Report IASRI, New Delhi.

Singh, R., Semwal, D.P., Rai, A. and Chikkara, R.S. (2002). Small area estimation of crop yield using remote sensing satellite data. *Int. J. Rem. Sens.*, **23(1)**, 49-56.

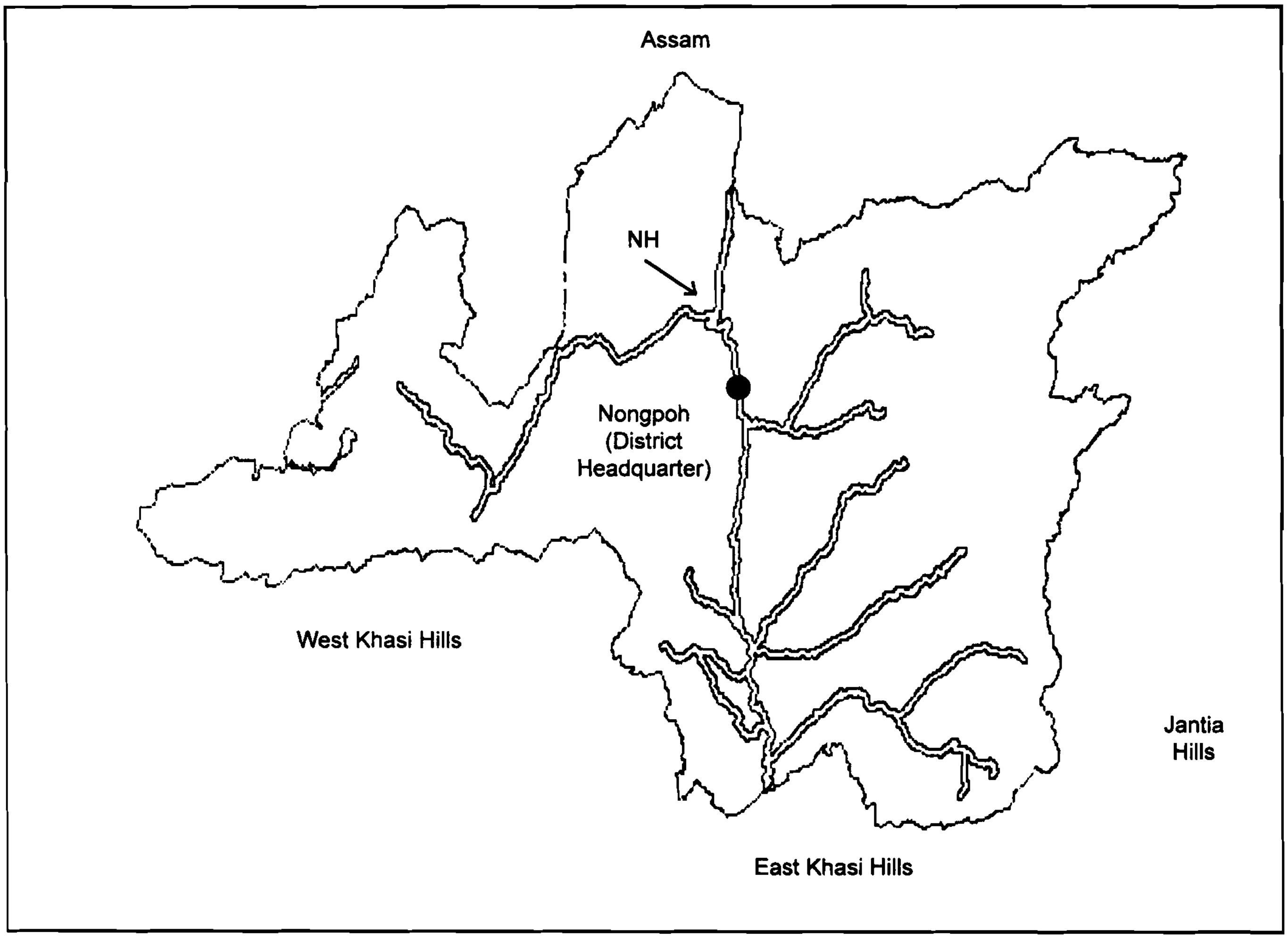

Figure 1 : Buffer of 250 m created on both sides of the roads in the district Ri-Bhoi