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LAND UTILIZATION AND ECOLOGICAL ASPECTS IN THE SYLHET-MYMENSINGH HAOR REGION OF BANGLADESH: AN ANALYSIS OF LANDSAT DATA

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ABSTRACT

The Haors of Sylhet-Mymenisngh districts are by far the largest single inland depression in Bangladesh. The area is of significant agricultural importance and possesses unique geographic phenomena in terms of environmental and habitat supporting fisheries resources and migratory birds in the country.

The objectives of this paper are to indicate whether remote sensing data from Landsat (ERTS) imageries could be used in identifying, evaluating, and mapping landuse patterns of the Haor area in Bangladesh. In the present study one Landsat imagery of the 16 covering Bangladesh provided sufficient coverage for the Haor region of Sylhet-Mymensingh districts. Selected cloud-free imageries of the area for the period 1972-75 were studied. Imageries in bands 4, 5 and 7 were mostly used. The method of analysis involved utilization of both human and computer services of information from ground, aerial photographs taken during this period and space imageries.

The principal outcome of the Landsat data analyses on this region have been classified under the following heads in the text: general findings, technical findings, and ecological evaluation of landuse aspects.

The Haors[1] of Sylhet-Mymensingh districts are by far the largest single inland depression located in northeast Bangladesh (Fig. 1a). The area is of significant agricultural importance and possesses unique geographic conditions in terms of environment and habitat supporting fisheries resources and migratory birds in the country.

For centuries the inhabitants have been aware of the capacities and potentials of the area and the available resources. The economic activity has closely been tuned to the environmental uniqueness of the area and still there has been little change in the trends of landuse and resources exploitation. The objectives of the present investigation[2] have been to identify whether remote sensing data from Landsat imageries[3] could be used in identifying, evaluating and mapping landuse patterns, mainly the agricultural landuse, of the Haor area in Bangladesh.

Delimitation of the area

In this study a broad Haor region has been considered in four subdivisions - two in Sylhet and two in Mymensingh districts (Fib. 1b). The actual Beels making the deepest part of the Haors are, however, located between Netrokona and Kishoreganj subdivisions in one hand, and Sunamganj and Habiganj subdivisions on the other. The Haor lies as an inverted funnel. The typical Haor area can be identified in the Landsat imageries which covers are area of 3,128 sq. miles (Fig. 2).

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Importance of the Haor area to the economy of Bangladesh

Agriculture is the dominant activity of the Haor area and all other economies are oriented around it. The very topography and soil condition facilitate large scale cultivation of a number of varieties of rice. In summer, Boro paddy is grown on the rims of the Beels and numerous abandoned channels in the Haor area. Now a days, drainage has been improved in certain areas, where by early draining the areas varieties of paddy are also being cultivated. In many parts, Boro is being replaced by HYV rice. In the periphery of the Haors other crops are also grown.

During the rainy season the entire area goes under water and as soon as water recedes preparation of land for the cultivation of rice starts. In the area there are patches of rich pastures for cattle to graze. Immediately after the recession of floods, fishing activity in the area becomes prominant. The water bodies and the pastures also provide sanctuaries for flocks of migratory birds.

Apart from rice cultivation, cattle rearing and fishing are the main secondary occupations of the population in this area.

It has been estimated from the Landsat imageries that about 66 percent of the land is oriented towards Boro rice, 15 percent Aman rice and about 16 percent grazing land (including fallow). Obviously the rest covers other landuse including settlements.

The total area under rice in this area contributes to about 4.12 percent of the total for Bangladesh, producing about 3.0 percent of total Boro rice and about 2.0 percent of other rice in the country[4].

In the past, when the population was not so dense, the yield from the land was more than sufficient to meet the demand for food. There were abundant pastures for cattle to rear. At present, because of population pressure (population per sq. mile is about 1291, and the rate of increase of population is about 3.2), the grazing lands are being increasingly converted to rice fields. The conversion is recently being facilitated by the availability of lift pumps/power pumps for irrigation and the prospects of cultivation of HYV rice in many parts.

Methodology

In the present study, one imagery of the 16 covering Bangladesh, provided sufficient coverage for the Haor areas of Sylhet and Mymensingh districts (Fig. 1b). Selected cloud-free imageries of the area for the period 1972-75 were studied. It should be noted that satisfactory cloud-free imageries are available for this part of the world (Table 1). Imageries taken in the bands 4, 5 and 7 were mostly used for the study. The method of analysis involved utilization of both human and computer services of information from ground, aerial photographs and space imageries.

Landsat imagery taken at various times clearly show current landuse practices in northeastern Bangladesh. In particular, Landsat-2 frame E-2064-03434 (27 March, 1975) was selected for digital processing. This nearly cloud-free scene was obtained near the height of the dry season and shows the extent of agricultural production associated with the Haor areas.

The initial step in the inventory process consisted of delineation of Landsat images into relatively homogeneous strata by human interpreters. For this purpose, black and white aerial photographs and topographical maps were used so as to detect major landforms - in the present case, water bodies, agricultural and non-agricultural features.

Ground truth information for two major training sites or test areas: Astagram-Bhatsala area, and Baniachang-Baruiuri area, was collected in early 1975. Subsequently other visits were made to the area. This had, however, limited practical use in correlating ground truth data with the imagery and mapping the area.

In this connection, it may be mentioned that training sites of known identity are required for computer mapping and evaluation of results. As such the training sites are selected and designed in association with aerial photographs and/or topographic maps. The task of separating or identifying pixels in Landsat-MSS data from within ground areas was found to be difficult. The problem was caused primarily by the relatively large size of the MSS-ground resolution element compared to the size of fields and other ground data. The fields in the test areas are mostly less than one acre - again they are under different landuse practices. It has been noted that a maximum of 18 pixels could fall wholly within the boundaries of a 20-acre field[5], and such a field size is uncommon in Bangladesh.

Further, colour composite imageries (bands 4, 5 and 7 were combined with blue, green and red filters respectively) were used to further separate landuse features and geomorphic elements.

The computer compatible tapes (CCT) offer the greatest opportunity for systematic and quantitative data anslyses. These CCTs can be processed using general and special-purpose computing system for the purpose of identifying the location of a variety of terrain (especially vegetative) features and for determining the total area represented by each identifiable feature.

For the present purpose, the ERIM Multivariate Interactive Digital Analysis System (MIDAS) was used. The MIDAS special-purpose computer offers an interactive, low-cost user-oriented capability for producing thematic maps derived from Landsat multispectral data. In this computer the parallel digital implementation capabilities of the processor are combined with a mini-computer to achieve near-real-time operation coupled with multiple preprocessing functions and colour displays. The data classifier is designed to perform a one pass maximum-likelihood decision with a priori probabilities, assuming multi-model Gaussian multi-variate spectral distributions.

The output of this classification process is a geometrically-rectified colour-coded hard-copy map. These maps may be produced at any convenient scales. For the present case, such maps have been prepared for Astagram-Bhatsala area (Fig. 3).

Owing to the lack of detailed ground truth, because of the problems mentioned earlier, for the area under study, an unsupervised classification procedure was selected for obtaining scene class or signatures. In this case, the Cluster programme automatically grouped Landsat data into 16 separate classes based on their spectral uniqueness in all four bands. This is further, as shown below, synthesised 6 classes to get a total or easily explicable view. These classes comprise the range of spectral variation represented in this scene. In this procedure, it is assumed that spectrally distinct scene elements represent different terrain classes and that similar elements probably contain the same or similar object[6].

The resultant maps have been checked in the field in early 1976 and attempts have been made to establish their accuracy. The results are noted under different findings below.

General Findings

The results reported herein indicated that broad landuse pattern and geomorphic features are readily identifiable and interpretable from Landsat data. Soil types and moisture conditions can be discernable from the imageries in association with aerial photographs data or with ground truth information.

Because of very small land holding size and fragmented land utilization detail landuse pattern is difficult to delineate. In some cases, the perennial crops and aquatic covers (such as water hyacinths) overlap the rice crops and give misguided spectral information requiring degree of correction in the detail computer maps. Such an anomaly is observed in the computer map of Astagram-Bhatsala around Dhopa Beel (Fig. 4). Water bodies, nevertheless, were detectable under the best condition down to less than 5 acres in size. As such most Beels are possible to map by computer. Rural settlements, being relatively complex features mixed with orchards/perennial trees, horticulture, etc., could not be detected with confidence. Nevertheless, larger and continuous settlement units, such as Astagram and Baniachang, and a few others, such as Kishoreganj at the periphery of the Haors are identifiable (Fig. 4). Transport networks can be distinguished partially and are apparent at some time of the year in some areas, but may be very difficult to detect at other times or in other areas. Kutcha roads, road side Khals, canals, etc., which are too narrow (less than 15 feet) are difficult to detect. But such roads in association with embankments or Bandh are discernable for some areas.

Technical Findings

Broad agricultural lands (cropped and non-cropped) can be separated from other types of landuse by conventional image interpretation and image enhancement efforts with the help of colour-additives.

Generalized agricultural landuse types can be identified by spectral pattern recognition techniques with about 70 percent accuracies[7].

Multiple imageries taken on different dates and bands can improve identification and interpretation performance significantly.

Ground truth data from training sites in the Haors were used to identify landuse pattern with some success. For some features no recognition was established but for Boro rice, fallow lands, permanent pastures, water bodies, continuous settlements and soil condition, some recognition was established.

Area measurement for large water bodies agrees with data from aerial photographs to a very high degree of accuracy.

Aquatic covers on Beels were not clearly identified in the imageries and were easily misunderstood for cropland while interpretating. But this phenomenon is possible to correct by field checking and with the help of aerial photographs.

Ecological Evaluation

Being located in the humid tropics and the area being a natural depression the Haors are covered with alluvium with lateritic intrusions or old alluvium in the periphery. Since water receds quickly during the post-monsoon months (leaving water only in the deeper Beels), the water supplying power of the soil in winter and post-winter dry months is a critical and a crucial factor for cultivation in many parts.

The conditions which affect the water supplying power of the agricultural lands are the natural drainage and the applied irrigation. These conditions very much depend on the local climate, geology, soil profile, texture, gradient of the land and the geographical orientation.

Soil moisture affects the structural characteristics and the leaf development of the vegetation. The reflectivity of vegetation cover is known to decrease in all bands with increasing moisture content[8]. Consequently, the reflectivity of the vegetation can be used as a measure of the effectiveness of natural drainage and/or irrigation in the agricultural lands and hence the quality of the lands.

The colour composite imageries show a range of red colours corresponding to vegetation (including rice fields). A closer inspection of the areas of degrees of redness in the imageries indicate the possibility of assigning them to different moisture or land quality classes[9]. Naturally, bright red corresponds to vegetation grown in rich well moistured and deep soil, while light-red is an indicative of shallow soils with lesser moisture content. The laterite periphery, having low moisture content and higher reflectivity gives maroon to brown hue (Fig. 5). Reconnaissance aerial survey, aerial photograph interpretation and sample ground data confirm these observation. It is possible that on such information irrigation planning and eco-agricultural orientation in the Haor areas are feasible in the near future.

In this connection it should be noted that Tertiary (Mio-Pliocene) hills with troopical forest cover in further north (outside Bangladesh and overlooking the Haor areas) are represented by dark red colour in the colour composite imagery. This is obvious because of gradient affecting water table, moisture condition, vegetation cover as well as geomorphic structure facilitating runoff. Along the southern facies of the foothills, overlooking the Haors, and characterized by sudden gradient change, there are intermediate area of alluvial fans of well drained sand and sandy soil (Fig. 5). These areas are of lesser agricultural importance. They look bright on the black and white imageries, and greenish (light green where sandy soil predominates) in colour composite imagery.

Within the Haors the pinkish red and greenish patches correspond to pastures and fallow lands respectively. While deep waterbodies are shown in these imageries in black or bluish-black colour. The location are distribution of these features are of utmost importance for planning fishing industry and protecting wild migratory birds in the Haor areas.

Conclusions and recommendations

Landsat data can be used to provide useful information for a number of resources appraisal and planning, such as, agriculture, water resources, settlements and transport management, etc. This information is chiefly inferential and related to spatial reference and ground truth data. Particularly, the possible quantification of landuse data and their variations results in the applicability of these information for micro and macro planning purposes.

Repetitive Landsat coverages of a particular area are of great importance for evaluating hydrologic aspects as they affect agriculture and changes in river characteristics in a deltaic area as in Bangladesh. It is possible to estimate and forecast cultivation of different crops throughout the year provided ground information is at hand. Thus the main advantage of Landsat is its ability to record and transport large aerial data quickly and in succession and in different bands to ensure particular purpose.

Logical selection of Landsat spectral bands and processing techniques are important for effective use of derived data from the imageries. Indeed, the best utilization of Landsat data requires ground truth information as well as aerial photographs.

From the present study it has been felt that similar and other studies should be undertaken elsewhere in Bangladesh. The possible sites of such studies are the moribund delta and the coastal areas of Bangladesh. The Landsat data taken in succession of a particular area over a period may be effectively used for the study of floods, river erosion and aggradation processes in many parts of Bangladesh[10]. Such studies would highly be complimentary to the existing data sources in various geographic and allied fields in the country.

NOTES

1. Haors are the annually flooded depressed areas with deeper and permanently innundated parts called Beels. The area can readily be delineated from Landsat imageries of any band taken in any time of the year.

2. This paper is a part of the Sylhet-Mymensingh Haor Project undertaken by the Department of Geography, Jahangirnagar University, Dacca (Bangladesh) in collaboration with the Environmental Research Institute of Michigan (ERIM), USA in 1975. The overall project, sponsored by a grant from the USAID, is designed to demonstrate the application of Landsat data to agricultural planning and regional development in Bangladesh.

3. Synchronized with the sun, an earth satellite called Landsat swings in a near-polar (99.1°) orbit in an 18-day cycle about 560 miles above the earth. At the equator each pass is some 1,800 miles west of the previous one and every 25 seconds it scans an area of about 1,300 sq. miles. The Landsat-I (earlier termed ERTS-I) launched on July 23, 1972, is still gathering earth resources data. It was joined on January 22, 1975, by Landsat-II. The Landsat does not use photographic cameras but an ingenious instrument called a Multispectral Scanner or MSS, which uses an oscillating mirror that scans the earth and a telescope that focuses visible and near infra-red light waves reflected from the earth into the satellite's radiation detectors, which measures the light intensities of 1.1-acre picture elements or pixels in four different bands. These values are converted into computer digested numbers and transmitted back to earth at the rate of 15 million units per second. Through an electron-beam recorder, this stream of data becomes imagery on photographic film ready for various uses.

4. Govt. of Bangladesh, Bureau of Statistics (agriculture section), Unpublished data on Mymensingh and Sylhet districts, 1975; and Govt. of Bangladesh, Ministry of Agriculture, Bangladesh Agriculture in Statistics, Nr. 1, 1973, Dacca, 1974.

5. A maximum of 18 pixels could fall wholly within the boundaries of a 20-acre field (see: Myers, W.L., Malila, W.A., Sarno, J.E., Wagner, T.W and Lewis, J.T., The use of ERTS data for a multidisciplinary analysis of Michigan resources. Michigan State University - Agricultural Experiment Station. ERIM, 1974, p. 19).

6. The authors thank Mr. T.W. Wagner, A.R.G. of the ERIM, USA, for kindly supplying the computer processed maps for the Haor Project which have been used in this paper.

7. This is as good performance as has been achieved with aircraft data (note: Erb, R.B., The utilization of ERTS-I data for application in agriculture and forestry. Third ERTS-I Symposium, Vol. 1(A), Washington,D.C., Dec. 10-14, 1973, Pp. 75-81).

8. Mayers, V.I., Soil, water and plant relations in remote sensing. National Academy of Sciences, Washington, 1970.

9. Oime, A.R., Bowden, L.W., and Minnigh, R.A., Remote sensing of disturbed insular vegetation from colour infra-red imagery. International Symposium on Remote Sensing of Environment, Vol. 2(7), 1971, P. 1235; and also Mayers, V.I., op. cit.

10. Chowdhury, M.I., and Elahi, K.M., Aspects of land utilization in the Sylhet-Mymensingh Haor areas of Bangladesh: an analysis of Landsat data. Second Annual Conference of the Bangladesh Association for the Advancement of Science, January 23 to 26, 1977, Bangladesh Agricultural University, Mymensingh.

TABLE I. LANDSAT-I (ERTS) Imagery: Percentage of Frames with below 30 per cent Cloud, 1972-73.

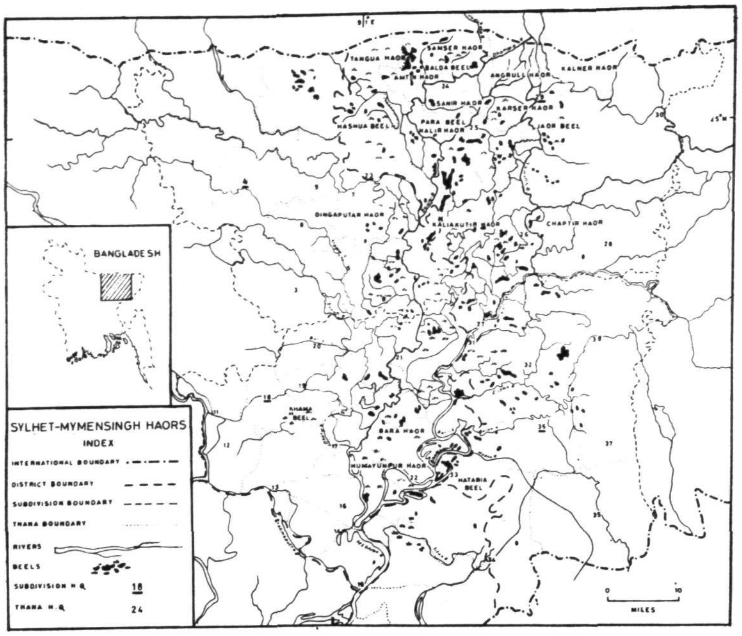
Area	Per cent of frames for spatial studies	Per cent of frames for time dependent studies
Latin America	50	38
Africa	85	63
South Asia	93	88

Source: Howard, J.A., Concepts of integrated satellite surveys, Third ERTS-I Symposium, Vol. 1(A), Washington, D.C. Dec. 10-14, 1973, Pp. 523-537.

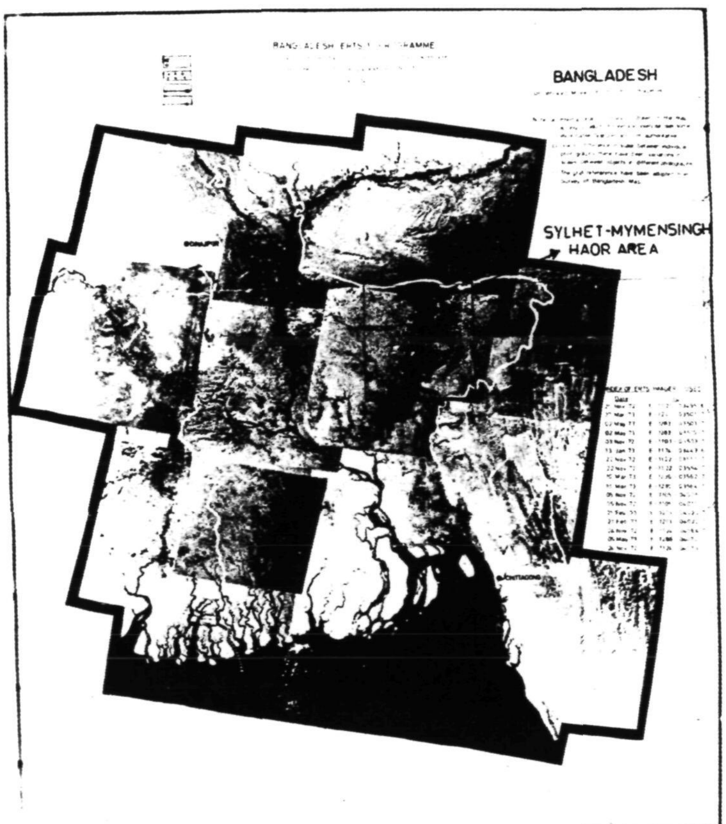
FIGURE 1. Location map of the Sylhet-Mymensingh Haor Area, Bangladesh.

INDEX OF PLACE NAMES

1. Durgapur
2. Purbadhala
3. Kendua
4. Netrakona
5. Madan
6. Kaliajhuri
7. Mohanganj
8. Atpara
9. Barhatta
10. Kalma Kanda
11. Hussainpur
12. Pakundia
13. Katiadi
14. Kuliarchar
15. Bhairab
16. Bazitpur
17. Nikli
18. Kishoreganj
19. Karimganj
20. Tarail
21. Itna
22. Aushtagram
23. Dharmapasha
24. Tahirpur
25. Jamalganj
26. Derai
27. Sulla
28. Jagannathpur
29. Sunamganj
30. Chhatak
31. Azmiriganj
32. Baniachang
33. Lakhai
34. Madhabpur
35. Chunarughat
36. Habiganj
37. Bahubal
38. Nabiganj



1a



1b

FIGURE 2. LANDSAT Imagery of Northeast Bangladesh.

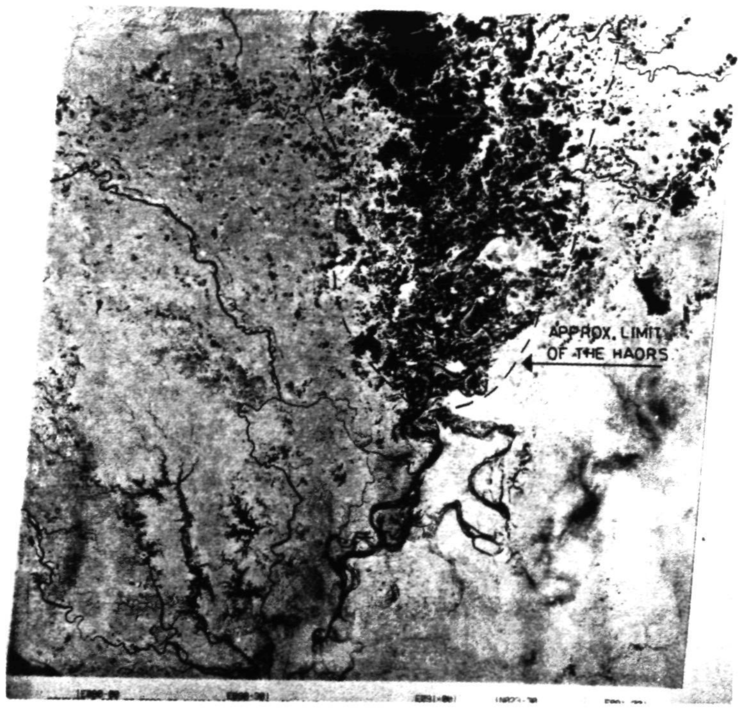
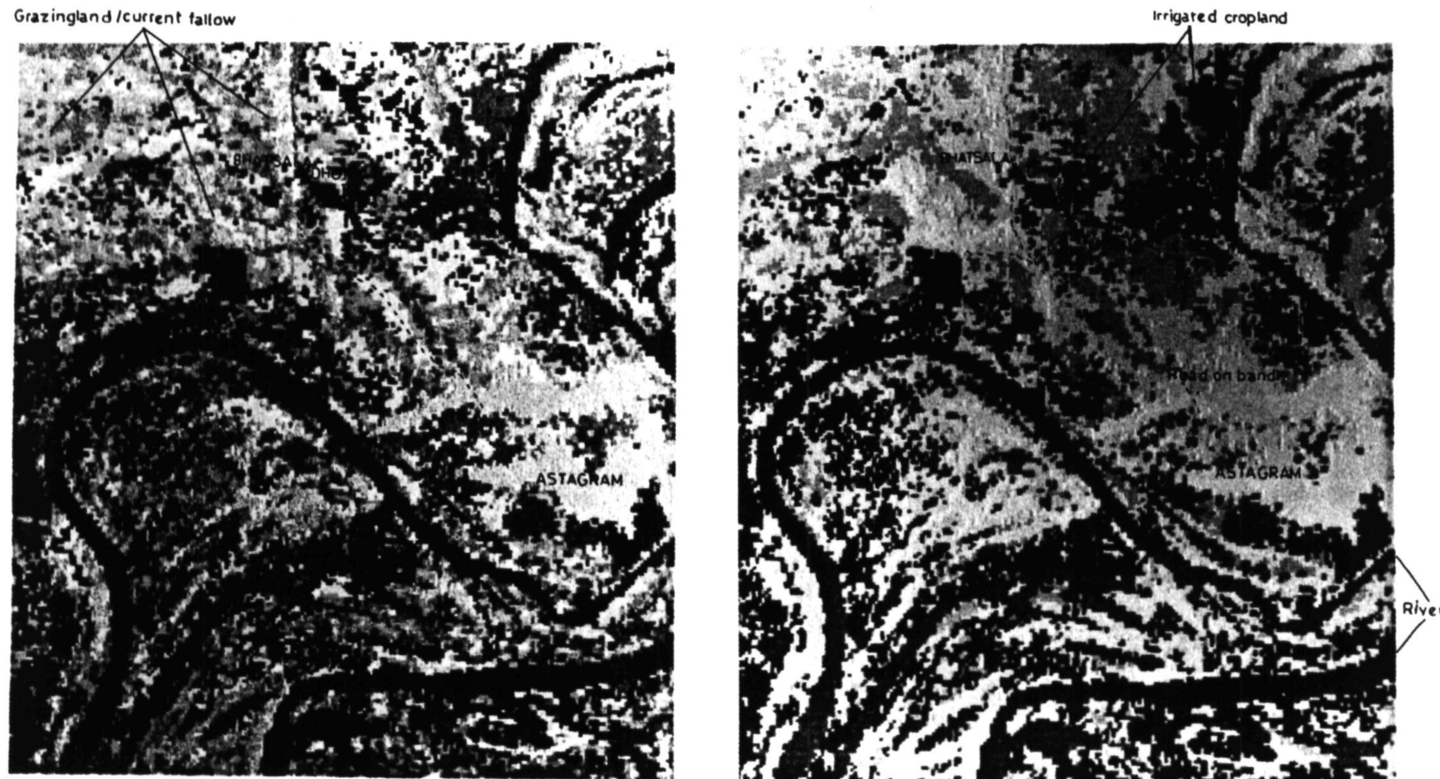


FIGURE 3. Computer maps of Astagram-Bhatsala area in relation to Northeast Bangladesh.

a) Meghna depression: Northeast Bangladesh.



AUSHTAGRAM AREA (64 km^2)
Northeastern Bangladesh
27 MAR 75
Landsat Frame 2064-03434
16 Classes

AUSHTAGRAM AREA (64 km^2)
Northeastern Bangladesh 27 MAR 75
Landsat Frame 2064-03434
6 Classes

b) Astagram-Bhatshala area.

FIGURE 4. Sections from Aerial photographs and Topo-sheet showing Astagram-Bhatsala area (refered in relation to Figs. 2 and 3).

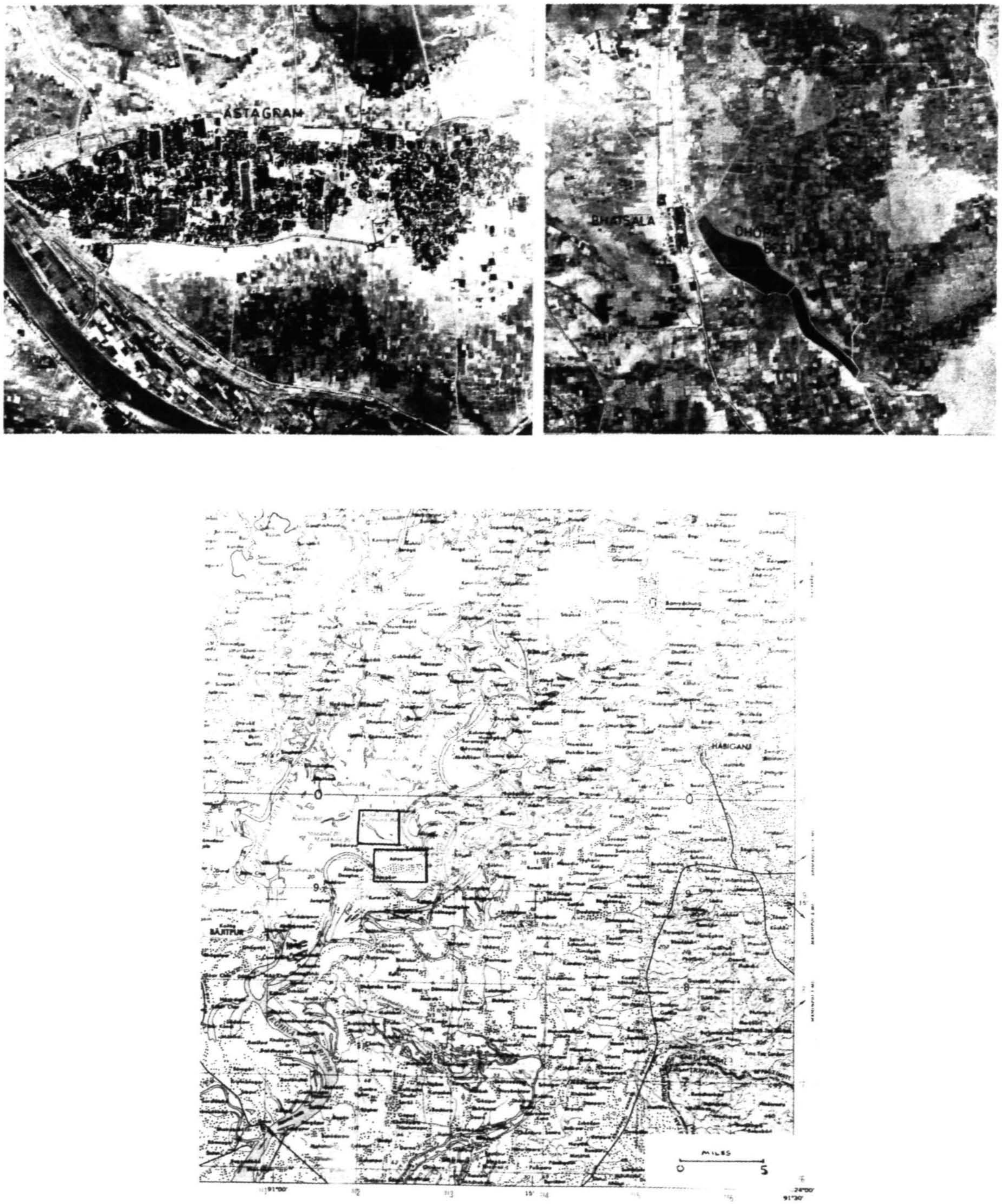


FIGURE 5. Colour Composit Imagery of Northeast Bangladesh.