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APPLICATIONS OF LANDSAT DATA TO THE INTEGRATED ECONOMIC DEVELOPMENT OF MINDORO, PHILIPPINES

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ABSTRACT

Landsat data is seen as providing essential up-to-date resource information for the planning process. As part of a USAID-funded grant, Landsat data of Mindoro Island in the Philippines was processed to provide thematic maps showing patterns of agriculture, forest cover, terrain, wetlands and water turbidity. A hybrid approach using both supervised and unsupervised classification techniques resulted in 30 different scene classes which were subsequently color-coded and mapped at a scale of 1:250,000. In addition, intensive image analysis is being carried out by the various Philippine government agencies in evaluating the images.

The images, maps, and aerial statistics are being used to provide data to seven technical departments in planning the economic development of Mindoro. Multi-spectral aircraft imagery has been collected to compliment the application of Landsat data and validate the classification results.

INTRODUCTION

The purpose of USAID's Remote Sensing Grant Program is to support establishment of an indigenous capability in developing countries to use appropriate remote sensing technology. In instituting the Grant Program AID recognized that developing-country planners and scientists are frequently in the best position to determine their country's priority information needs and in what way remote sensing is likely to contribute to national development.

The Bureau of Mines of the Philippines' Department of Natural Resources submitted a proposal to USAID to use remote sensing data in connection with large-scale integrated economic development program for the Island of Mindoro. This proposal was competitively selected and subsequently approved for funding in late 1975. In 1976 the Philippines grantee received an award of $20,000 and technical assistance from the Environmental Research Institute of Michigan (ERIM), AID's contractor for administering these grants.

As a small part of the Philippines' Grant project ERIM processed Landsat data in preparation of three thematic image-maps of Mindoro. Herein is a brief description of that effort in support of the Mindoro project.

The purpose of producing thematic image-maps was to determine the nature and accuracy of the information available from Landsat data of the Philippines. While it is recognized that manual image analysis techniques provide highly useful land cover and water quality data, computer compatible tapes may offer the greatest opportunity for systematic and quantitative analysis. This task was intended to test the use of digital Landsat data for large-area development planning.

MINDORO ISLAND

Mindoro is the seventh largest island in the Philippines and comprises 10,347 square kilometers (3,995 square miles) of hilly or mountainous terrain and narrow coastal lowlands. It is located due south of the Island of Luzon and 123 kilometers from Manila. Mindoro has a population estimated at 300,000 people, many of whom belong to tribal groups with fairly primitive methods of fishing and shifting agriculture. Development has lagged on this island owing to the relatively small proportions of good level agricultural land in relation to the extensive areas of forested mountain slopes. However, it is clear that with comprehensive resource development Mindoro could become more prosperous. It is rich in primary forests, aquatic resources, and possibly economic minerals. Forestry, fishing, mining, and agriculture are economic activities which could benefit from a more accurate knowledge of Mindoro's resources.

Mindoro is positioned such that the entire island is usually recorded on a single Landsat image frame (see Figure 1). The first satellite picture of the island was obtained in the fall of 1972 and subsequently the island has been imaged more than a dozen times on successive passes of Landsat. Cloud cover is always a problem in viewing Mindoro because the northwest-southeast trending mountain ranges are perpendicular to the directions of the moisture carrying monsoons. Clouds usually cover either the northeastern half or the southwestern half of the island. Only occasionally, during the inter-monsoon period, is Mindoro largely free of cloud cover. Landsat I data collected on December 23, 1972 showed relatively few clouds; these data were used for machine-processing.

PROCESSING PROCEDURES

The objective of the machine-processing was to produce thematic maps and areal statistics which would assist in integrated development planning. Specifically, different terrain and cover classes were selected and mapped at a scale of 1:250,000. It was felt that the available satellite information could be lumped into five general classes on the basis of spectral characteristics: (1) forests (including primary and secondary), (2) agricultural lands, (3) natural aquatic vegetation (swamps and marshes), (4) geologic structure and drainage patterns, and (5) coastal water quality (primarily turbidity). On the maps produced, forests and aquatic vegetation were shown on the same map, and geologic structure and water quality were combined -- resulting in a total of three maps.

The ERIM Multivariate Interactive Digital Analysis System (MIDAS) was used for this task. The MIDAS special-purpose computer provides an interactive, user-oriented capability for producing thematic maps derived from Landsat multispectral data. In this machine, 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 color displays. The data classifier is designed to perform a one pass maximum-likelihood decision with a priori probabilities, assuming multi-model Gaussian multivariate spectral distributions. The output of this classification process is a geometrically-rectified color-coded hard-copy image-map. These maps may be produced at any convenient scales; 1:250,000 for this large-area project.

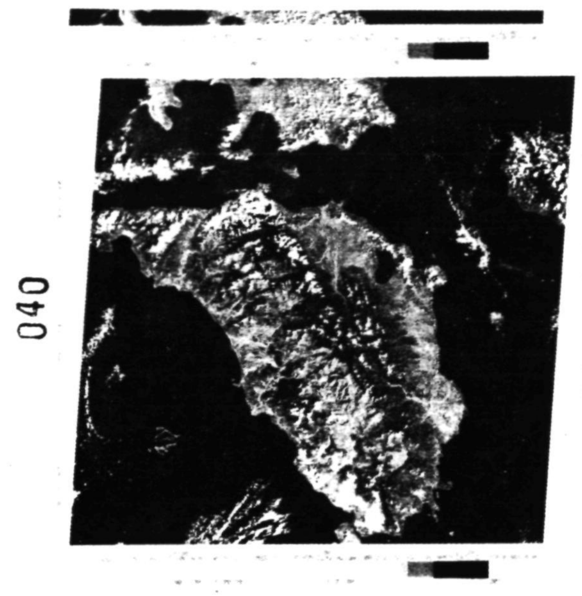

FIGURE 1. Landsat Image of Mindoro Island (Band 5)

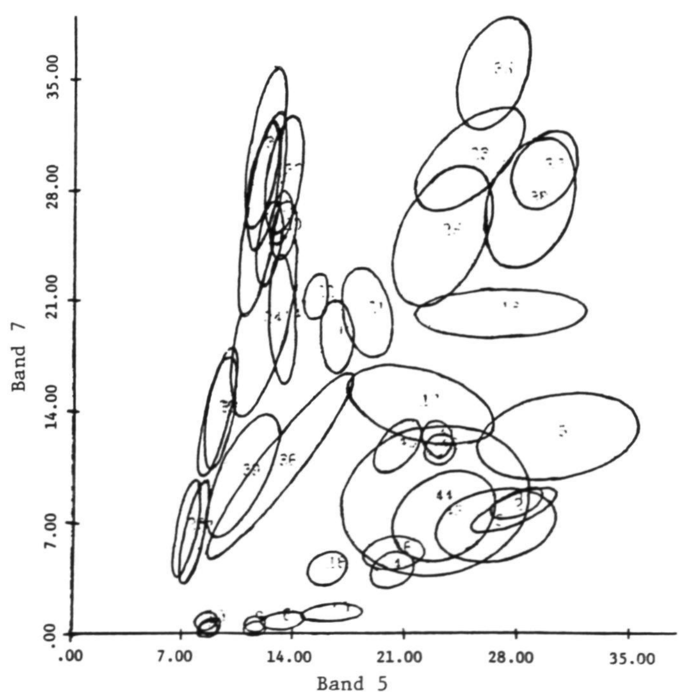

FIGURE 2. SIGNATURE VALUES IN LANDSAT BAND 5 AND BAND 7.
ELLIPSES REPRESENT ONE STANDARD DEVIATION FROM MEAN VALUES.

SIGNATURE SELECTION

Spectral signature selection for classifying Landsat MSS data is the key to successful processing results. Therefore, careful attention was given to data analysis directed at appropriate signature selection.

Utilizing the forestry, soil, crop, wetland, and bathymetric information supplied by the Bureau of Mines, some 43 different signature locations ("training sets") were selected. The spectral characteristics of such features as primary forest, secondary forest, beach, stream courses, rice, marshland, coconuts, other crops, and turbid and clear water as nearly as could be identified were obtained in all four Landsat bands. These were described by their mean values and covariances in each band. Subsequently, these characteristics were plotted as one-standard deviation ellipses for two band combinations. One of these is shown in Figures 2 (Band 5 vs Band 7). As can be seen, considerable overlapping occurs between ellipses, indicating that there is a spectral continuum associated with the data and that it is not possible to selectively eliminate all overlapping and consequent probable misclassification of features. (Other band combinations showed greater overlapping.)

In addition to the training-set selection (for supervised classification), data clustering, for unsupervised classification, was also performed. The clustering procedures allow an even, non-overlapping arrangement of signatures (see Figure 3) but considerable uncertainty concerning signature identification.

Finally, spectral signatures selected for data classification comprised a combination of subsets of both the known training set signatures and the cluster signatures. Training-set signatures of known scene classes were used where possible, but for spectral conditions not covered by some selected training set, cluster signatures were used to "fill-in". Twenty-nine different signatures were subsequently classified.

CLASSIFICATION RESULTS

The twenty-nine signatures selected were thought to represent almost the entire spectral range of the Mindoro data. Only 1.4% of the data was subsequently left "unclassified" on the basis of a maximum likelihood ratio decision rule implemented by the computer.

Essentially the computer compared the recorded spectral characteristics of each and every picture element (pixel) and determined which of the twenty-nine signatures, if any, is most similar. Therefore, each of the pixels were assigned to one of twenty-nine different classes or an "unclassified" class if it was very different. In doing so, the computer tabulated the number of pixels identified in each class and the total area represented by each.

Forty percent of the total area was classified (16,370 sq km) as water and 3.7% was cloud and cloud shadow. Of the land area classified 21% (2,043 sq km.) is forest, 38% (3,750 sq km) is cropland or aquatic vegetation. Some misclassification occurred due to the overlapping spectral characteristics of certain features -- for example, secondary forest appeared similar to certain types of cropland and lowland rice appears similar to wetland.

MAP GENERATION

In addition to the statistics generated by the data classification procedure, the final product of this task was the production of three thematic maps wherein different terrain classes and combinations of classes were color-coded. It is not possible to clearly display 29 different colors, representing 29 different terrain classes at a scale of 1:250,000. In general, the eye is able to discern about 10 different colors when they are complexly interwoven

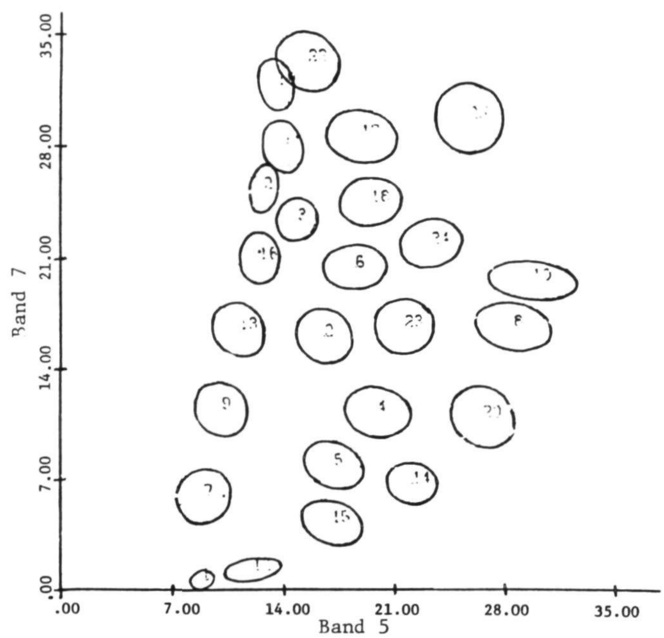

FIGURE 3. UNSUPERVISED CLUSTER VALUES IN LANDSAT BAND 5 AND BAND 7. ELLIPSES REPRESENT ONE STANDARD DEVIATION FROM MEAN VALUES.

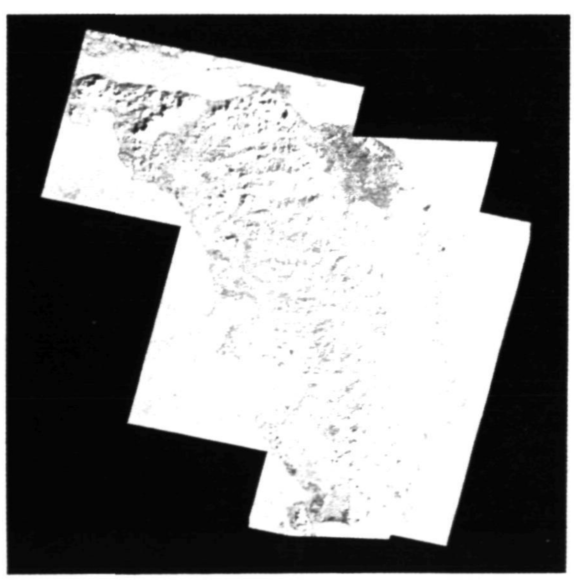

FIGURE 4. ERIM MIDAS CLASSIFICATION MAP SHOWING TOPOGRAPHIC STRUCTURE.

in a detailed map. Using the 29 different classes, colors were selected to show spatial patterns associated with forests, topography and water quality, and cropland and wetland on separate image-maps. While the agriculture and forest maps were conventionally represented, the image map showing topography was somewhat unique. Signatures for north and west facing slopes were colored violet in contrast to the south and east slopes which were gray (see Figure 4). Solar illumination differences resulted in different signatures for these slopes (the sun elevation was 42^o and azimuth, 139^o).

MAP EVALUATION

Using the ground truth information supplied by the Bureau of Mines some preliminary comparisons with the MIDAS map results showed the Landsat data to provide greater spatial detail than is possible to obtain using simple manual techniques. The results also demonstrate that the illumination of slopes varied greatly with orientation and that several signatures were required to map the same features. For example, primary forests on northern and western slopes appeared quite different from similar forests on eastern and southern slopes. Some areas indicated on the ground truth maps as primary forest did not appear on the Landsat forestry map and need to be investigated further. Similarly extensive agricultural areas show complex spectral patterns indicating a variety of crop and cultivation conditions. Aerial photography and ground observations are being used to evaluate the accuracy of specific classifications.

CONCLUSION

The Republic of the Philippines is an archipelago extending for 1,100 miles and is composed of 7,100 islands and islets. With its burgeoning population of 46 million people and increasing need to develop its resources, the Philippines is looking, in this and other projects, to the use of Landsat data for resource information required for sound development planning. This space-acquired information can then be combined with other information (such as aircraft and/or ground survey data) through a planning or management system. Ultimately this information will be supplied to a decision-making institution which can use the information for development planning purposes.

ACKNOWLEDGEMENTS

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