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Paper A 5

ENGINEERING ANALYSIS OF ERTS DATA FOR SOUTHEAST ASIAN AGRICULTURE

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The present program focuses on rice because of its importance world-wide as a food. Specifically, the focus is on rice fields in the Philippines. Two primary program objectives are (Figure 1) to establish the feasibility of extracting from ERTS imagery the areas where rice is grown, and to determine those measurements on the imagery which enable the assessment of crop condition (moisture vigor, maturity, etc.). Achieving these objectives with procedures which can be cost-effective can lead the way toward yield prediction, irrigation system management, and similar functions which are known to be important needs in Southeast Asia.

The program team is comprised of specialists in several disciplines from (Figure 1) Cornell University, General Electric Company, and two groups in the Philippines concerned with ground truth information functioning under the auspices of the Philippine national program in remote sensing. We particularly wish to acknowledge the efforts of Prof. S. M. Miranda, University of the Philippines, Los Baños and Dr. Thomas Wickham, International Rice Research Institute, Los Baños.

There are a few special aspects of the investigation which should be noted (Figure 2). First, we have an adequate number of test sites where good ground truth data can be acquired. The sites span a range of plant varieties, irrigation and fertilization conditions, and they are dispersed geographically. Some of the sites can be used for signature training, others for recognition algorithm testing. When some sites are cloud-covered in a frame of imagery others may be clear. However, these sites, while located in areas where considerable rice is grown,

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EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

are each very small and quite difficult to recognize precisely in ERTS imagery. It is still possible to carry out the planned program in this situation, but the problem is probably more acute than for most sites in the U. S.

Indications are that the observed signatures for rice fields will vary rather rapidly with time through the growing cycles. This should be an asset; use will be made of temporal variations in spectral signatures. There will be need, however, to communicate interim results of the imagery analysis process to ground truth personnel in the Philippines for their specific comments relative to particular situations. This will involve certain time delays but, again, is not an overwhelming obstacle.

Figure 3 is the color composite imagery for a portion of the island of Luzon for October 31, 1972. Two of our test site areas, each with several individual test sites, are contained in this frame. The individual sites often have areas of 200 hectares or less and their linear dimensions are less than one percent of the field-of-view of the ERTS imagery frame. In order to achieve the objectives of this investigation it is our plan to extract reliable spectral signatures from test site areas, carefully correlate signatures with ground truth, and use the correlation results to develop recognition algorithms. Procedures for recognition of the locations where rice is grown will be developed first. Then, attention will be focused on procedures for assessing crop conditions. But for this approach, a considerable amount of signature extraction and correlation with ground truth will be involved in the first part of the program.

We are using color composites as the principal form of imagery input in the analysis process. The composite transparencies are analyzed at General Electric using a three-color man-machine analysis system (GEMS) operating in near-real-time with a digital computer tied in. The GEMS will not be described here, but prior to presenting results to date it is necessary to describe the color space framework used.

We acquire spectral signature data in three-dimensional color space as illustrated in Figure 4. The bounds to the rectangular volume in 3-space are set by the analyst to cover the spectral-radiometric range for the test site with which he is concerned.

We have found it adequate to sub-divide this volume into 5 x 5 x 5 = 125 individual color cells. The significant items to note here are that the overall 5 x 5 x 5 volume can be positioned repeatably to its proper location in the 3-D color space, and, further, it is referenced in each color channel to the gray steps in the step-wedge for that color composite. Thus, the 5 x 5 x 5 volume can be referenced to the spectral radiation in the scene.

The San Nicolas test site area is shown in Figure 5, which is a photograph of the analysis system color TV monitor displaying an optically zoomed portion of the overall color composite. The rectangular cursor, set to include the test site, is positioned by the analyst. The cursor dimensions in the scene are approximately 9000 ft. x 4000 ft.. In the color composite the region within the cursor contains considerable deep blues plus a little red and some light pinks or beiges. (The imagery was obtained at harvest time and it is suspected that the blues pertain to moist soil exposed as a result of harvesting). The analysis system is asked to indicate where the picture cells within the cursor (there are about 650 such pixels) fall in the 5 x 5 x 5 color space. The result is shown in Figure 6.

To show the results quantitatively the 5 x 5 x 5 volume in Figure 6 is broken into five layers each containing 5 x 5 = 25 color cells. The numbers in the color cells indicate the percentage of the total number of pixels within the cursor which pertain to each color cell. It is noted that 33 of the 125 color cells are occupied, but of these only about a dozen cells are significantly populated. In 3-space it would be found that the populated color cells are in clusters with a few regions of high population corresponding to the blues, reds and light pinks or beiges in the cursor area. These cluster locations are found to be quite repeatable with successive analyses on different days.

To continue the analysis, it is now necessary to reverse the process. That is, go to particular color cells and ask the analysis system to indicate where the picture cells are located in the scene (within the cursor) which populate those color cells. This is illustrated for a second test site shown in Figure 7 - the Malimba site. Note that within the cursor (includes the test site) there are regions of deep blue, pink-light beige - whitish regions, and areas of red.

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In Figure 8 twelve of the most populated color cells are indicated for the pixels within the cursor. For each of these color cells the analysis system determined and produced a computer printout showing the locations of the picture elements corresponding to these color cells. The printouts are reproduced and superimposed in the figure with different types of cross-hatching foi groups of color cells. The combined printout results shown in the figure correspond quite well to the scene features within the cursor as shown in Figure 7. Presumably these features are related to conditions in the scene at the time of the overflight. That is, they presumably relate to areas of recent harvesting where moist soil is exposed, to areas of growing rice, to areas of less vigorously growing rice, to harvested areas where there are weeds or drier soil, etc. Detailed ground truth, available to the ground truth team for the precise time of the overflight, is to be examined by that team to provide the correlation. Once that correlation is made, then spectral signatures in the 5 x 5 x 5 color space may be assigned to particular features or crop conditions.

The dashed line in Figure 8 outlines our best estimate of the location of the test site area. The exact location (to an accuracy better than 500 feet) is difficult to determine because of the lack of good spatial reference points in the scene. Precise test site location may have to be determined in the imagery by relating it to the observed feature patterns and their correlation with ground truth.

The scene in Figure 9, the color TV display of a zoomed portion of the color composite, includes a third test site area - Mahipon. The analysis system has once again related the key color cells with the locations of the picture elements which populate these color cells. Results of this analysis, analogous to that for the Malimba site, are shown in Figure 10. The estimated location of the test site relative to the cursor boundaries is shown with the dashed line. Once again there is the difficulty in establishing its exact location, and correlations of observed feature patterns with ground truth may be the necessary approach. In any event some questions arise concerning the results as shown in Figure 10. Ground truth indicates that the site is at least 27 percent harvested. Yet none of the picture cells within the test site boundary fall into color cells corresponding to the blue in the color composite (color cells indicated by the horizontal-vertical cross-hatch). Thus, either the location of the test site in the imagery is slightly in error, or the harvested areas involve a drier soil or perhaps weeds which are represented by picture cells which fall in some of the other color cells. This question is to be examined and answered by the ground truth team.

Once questions such as that just described are answered, then it is a relatively simple matter to establish the spectral signatures for the test site as a whole and for the features within it. For example, if the horizontal-vertical cross-hatched areas in Figure 8 actually represent harvested fields with exposed moist soil, the data now exist to show where the picture cells fall in 5 x 5 x 5 color space for just those harvested fields which are within the site boundary. Figure 11 illustrates what such results would be like for the Malimba and Mahipon sites assuming the site boundaries have been properly located in the imagery. In this illustrative case it is seen that there are differences in site signatures. There are more occupied color cells corresponding to deep blue for the Malimba site than for Mahipon, and conversely Mahipon has more color cells occupied which correspond to pink, light beige and whitish tones. The numbers in the color cells represent cell population in percent of total picture cells involved.

Thus, the techniques are in hand to extract the desired feature signatures, and the necessary ground truth correlations are underway. Because test site areas are small and not readily recognizable in the imagery, a clustering approach in color space with corresponding picture cells correlated with ground truth is used as the basis for determining signatures for features or conditions within the site boundaries. It would have been virtually impossible to proceed directly to a test site feature for signature extraction since there is no apparent direct way to assure the location of that feature in the imagery.

Signatures vs. time for several test area rice fields with a variety of associated conditions will be extracted from ERTS imagery throughout the growing cycle. These will form the basis for recognition procedures to be tested and applied to larger areas later in the program. Expected results at that time can be in the form illustrated in Figure 12. The Mahipon site area is shown once again with analysis system enhancement of rice fields within the site which have a certain set of characteristics. Rice fields external to the test site having a similar signature and presumably having similar field characteristics are also enhanced. Ideally, a recognition process is illustrated. But its accuracy is not known at this time. That is to be established during the program. Once accuracy is known and is acceptable, then area measurements, position locations, and statistical analyses for the enhanced areas in the scene are readily obtained from the digital data producing the enhancement. This, in turn, will assist government agencies in yield predictions and in improved irrigation and crop management. The thrust of our effort is toward achieving that capability cost-effectively.

Program Objectives

- Establish the feasibility of extracting from the imagery the areas where rice is grown.
- Determine those measurements on the imagery enabling assessment of the crop condition.

Program Team

- Cornell University, Civil and Environmental Engineering, Agricultural Engineering.
- University of the Philippines, Los Baños.
- International Rice Research Institute, Los Baños.
- General Electric Company.

Figure 1

Special Aspects of the Investigation

- Adequate and diverse number of test sites.
- Test sites are small and difficult to recognize.
- Rice signatures can be expected to vary fairly rapidly with time.
- Long communication link to the ground truth team.

Figure 2

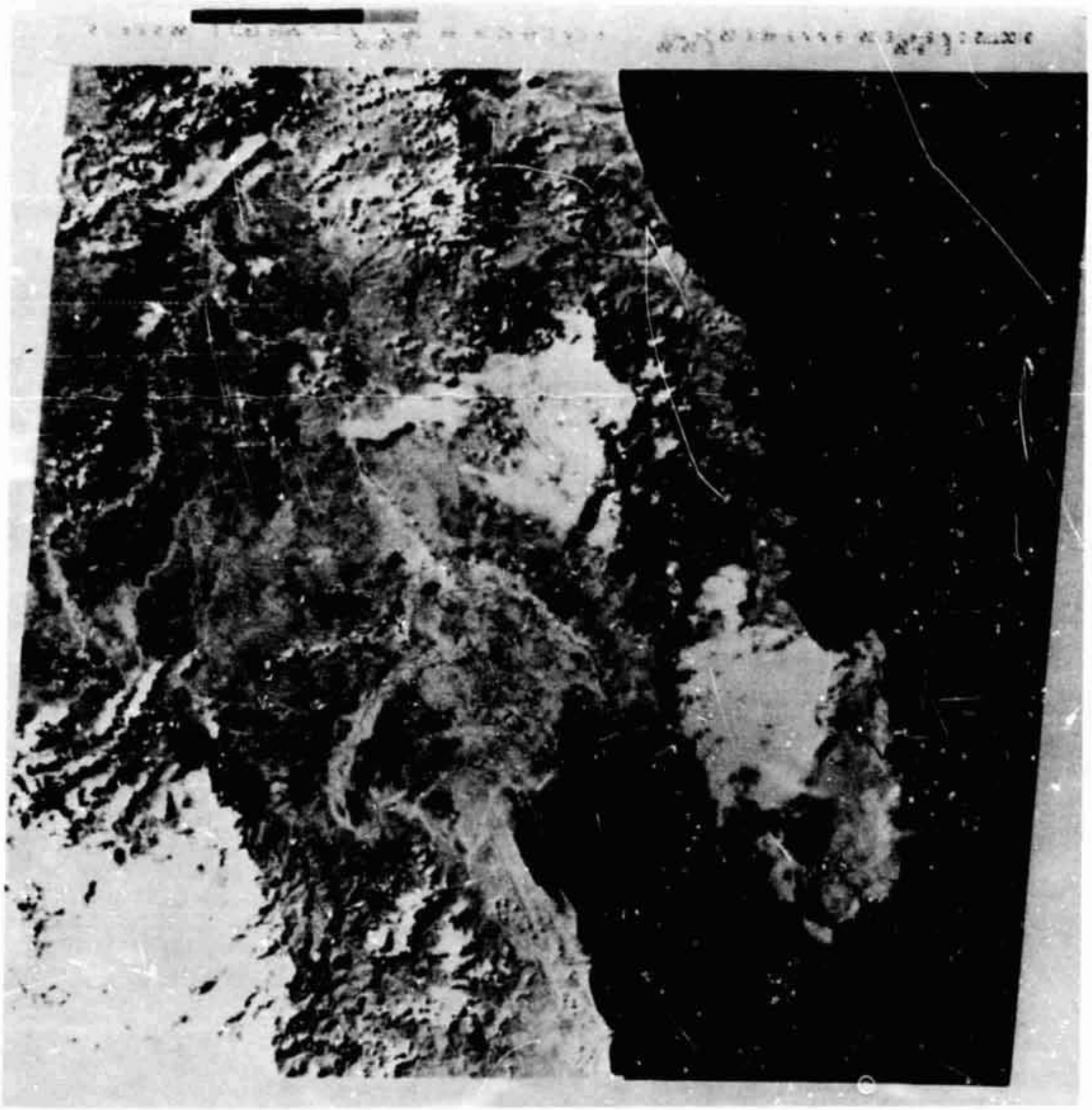


Figure 3

3 - D COLOR SPACE

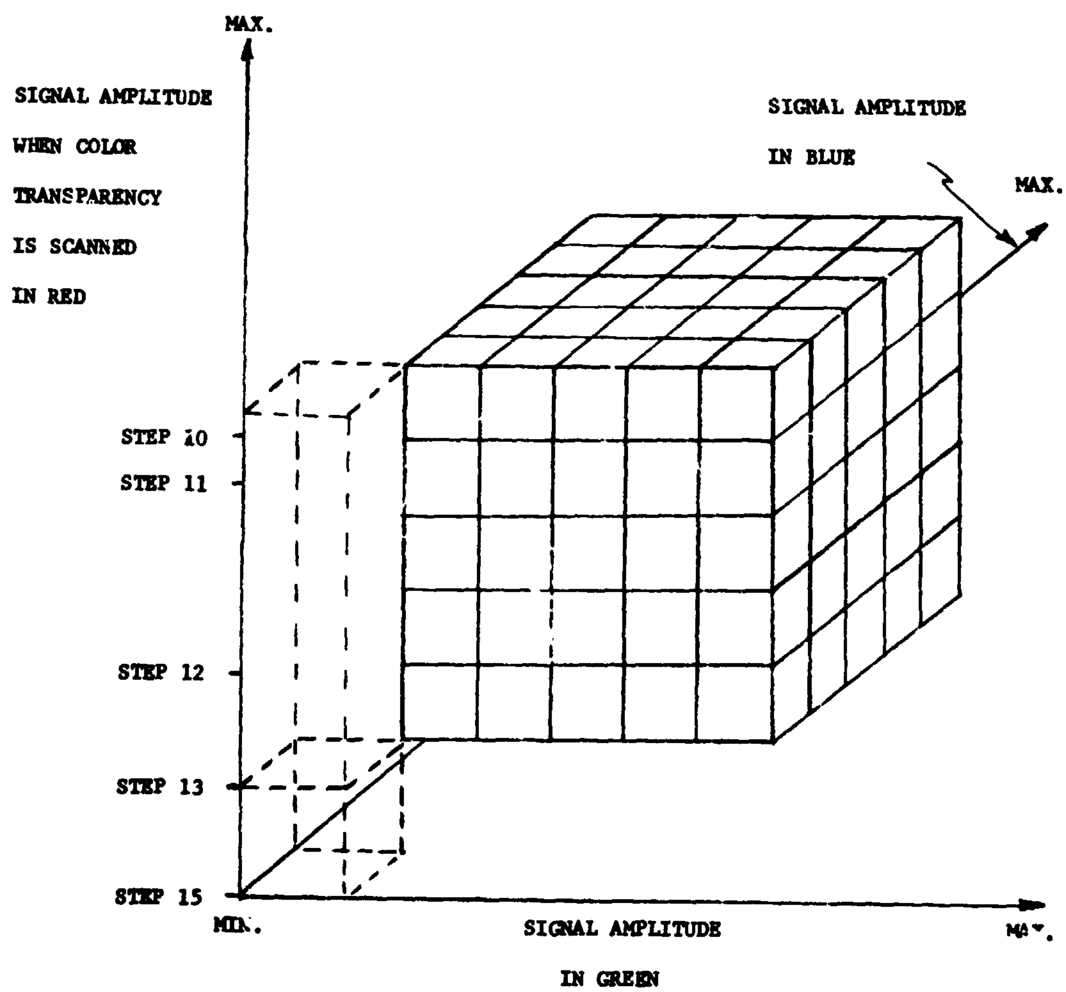


Figure 4

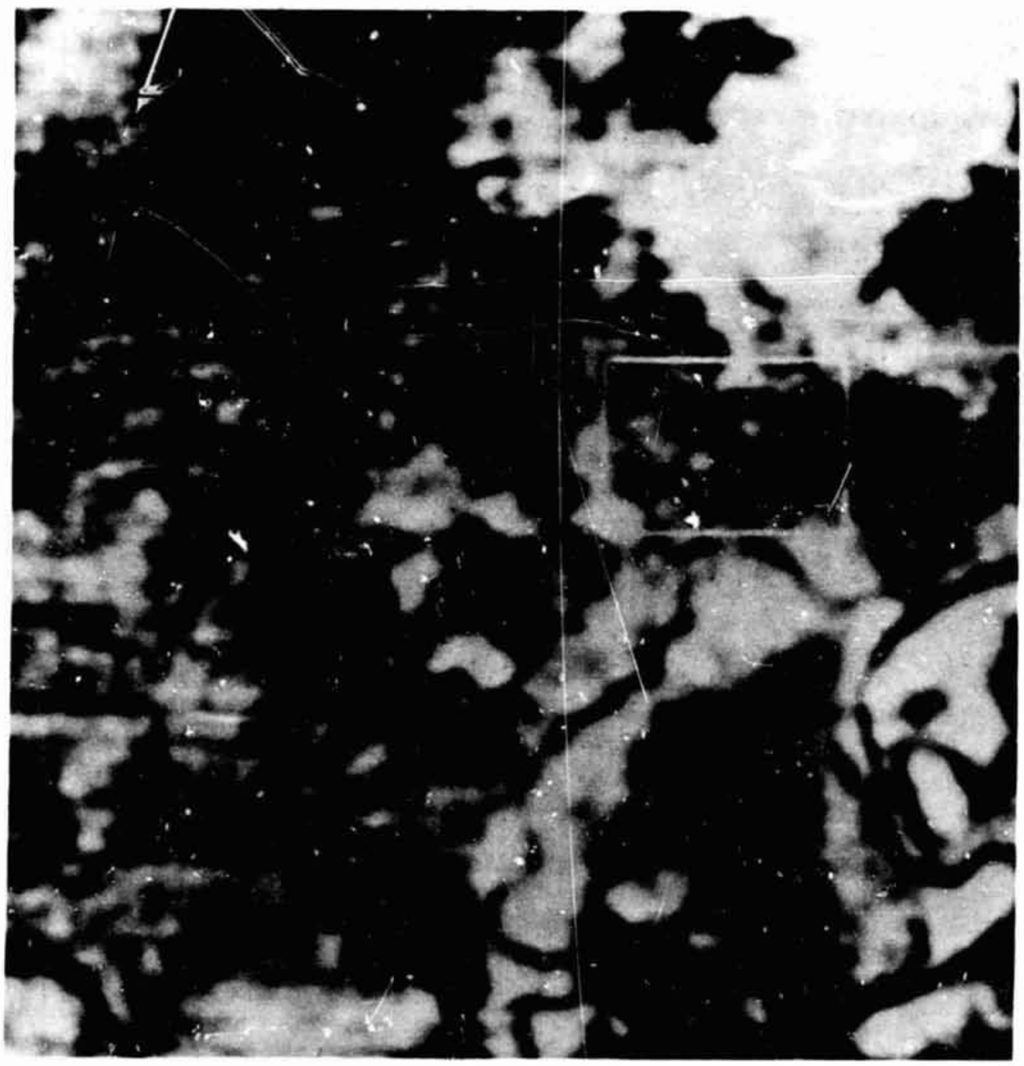


Figure 5

POPULATION OF 125 3 - D COLOR CELLS
IN PERCENT OF TOTAL PICTURE ELEMENTS*
WITHIN CURSOR (SAN NICOLAS SITE)

*APPROXIMATELY 650 ELEMENTS

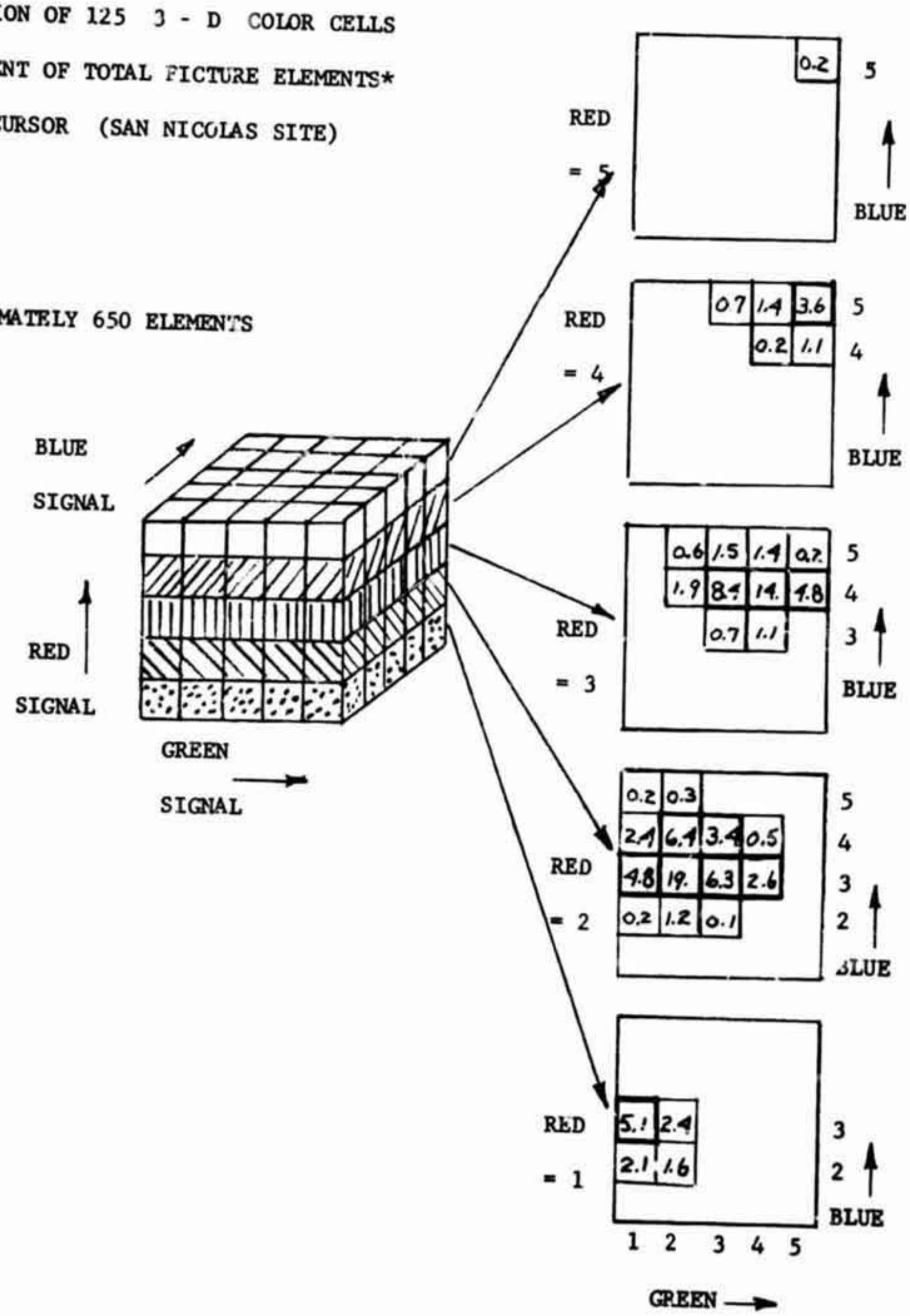


Figure 6

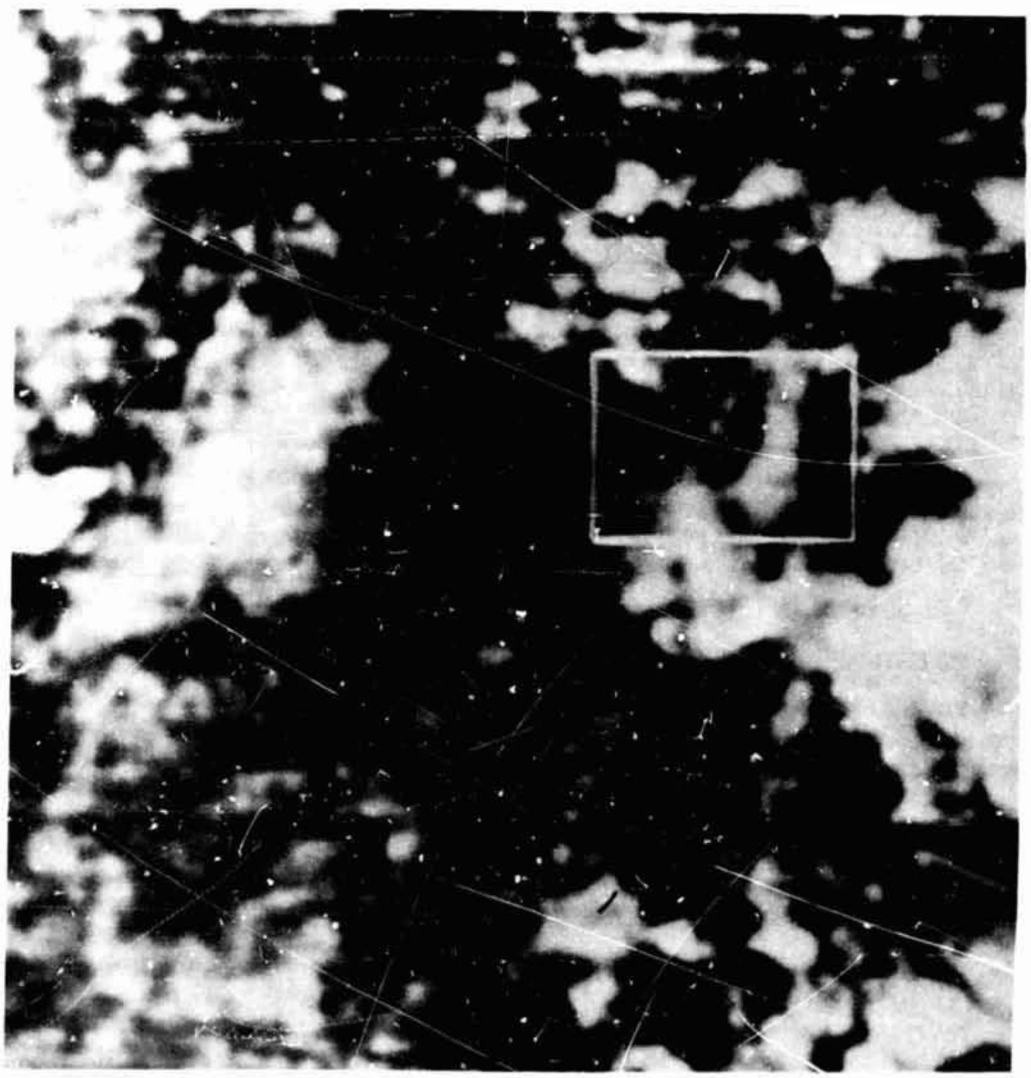
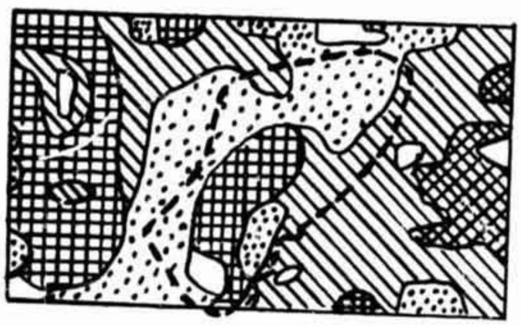


Figure 7

MALIMBA TEST SITE

AREAS CORRESPONDING TO
COLOR CELL CLUSTERS



GROUND TRUTH:

52% HARVESTED

5% FLOODED

FERTILIZER - 41.6 kg N/ ha

YIELD 3.09 T/ ha

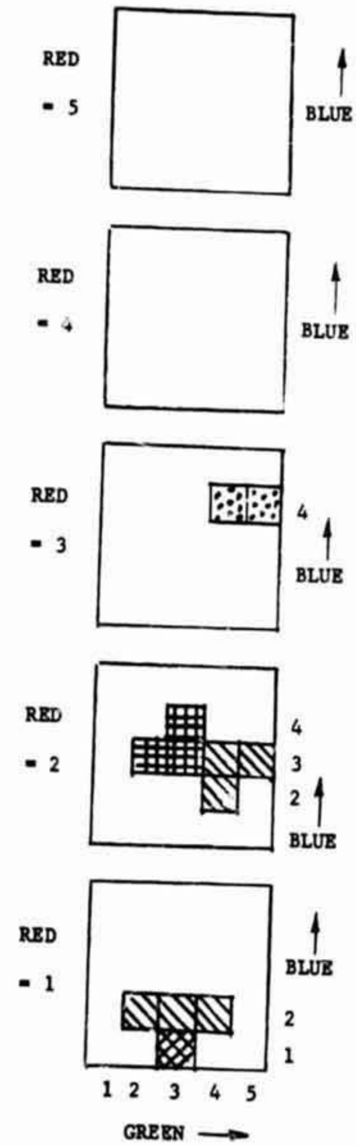


Figure 8

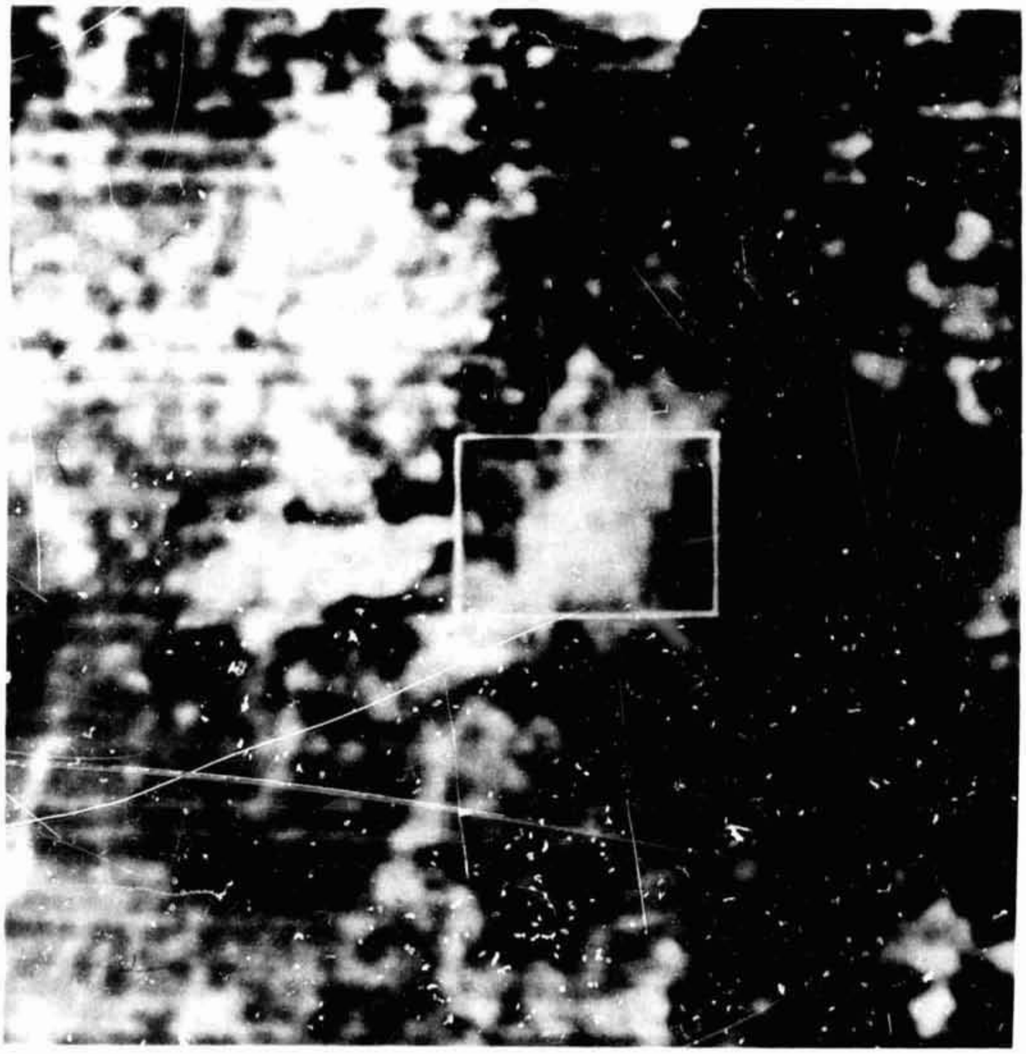
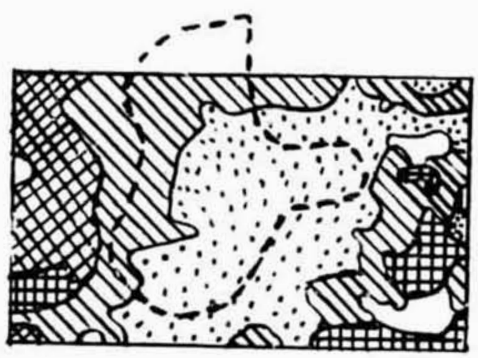


Figure 9

MAHIPON TEST SITE

AREAS CORRESPONDING TO

COLOR CELL CLUSTERS



GROUND TRUTH:

27% HARVESTED

14% FLOODED

FERTILIZER - 29.8 kg N/ ha

YIELD 1.95 T/ ha

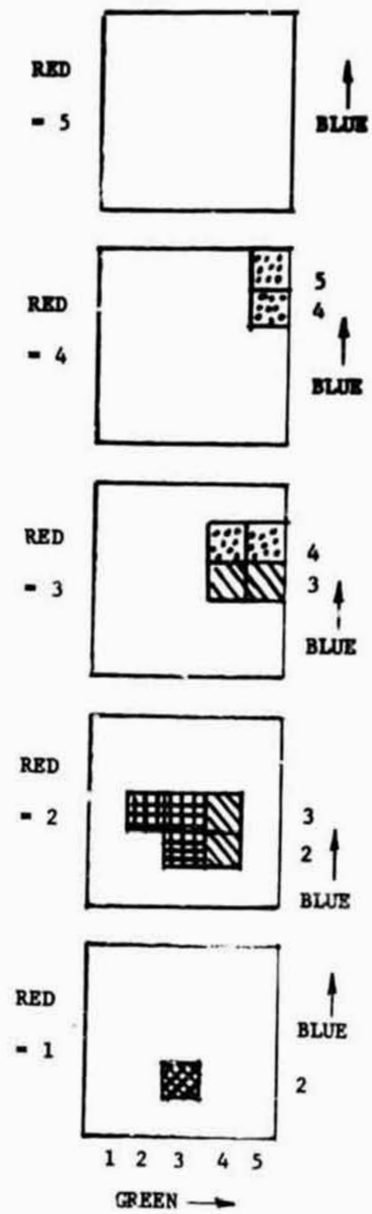


Figure 10

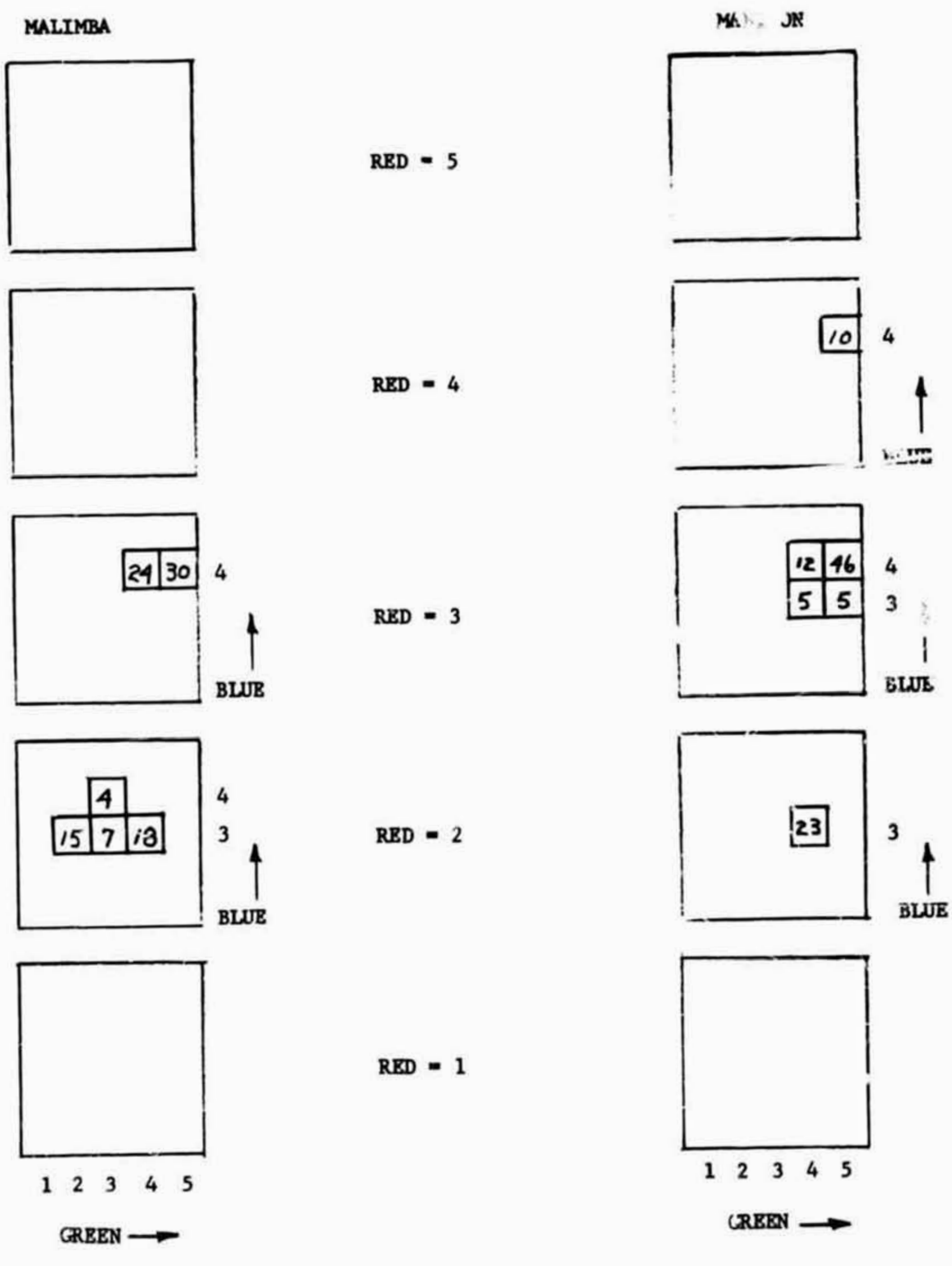


Figure 11. Signature Comparison for Two Test Sites

Figure 12