LARS Technical Report 042980

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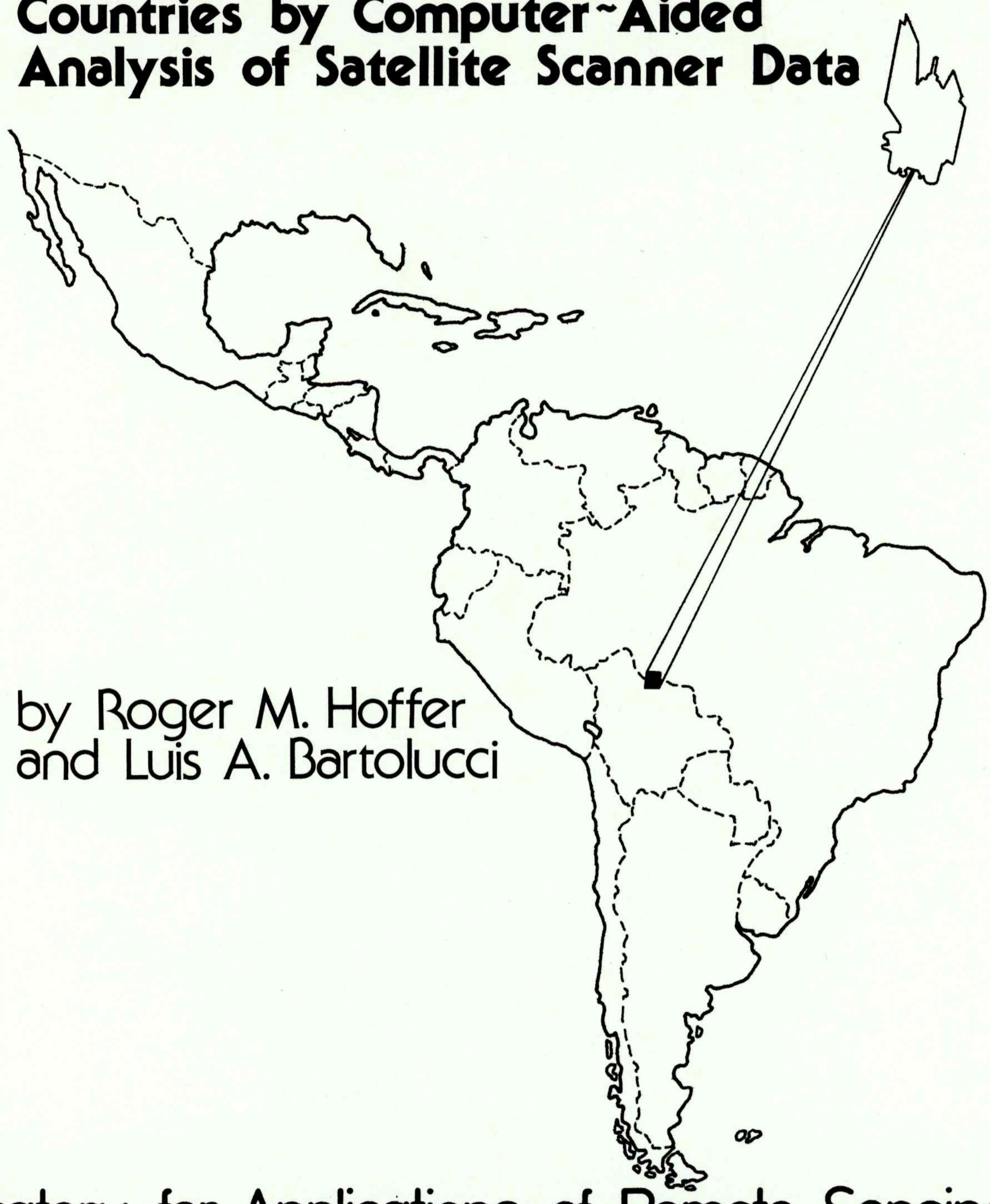

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1980

MAPPING LAND COVER IN LATIN AMERICAN COUNTRIES BY COMPUTER-AIDED ANALYSIS OF SATELLITE SCANNER DATA

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ABSTRACT

Since the launch of Landsat-1 in 1972, there has been tremendous interest in using these data for mapping land cover. Some of the Latin American countries have been involved in the use of the satellite images since the very beginning of the Landsat program. Much of the work has involved visual interpretation of the Landsat imagery. However, as techniques for computer-aided analysis of satellite MSS data have developed, there has been a growing interest in many of the Latin American countries in using these more sophisticated analysis techniques to map land cover. This paper evaluates the results of several projects in Latin American countries involving the use of computer-aided analysis techniques for mapping land cover. The results of these and other recently completed research projects indicate a number of key points which should be considered in applying such analysis techniques. These points include the following:

(1) The need to develop a locally adapted land cover/land use classification scheme. Such a scheme should be developed in the preliminary planning phases of the project.

(2) The need to stratify the entire region involved into areas of similar characteristics, (physiographic/cover type), using visual image interpretation techniques. Such an approach enables the subsequent computer analysis to be much more effective and efficient.

(3) The need to define a representative set of training statistics for each strata to be classified. Many different approaches are available. However, the effectiveness with which some of these can be used often depends on the level of training and the experience of the analyst. The characteristics of the area involved and the objectives of the project can influence the approach to be used as well. In many Latin American countries, hardware and software availability also can play a major role in this phase of data analysis.

(4) Many classification algorithms are available, and the selection of the one to be used can significantly impact the characteristics of the results obtained, as well as the costs involved.

(5) Evaluation of the classification results should be considered an integral part of the entire analysis sequence. The availability of aerial photos in some of these Latin American countries can have a major impact on this phase of

the mapping sequence. The need of adequate aerial photo coverage for both developing the training statistics and evaluating the classification results must be given careful consideration in the initial planning phases of the project.

Results of classifications of Landsat data from six Latin American countries reveal some interesting situations of spectral similarity between cover types that are, in some cases, very different, such as recent lava flows and clear water. In other situations, spectral separability could not be reliably achieved between sugar cane and tall grass, or between areas of coconuts and mangrove.

The paper also addresses the importance of and the need for effective training programs for data analysts, and the need for spectral field research on Latin American cover types.

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1. INTRODUCTION

Since the launch of Landsat-1 in 1972, many countries have been involved in assessing agricultural, forest, geologic, water, and cultural resources of their country. A considerable amount of effort has involved image interpretation of black and white and color infrared composites of Landsat images. There has also been interest in exploring the advantages and limitations of computer-aided analysis techniques. Scientists from Bolivia, Nicaragua, Guatemala, Costa Rica, Honduras, and El Salvador have worked closely with scientists at the Laboratory for Applications of Remote Sensing, Purdue University, in evaluating the potential for using computer-aided analysis techniques (CAAT) to assess the natural resource maps for the countries involved, but also provided useful insights concerning some of the more critical aspects involved in applying computer-aided analysis techniques to Landsat data. The objective of this paper is to discuss several of these key steps in using computer-aided analysis techniques, as well as to describe some of the problems encountered in classifying some of the cover types present in Latin American countries.

2. KEY STEPS IN APPLYING CAAT TO SATELLITE DATA OF LATIN AMERICAN COUNTRIES

2.1 DEVELOPMENT OF AN APPROPRIATE LAND LAND/USE CLASSIFICATION SCHEME

The development of a locally adapted land cover/land use classification scheme is a particularly important and critical phase in the successful utilization of Landsat data. The land cover/land use classes into which the data is to be categorized or classified must be well defined according to some type of system that is appropriate for the particular characteristics of the area involved. Such a classification scheme is important whether one is applying computer-aided or manual interpretation analysis techniques to the Landsat data. In the United States, Anderson et al. developed a classification scheme which was initially published as U.S.G.S. Circular 671, entitled "A Land Use Classification System for Use With Remote Sensor Data". After receiving various comments which had been requested, concerning the use and limitations of the proposed system, it was modified and published as U.S.G.S. Professional Paper 964 entitled "A Land Use and Land Cover Classification System For Use With Remote Sensor Data." It is significant to note that one of the modifications of the system was the use of both the terms land use and land cover. This clearly recognizes the fact that land cover and land use are not synonymous terms. In many cases, one particular type of land cover may be used for a variety of purposes. For example, forest cover could be used for timber production or an area of forest cover might be used primarily for recreation. The satellite data shows land cover, but sometimes it is difficult to infer the land use.

Dr. Carlos Brockmann, Director of the ERTS-Bolivia Program found that some aspects of the land use/land cover classification scheme developed by the U.S.G.S. (Anderson, et al., 1977) could be modified in order to more effectively characterize the land use and land cover of Bolivia. The Level-1 groupings were essentially the same as those defined by the U.S.G.S. system, as shown in Table 1.

Table I. Comparison of Bolivian and USGS Level-I Land Use and Land/Cover Classification Systems.

Bolivian Land Cover and Actual Land Use Classes	The USGS Land Use and Land Cover Classification System
1. Range and/or Shrub Lands	1. Urban or Built-up Land
2. Forest Lands	2. Agricultural Land
3. Crop Lands	3. Rangeland
4. Wet and/or Flooded Lands	4. Forest Land
5. Water Bodies	5. Water
6. Barren Lands	6. Wetlands
7. Permanent Snow and Ice	7. Frozen Lands
3. Cultural Patterns	8. Tundra
	9. Perennial Snow or Ice

The order of the Level-I classes in the Bolivian system is somewhat different than that of the USGS system, but the classes are basically similar. However, the level of the classification system differs considerably from the USGS system. Bolivia is a country with a large mountainous region, a very high elevation altiplano, and a fairly low-land region in the eastern portion of the country. It was found that the spectral patterns and characteristics of agricultural fields, for example, were very different in the altiplano than they were in the low-land regions near Santa Cruz in eastern Bolivia. Therefore, Dr. Brockmann and his associates felt that it would be best for the Bolivian situation to divide most of the Level I categories into high land, intermediate altitude and low land cover types at the Level II degree of detail. This approach was found to meet their particular needs quite satisfactorily.

We believe that in any country or situation, it is very important for the analyst to carefully evaluate the land use and land cover characteristics of the area, and then adapt existing land cover/land classification schemes to meet his particular needs.

Of course, before one can develop a land cover scheme that is suitable and is adapted to the local situation, one must first define the objectives. In most cases one is interested in grouping cover types or land uses into categories that are meaningful and useful for a variety of management purposes.

In the system developed for Bolivia, it is significant to note that it is titled "A Land Cover and Actual Land Use System." Dr. Brockmann and his colleagues recognized that the actual land use as seen on the satellite data might be considerably different from the potential land use. One of the objectives of their analysis of Landsat data in Bolivia was to obtain better information concerning the extent of agricultural lands and to obtain additional information concerning the potential area within Bolivia that might be suitable for agricultural use. Their preliminary work with the Landsat data indicated that only 1.8% of the country is acutally being used for agriculture, although Bolivia is considered to be an agricultural country. Their survey also indicated that a much larger area could be potentially used for agricultural purposes, perhaps more than 10 times the area now being used.

In applying their land cover and actual land use classification system to the Landsat data, they followed an approach in which they would first identify the existing cover type and then, if possible, they would relate the cover type to a particular land use. If a land use category could not be defined that related to the land cover, then the map simply displays the land cover characteristics of the area. Thus, it is truly a map that displays both land use and land cover. By identifying land use if possible, and only when they could not identify land use to indicate the land cover categories on the map appears to represent a very reasonable approach for combining land use and land cover.

2.2 STRATIFY THE REGION OF INTEREST INTO AREAS OF SIMILAR PHYSIOGRAPHIC COVER TYPE CHARACTERISTICS.

Many of the Latin American countries do not currently have detailed information concerning the various natural resources of their country. The governments of these countries tend to centralize their decision processes. Therefore, the governments of these countries need basic information for the entire country, even though the level of detail includes only broad categories or classes of cover types. Visual image interpretation can and should be used to stratify the entire country or major portion of the country into large physiographic or cover type areas of similar characteristics. Such an approach allows the analyst to stratify and prioritize the categories that are of particular interest and to effectively mask out the regions of lesser interest. For example, areas of agricultural land can be quickly and easily separated from regions of mountainous terrain containing forest cover. Such a stratification procedure allows subsequent computer processing of the data to be much more efficient for several reasons. First, it allows the computer analysis to be concentrated on the cover types and/or land use categories that are of particular interest, such as agricultural land, or forest cover, or rangeland, etc. Secondly, and of particular importance, is the fact that stratification allows the analyst to keep to a minimum the number of spectral classes with which he/she is working at any one time. Thus, one might find that for a particular cover type grouping perhaps seven to ten spectral classes would characterize a particular strata, whereas maybe 40 or 50 spectral classes would be required to characterize the entire Landsat frame. By working with a relatively few number of spectral classes, it maximizes the efficiency of both the computer and the analyst in developing an effective and representative set of training statistics that will truly characterize each cover type in the data. This in turn, should allow an improvement in the classification accuracy.

Considering manual interpretation techniques for stratifying Landsat data, one sometimes encounters questions relating to the relative value of black and white imagery in the visible and near infrared Landsat bands versus the color infrared composite. Black and white Landsat imagery can be obtained at a 1:250,000 scale at a much smaller cost than is required for the color infrared composite. This is particularly true if the initial fee for preparing the color infrared composite is also involved. One approach has been to use a black and white infrared Landsat image and delineate on an overlay all of the features of particular interest that can be seen and then to use the same overlay in conjunction with a visible band image to delineate additional features that could not be observed on the infrared image. The result is an overlay which hopefully contains most of the information present in the scene.

In a recently completed study, the use of black and white images was compared to the use of color infrared images. The results indicated that the accuracy obtained was very similar, although there did seem to be some situations in which subtle tone differences could be detected and delineated on color infrared composites that were overlooked on individual black and white visible and black and white infrared images. Of more importance, however, was the fact that the analyst could delineate boundaries around various features and cover types of interest much more rapidly, and with a greater degree of confidence when using the color infrared composite than was the case with the black and white images. There are relatively few trained analysts who can effectively interpret Landsat imagery. Thus, in order to maximize effectiveness of the analysts available, it would appear that the use of color infrared composites is a much more effective and efficient way to stratify Landsat data than the use of individual black and white images and overlays. It would seem reasonable that the increased efficiency of the analyst would more than offset the increased cost of obtaining the color infrared composite images. Therefore, we highly recommend the use of color infrared composite images for stratifying the Landsat data into major cover type groupings as a first step in preparation for computer analysis of the data.

2.3 DEFINE A REPRESENTATIVE SET OF TRAINING STATISTICS FOR EACH OF THE STRATA TO BE CLASSIFIED.

The concept behind computer-aided analysis of multispectral scanner data is that the computer can be "trained" to recognize a particular combination of reflectance values which represent the spectral characteristics of the various cover types of interest. Once the computer has been trained to recognize these different cover types it can then be programmed to classify the entire area of interest. This concept assumes that different earth surface features do in fact reflect differently as a function of wavelength. One finds, however, that the spectral reflectance of a particular material does not always characterize that one cover type and only that cover type. In many cases different species of green vegetation have very similar reflectance characteristics. In addition, one also finds various degrees of spectral variability within a particular species of cover type of interest. It is not a straight forward procedure to define a particular spectral response pattern that can be used to train the computer. Thus, one of the basic questions involved in the use of computer-aided analysis techniques focuses upon the problem of defining those cover types or classes of interest that can be spectrally separated from all other classes.

There are three general approaches to developing training statistics. These three generalized approaches include the so-called supervised approach, the unsupervised clustering approach, and various hybrid techniques which incorporate aspects of both supervised and unsupervised approaches. These have been well described and documented previously in the literature (Swain and Davis, 1979). In the supervised approach, the analyst designates training fields or areas of known cover type to the computer. Several different training fields must be designated for each of the cover types of interest in order to completely characterize all of the variations in spectral response that may be present for that particular cover type. In the unsupervised or clustering approach, one simply designates the area of interest to the computer and then defines a number of parameters which (depending on the particular clustering algorithm used) will indicate to the computer the number of spectral classes into which the data is to be divided or will define the spectral separability that must be present in order to define a particular spectral class. The data is then classified into the various spectral classes and the analyst must use aerial photos or some other type of reference data to relate the spectral classes to the actual cover types or land use classes that are actually present on the ground. One of the advantages of the clustering technique is that it gets around the problem of requiring that the analyst be familiar with all of the potential causes of spectral variability that may be present in the scene for each of the cover types of interest. However, if the area to be classified represents a fairly large geographic region, the number of pixels involved may be too large for many computer systems to handle if all of the data is clustered. In addition, the clustering algorithm is often used in an iterative mode, and if the number of pixels involved in the clustering process is relatively large, a very large amount of computer time may be involved in clustering the data, thereby making this technique prohibitively expensive.

At LARS we have found that one of two different hybrid techniques seem to be the most effective for developing training statistics. One technique, called the Multicluster Blocks Approach, involves a procedure whereby the analyst designates small blocks of data to the computer--each of which is spectrally heterogenous and represents several different cover types of interest. These blocks are clustered individually and then the spectral classes present in the various cluster blocks are combined into a single set of training statistics. This combined set of training statistics is then used to classify the entire area of interest. A modification of the Multicluster Blocks technique is called the "Mono-Cluster Blocks" approach. Mono-Cluster Blocks starts off with the same type of spectrally heterogenous blocks, each of which involves several different cover types. However, instead of clustering each block individually, the blocks are grouped into a single composite block within the computer system and then clustered together in a single step. Although more computer time is involved in using Mono-Cluster Blocks, there is much less work and time involved for the analyst.

Previous work at LARS has indicated that the supervised approach may be fairly effective for agricultural situations but that it has very distinct limitations when working in areas of wild-land cover types. Because of the computer time involved in clustering the entire data set and the lack of aerial photos over the entire area to use in relating the spectral classes to the cover types on the ground, either the Multi-Cluster Blocks or the Mono-Cluster Blocks techniques have been found to be the most effective approaches for developing training statistics. In one study, it was found that the Multi-Cluster Blocks technique provided classification performances that were 14% higher than when a supervised approach was used in classifying an area of wild-land cover types (mostly forest and rangeland) (Fleming and Hoffer, 1977). Several analysts working in a large variety of geographic areas and various complexities of cover types have found that the Multi-Cluster Blocks or the Mono-Cluster Blocks approach consistently provide the most effective methods for developing training statistics.

Based upon our experience at LARS, when we started the analysis of the data from the various Lating American countries, both the Mono-Cluster Blocks and the Multi-Cluster Blocks approaches were used. The former approach was used to analyze spectrally simple areas, such as the extensive non-vegetated regions of the Bolivian Altiplano, and the latter approach was used to analyze the more spectrally complex areas in the tropical zones of Eastern Bolivia and Central America.

In addition to determining the most effective method for developing training statistics, consideration must also be given to the hardware and software that is available to the analyst. In many of the Latin American countries, sophisticated interactive color display systems are not available. Although the software is fairly straight forward for using a supervised approach for developing training statistics, many small training areas must be carefully defined in the data. If the primary computer system available is a standard general-purpose digital computer with line printer output, experience has shown that it is very difficult to accurately locate many small training areas on standard line printer printouts. Therefore, the potential for using these kinds of systems is greatly enhanced if one can designate relatively large training blocks in the Landsat data rather than many small training fields. By grouping the blocks and using the Mono-Cluster Blocks technique, some of the software that is required for effective use of some of the other techniques, such as Multi-Cluster Blocks, is not required. Therefore, from the standpoint of many of the Latin American countries, the Mono-Cluster Blocks technique is again the most effective technique for developing training statistics, this time because of both the hardware and the software necessary to develop an adequate set of training statistics.

2.4 SELECTION OF THE CLASSIFICATION ALGORITHM TO BE USED

Once the training statistics are developed, the next step in the analysis sequence is to actually classify the data. Many different classification algorithms are available and have been described at length in the literature. The question is: Which algorithm should be used? A number of things should be considered in deciding which algorithm would be best. First, one should consider the objectives of the analysis, particularly in relation to the characteristics of the output products that are desired. Second are considerations of cost and accuracy. Some algorithms are considerably more complex than others and therefore more computer time is used and a larger cost is involved in carrying out the classification. Other algorithms are much simpler computationally, and therefore less computer time is required and the cost is significantly lower. However, some studies have indicated that the simpler algorithms may also result in a decreased accuracy of the classification. That seems to be particularly true if the cover types being classified are spectrally very similar and if there are many different spectral classes involved in the analysis. However, if only a few cover type classes are involved and they are spectrally very distinct, experience has shown that even the simple classification algorithms seem to produce approximately the same classification accuracy as the more complex algorithms. A critical part of achieving an accurate classification is related to the quality of the training statistics. If the training statistics do not truly represent spectral characteristics of the different ground cover types present, then one cannot hope to achieve a highly accurate classification. Thus, the more complex the area, the more important it is to develop an effective and representative set of training statistics.

In considering which algorithm to use for the classification, a third consideration involves the type of data that will be used. Most algorithms such as the Maximum Likelihood Per Point, Minimum Distance to the Means, Parallelpiped, Nearest Neighbor, and others have been developed for use with spectral data alone. However, if other types of data such as soil type or topographic position are also used in the classification process, a different algorithm is required. In the 1960's and 1970's nearly all of the analysis was directed at the use of spectral data alone, and the algorithms that were developed were for use with spectral data only. We believe that as remote sensing technology develops in the 1980's, however, we will see an increased use of ancillary data in a classification process. This will require algorithms such as the Layered Classifier, in which one can use spectral data in one or more phases of the classification sequence, and ancillary data in other steps. The layered classifier has also been used very effectively to simplify the classification process.

In working with the Latin American scientists on the analysis of data from their countries, only Landsat spectral data was involved. We found that there were many situations in which the spectral cover types of interest were spectrally very similar and a large number of spectral classes were involved in the analysis. For these reasons, and because the Maximum Likelihood Per Point Classifier is well documented and is theoretically sound, this algorithm was used for all the classifications being discussed in this paper.

2.5 EVALUATION OF THE CLASSIFICATION RESULTS

A careful evaluation of the results of the classification should be considered as an integral part of the entire analysis sequence. Such evaluations can be fairly qualitative in nature or can be rather quantitative. A qualitative evaluation is basically a simple comparison between the classification output map and aerial photos or type maps of the same area. Quantitative evaluations usually involve a set of test areas or test fields of known cover types which are designated by the analyst. The computer classification for these areas is then tabulated to obtain a comparison between the classification and ground truth or reference data. Another method of quantitative evaluation is to compare acreages of the computer classification in relation to acreage estimates obtained from other sources of information. In the classifications of the Latin American countries, the evaluations were primarily qualitative in nature because of the lack of existing information of the area. The availability of aerial photos can plan a key role in this evaluation phase of the analysis sequence. Existence of good quality aerial photos is critical for evaluating classification results as well as for developing an adequate set of training statistics. Therefore, the availability of such photos must be given careful consideration. In the initial planning phase of the project, it must be recognized that if such photographic coverage does not exist for at least a portion of the area or cannot be made available from existing sources of photography, both the training and evaluation phases of the analysis sequence are severely hampered. In the evaluation phase, it is also important to recognize that the reference data that is available must be closely related to the objectives of the classification in terms of the cover types being considered. In other words, one cannot use an existing potential land use map, for example, to evaluate the computer classification of actual land cover.

3. RESULTS OF COMPUTER-AIDED CLASSIFICATIONS OF LANDSAT DATA IN SIX LATIN AMERICAN COUNTRIES

As indicated in the introduction, scientists from six different Latin American countries worked closely with LARS scientists in using Landsat data to classify areas of particular interest in these various countries. Many excellent classification maps were obtained for each of the countries involved. However, a number of problems were also encountered. We believe that it is worth discussing these problem situations, so that future efforts can be approached knowledgably and with a good understanding of the importance of the season of the year in which the Landsat data is obtained, the importance of effective reference data, and difficulties of spectral inseparability which may be encountered. A considerable amount of effort has been devoted to classifications for different areas within Bolivia. One of the major problems encountered was that the data were not always available for the time of the year which would have been the most desirable from the standpoint of crop development and therefore the spectral characteristics of the various cover types of interest. Generally, during the growing season very little Landsat data were available. Therefore, most of the analysis work had to be conducted using data obtained in the winter. This made it particularly difficult to distinguish agricultural areas which were largely in a fallow condition during the winter season from rangeland areas which were mostly bare soil with a sparse dry grass cover. Two other interesting problems were found in analysis of the data in Bolivia. The first of these involved an attempt to classify sugar cane using summer-time Landsat data. We found that the spectral characteristics of full grown sugar cane were essentially identical to the spectral characteristics of tall native grassland areas. Careful comparison of the spectral response patterns from both sugar cane and tall grass verified that indeed they were spectrally so similar that an effective classification could not be obtained using that particular set of Landsat data. Data obtained from a different time of year should help to alleviate this problem. Another interesting result involved an area of rangeland in the northern central portion of Bolivia. In the Landsat data, one could quickly see very large areas with very low spectral response, particularly in the reflective infrared wavelength bands. This response was very similar to that of water and it thus appeared that there were large low lying areas of standing water throughout this region. However, the existing maps of the area and other reference sources, including statements of people familiar with the area, indicated that the region was covered with tall grass. An aircraft flight over the area proved that both statements concerning this area were correct! This area was indeed covered with tall native grasses but it also was covered with water in the spring time. During this portion of the year, tremendous quantities of water flow through this entire area, completely covering the ground and resulting in a low spectral response on the Landsat data. The grass was still present but was not in a lush green condition nor was it tall enough to completely cover the surface of the water at the time the Landsat data had been obtained. Thus, depending on the time of the year, these very large areas could be characterized by very different cover types and very different spectral response patterns.

Another area of interest involved classification of the Landsat data over regions of tropical forest land. In this case, the Bolivian Forest Service was interested in delineating areas of "tall forest," as compared to areas of "medium" or "low" forest land. The tall forest areas contain an overstory of very large and commercially valuable trees. We were able to successfully delineate many different spectral patterns within the tropical forest land area, some of which seemed to be related to the different categories of forest cover of interest to the Bolivian foresters. However, an inadequate amount of ground truth and aerial photography over the area did not allow an effective evaluation of the classification obtained. Thus, we were uncertain as to the significance of the spectral patterns produced. This example reiterates the importance of having adequate reference data available.

In El Salvador, we found that the spectral response of recent lava flows was very low and very similar to that of clear water areas! Again a careful comparison of the spectral response patterns for well defined areas of lava and clear water indicated that they were spectrally so similar that a reliable separation could not be achieved using only the reflective portion of the spectrum. However, it would seem reasonable that in this case, thermal infrared scanner data would allow the lava flows to be separated from the water area, since the rock would heat up and produce a much higher spectral response in the thermal band than would be obtained from the water bodies.

Another problem of spectral similarity was found in the analysis of the data from Costa Rica. In this case, we found that mangrove swamps have a very distinct high infrared reflectance characteristic and appear a very bright red on the color infrared photography and on color infrared composites of Landsat data. Since both mangrove swamps and coconut plantations were of interest to the users, we were attempting to map these two cover types separately. However, we found that both the mangrove and the coconut plantations had very similar spectral response patterns and could not be separated based upon spectral characteristics alone. The delineation and mapping of swamp areas is particularly important because of the relationship between mangrove and the shellfish industry in the area.

4. SUMMARY AND CONCLUSIONS

A number of observations and conclusions could be drawn from the work with these Latin American scientists. First, we feel that it is very important that scientists from countries throughout the world be trained thoroughly in the proper techniques for interpretation and analysis of Landsat data, so that the country involved can rely on <u>their own</u> personnel to interpret the data from <u>their own</u> country, and thus develop the information that is so often urgently needed concerning the resources of the country. This is an area where we feel that the countries that have had more experience in the interpretation and analysis of Landsat data should work very hard to train both scientists and decision makers in the countries that are not as far along in the process of developing their interpretation and analysis capabilities. We feel that it is important for each country to have the capability to be self sufficient and to have scientists qualified in interpreting and analyzing the data, rather than depending on other countries to do the analysis for them. Furthermore, it is important for a person who is familiar with the area and the characteristics of the cover types in the area to be directly involved in the analysis process in order for the results to be reasonably satisfactory. It is often rather difficult for someone from another country who is not as familiar with the cover types of the area to do as effective a job.

The transfer of existing remote sensing technology is thus a key and very important priority. In the work we have just described, we felt that the combination of scientists from the Latin American countries who are familiar with the characteristics of the cover types in that area, working with scientists who are familiar with computer-processing techniques and who also had at least some degree of familiarity with the characteristics of the cover types in the test site areas resulted in an effective method of training for the Latin American scientists. The next step in the process is helping the Latin American countries implement appropriate software on computer systems within their own countries and to conduct short courses for a larger group of scientists from their countries.

Another important point is that we must be careful not to oversell or undersell the capabilities and limitations of the Landsat system and computer-aided analysis techniques. For many of the countries, there is relatively little information available over vast regions; the information content that can be obtained using the synoptic view from Landsat is tremendously valuable. However, there are also some limitations in this data source. If cover types that are of great interest to the country involved cannot be spectrally separated on a particular data set, it is important that we recognize this fact, and study the problem to determine if there are other seasons of the year that would allow separation to be achieved, or to determine if there are other systems that could be utilized, such as radar or perhaps the thermal infrared portion of the optical region. Thus, part of an effective training program is not only to develop an awareness of the characteristics of Landsat data and computer processing techniques, but also to develop an appreciation of the need to study the spectral reflectance characteristics of the various cover types of interest. A thorough understanding of spectral reflectance characteristics is needed to define optimal seasons for achieving spectral differentiation among various cover types and the particular wavelength bands which will be most useful for such spectral separation. In addition to understanding the spectral reflectance characteristics involved, we believe that it is extremely important for the analyst to have a sound knowledge of the principles involved in computer-aided analysis techniques.

Thus, in conclusion, we feel that this project involving the mapping of land cover in several Latin American countries by computer-aided analysis of satellite scanner data resulted not only in useful maps for certain areas of interest, but even more importantly, resulted in the development of an appreciation for the capabilities and limitations of such computer analysis techniques and the scanner data used for the classifications. We believe that the key to successful training programs in remote sensing technology involves the development of the knowledge and understanding of remote sensing technology, not just the transfer of the equipment and software programs. Meetings such as this International Remote Sensing Symposium, held in locations such as Costa Rica, are an extremely important part of such technology transfer and development of the understanding of the capabilities and limitations in the use of remote sensor systems.

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