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AN OPERATIONAL APPLICATION OF ERTS-1 IMAGERY TO THE ENVIRONMENTAL INVENTORY PROCESS

James D. O'Neal and James R. Bwins

The organization which I represent, The Engineer Agency for Resources Inventories, is an element of the U. S. Army Engineer Topographic Laboratories. My agency is concerned primarily with the application of new technologies to current problems relating to environmental analyses in both civil and military functions of the army. We do this in the course of conducting studies aimed at specific user requirements. We have performed these kinds of services for numerous organizations within the Department of Defense, Department of State (Aid) and others, since our establishment in 1963, originally as an element of the office, Chief of Engineers. Experience gained during the past 10 years in supporting the USAID Foreign Assistance Program, in various developing nations overseas, with environmental resources assessments, has more recently been applied to domestic requirements of the Corps of Engineers. Over the past two years we have been conducting an environmental inventory program in support of civil works elements of the Corps. The earliest results of these efforts were reconnaissance inventories of Vermont, Washington, North Carolina, and the Charleston Engineer District. These were pilot studies to investigate the feasibility and desirability of a nationwide program. Their objectives were extremely narrow, involving primarily the earliest stages of project planning, and they dealt with only the most significant resources and amenities of the environment that should be approached with careful deliberation.

A more recent effort, which I plan to discuss today, is an in-depth inventory of substantially broader scope, aimed at providing basic input data for the preparation of environmental impact statements. This is a study of south Louisiana, with emphasis on the Atchafalaya basin, prepared on behalf of the New Orleans engineer district. The first Figure is a photograph of the cover of the study. The South Louisiana area includes a number of projects for which EIS's must be prepared. A single, overall inventory permitted a systematic approach and, we believe, substantial economy as compared with what the cost would be for separate inventory efforts for each project. The study area covered approximately 25,000 square miles and included all or part of 36 parishes in Louisiana and 8 counties in Mississippi.

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The chief application of remote sensing in this study was in the mapping of land use and vegetative cover for publication at a scale of 1:250,000. This involved parts of 8 quarter-million-scale quadrangles of the national map series. The categorization used was based on the classification, to second level, developed by the inter-agency steering committee on land use information and classification, published in USGS circular 671. This classification scheme is shown in Figure 2.

Our application of remote sensing technology in this effort was necessarily very conservative. Quite literally, our results would have to be able to "stand up in court", and only techniques of proven reliability could be used. This argued strongly for conventional exploitation of aerial photography and full use of ground truth and other available collateral data. The aerial photography available for most of the study area was 1:62,500-scale and 1:120,000-scale color and color-infrared imagery provided by NASA. Figure 3 is an example of this coverage. Our experience, and that of other agencies, indicated that the compilation effort by conventional means would require about 36 man-weeks. This created a definite problem because the allocation of effort available for this phase of the study was only 20 man-weeks, in a total elapsed time of 2-1/2 months. It was therefore decided to search for means of employing ERTS-1 imagery, illustrated by this next figure, showing coverage of most of the study area, to achieve substantial savings of time in a hasty operational mode. Experiments were conducted subject to two ground rules: first, while degradation in locational precision was permissible, the amount had to be known and controllable; and second, category identifications had to be accurate and directly verifiable without lengthy testing and evaluation. These ground rules dictated that ERTS imagery be used as a supplement to airphotos and collateral data, rather than as a source.

The experimentation was in two phases: single-band operations using Band 5 imagery, and multiband operations using false-color composites of Bands 4, 5, 6 and 7. Both operations were limited to the use of film-chip imagery. Under limitations of time and resources we did not undertake any processing of computer-compatible tapes. However, during our next study we plan to extend our experiments into this area.

The single-band operations addressed the problem created by intricate "salt and pepper" patterns of woodlots and clearings, as shown by Figure 5, which were particularly common in the terrace uplands of the study area. In our judgement, the degree of detail observable on the airphotos was excessive, both from the viewpoint of information requirements, and from the standpoint of publication scale. We recognized that the analyst could readily become bogged down in this intricate detail. To keep compilation time and effort manageable, it was essential to find some objective means of controlling the level of detail. ERTS

Band 5 imagery such as that shown in Figure 6, was found to exhibit very nearly the exact level of detail desired. It further appeared that, in the "salt and pepper" areas, delineation from ERTS of the single boundary between forest and open areas would result in completion of the major part of the total line work required for a complete land use map.

We devised two separate experimental approaches for exploiting the ERTS imagery. Both approaches provided for the use of aerial photography to correct gross errors and to make final identifications of categories.

The first approach was a sequential process. One analyst drew all boundaries between forest and open areas on a 1:250,000 scale black and white print of the Band 5 image. His sole source of information was the print itself. The print was developed in high contrast to minimize decision time. The Figure you are looking at was made from such a print. The completed boundaries were enlarged to 1:120,000 scale for use as overlays to the airphotos by two separate teams in succession. The first team worked entirely within the forest areas, classifying to the second level (evergreen, deciduous, and mixed) by adding appropriate symbols and, in relatively few areas, internal boundaries. The second team worked entirely in the non-forest areas, classifying urban, agricultural, and nonforested wetland categories to second level. Both teams were charged with correcting registry errors in the original forest boundary that were beyond acceptable limits - approximately 1/4 mile ground distance. Both teams were also charged with correcting gross errors resulting from misidentification of forest on the ERTS print. This occurred chiefly in residential areas having numerous trees: areas which appeared as forest on the high-contrast ERTS print. This assembly-line process allowed a maximum application of specialized skills to the land-use mapping process. Interpreters trained in forestry, and equipped with the best collateral data on forest types, made the final forest classifications. Interpreters trained in cultural geography and equipped with the best collateral data on urban and farm land use, made the final urban and agricultural classifications. The greatest difficulty of this approach was in coordinating the correction of gross errors.

In our second experimental approach during the single-band phase of operations, one analyst was assigned responsibility for all aspects of land-use mapping within a defined portion of the study area. He used airphotos and collateral data as sources, and a print of ERTS Band 5 enlarged to 1:250,000-scale as his plotting base. The ERTS print was in normal gray tones, rather than high contrast, to permit maximum recognition of detail. Again, most of the land-use delineations were related to features visible on the ERTS print. As a result, most of the delineation could be done effectively by "eyeballing". A relatively few cases involved boundaries unrelated to features visible on the ERTS. In these cases, boundaries were first drawn to an overlay to the photograph and then projected onto the ERTS base. After land-use mapping was completed to the second level of classification, the annotated ERTS print was turned over to the drafting staff for transfer to the 1;250,000-scale topographic map base. The fit was good. Horizontal control, and frequent checks on locational accuracy, were possible because of the many features, including roads, streams, shorelines, and small urban centers, that were visible on the ERTS image.

While this second approach avoided coordination problems and bottlenecks, because the work of multiple analysts was in parallel rather than in series, it lacked the capability of the first approach for a continuing quantitative check on locational accuracy. And it required broader expertise on the part of the interpreter. For these reasons, we consider it inferior to the first approach. It was in fact employed only in those parts of the study area where external considerations related to security classification of collateral source data warranted its use.

The second phase of experimentation involved multiband operations with ERTS imagery. Our initial investigations were broadly based, concerned with the potential not only for land-use mapping but also for identifying vegetation stands significant as wildlife habitats, water turbidity and shoreline configuration in areas of rapid sedimentation, and significant soil and soil-moisture variations. Using the I^2s additive color viewer, illustrated in Figure 7, composite images were put through various configurations of filter and illumination. Each configuration was selected to enhance one or more particular elements, and was recorded photographically to give the analyst a hard copy for annotation and transfer to the base map. As an example, the Figure 8, covering parts of the Mississippi River Delta, shows a configuration used to enhance water turbidity patterns in an area of rapid sedimentation. It also provides good discrimination between cropland and forests. Next, Figure 9, located immediately north of the preceding one, is configured to enhance forest distributions and it permits good differentiation between bottomland hardwoods and upland hardwood-softwood associations. Agricultural land use is also readily visible, and distinction within these is made between terrace soils (in the north central area) and recent alluvial bottomland soils. The results of some 20 or 30 configurations were tabulated in this manner for future reference as shown in Figure 10. Prior to these experiments we had reviewed similar work and recommendations by other investigators. For the south Louisiana area with which we were concerned, we arrived at configurations which we preferred for our specific elements of interest.

As we focused more sharply on the specific data gaps and operational problems of the study, it was decided to emphasize one particular application of the multiband operations — that of distinguishing evergreen and deciduous forest in areas where color and color infrared aerial photography were lacking. This composite, shown in Figure 11 using October 1972 ERTS imagery, renders a sharp color contrast between the two forest types, which was verified by detailed national forest maps covering part of the imaged area. The print was made at approximately 1:1,000,000-scale with the use of a film pack inserted in the holder of the I^2s viewer.

Various means are readily available for transfer of this information to a base map. Our own preference for this operation is the B&L (Bausch & Lomb) zoom transfer scope, shown in Figure 12, an instrument based on concepts originally developed by the engineer topographic laboratories.

In our atchafalaya study, the overall land-use compilation was completed during a 10-week period with a total interpreter effort of slightly more than 19 man-weeks. Considering the area covered and its complexity in the light of previous experience by our agency and others, it appears that there may be as much as a 45 percent savings in effort as compared with conventional utilization of high-altitude aerial photography. With respect to identification of categories, no compromise has been made with the best available results of airphoto interpretation, supported by collateral sources. With respect to detail and locational accuracy, the product is undeniably an expedient effort. It can be considered only for applications tolerating accuracies of, say 80 to 90 percent of all lines within plus or minus 1/4 mile. But for such applications, the method deserves consideration because of the real economies achievable.

I will spend the last few minutes in putting this effort into perspective with the overall product to which it contributed. This is an environmental inventory document designed primarily to provide basic input data for the preparation of environmental impact statements of a sizable number of Corps projects in the south Louisiana area. We believe that a broad integrated study such as this permits a systematic approach and an economy of scale not possible with separate, project-by-project inventories. The first and most direct contribution of this effort to the inventory is a series of eight 1:250,000-scale quadrangles treating land use, one of which is shown on Figure 13. The following Figure 13a is an enlargement of the NE corner of the graphic for greater detail. These maps permit the identification of land use types within a specific project area, and the determination of approximate acreages of each. The next Figure, 14, a shot of the 1:500,000-scale vegetation map from the study, permits further analysis of the forest, marshland, and cropland areas.

With the aid of collateral data supplied in the supporting text of the map, it is possible to make some estimate of the associated rare species, the sensitivities and vulnerabilities of the plant communities, and their value in both economic and ecological terms. This is illustrated by the next 4 figures. The type size of this Figure of a complete page of text on Flora is too small for you to read, but it shows the format: the following 3 Figures are enlargements on which we may be able to read the headings. The next Figure shows type, predominant species, and associated rare species; the next Figure, significance of the principal vegetation types including value to wildlife; and, the next Figure, sensitivity.

Further analysis and interpretation in the light of ecological data allows the recognition of major ecosystems and some quantitative estimates of their wildlife carrying capacities as illustrated in Figure 16. For example, the coastal marsh system of Louisiana (one of the ecosystems portrayed on the map) is known to support approximately 13 to 18 muskrat nests per 100 acres early in the year, and 6 to 14 late in the year. It also supports a significant alligator population, and is a breeding ground for numerous bird species, some of which are rare or very rare. Bottomland hardwood forests (another ecosystem treated) can be described in terms of numbers of deer, squirrel, swamp rabbit, turkey, wood duck, and migrant waterfowl that can be supported per unit area.

In summary, ERTS has taken a useful place as one of many tools we require to produce a comprehensive environmental inventory. In the overall study contents shown here on my last figure, we have so far made application of ERTS to those items which are outlined. In subsequent studies we plan to explore further applications in the areas of geomorphology and surface drainage. Because our applications are operational, and high-volume, we must continue to be conservative and to use readily verifiable procedures.

To conclude — as a supplementary source, used in conjunction with airphotos, ERTS has proven itself to us as a significant means of economy. As a primary source, we are not yet ready to accept ERTS for our own particular applications; but we believe that through digital tape processing experiments, some objective evaluations can be made, and this is the way we hope to move in the near future.