E7.4-10346
CR-136858

(E74-10346) THE USES OF ERTS-1 IMAGERY IN THE ANALYSIS OF LANDSCAPE CHANGE (Tennessee Univ.) 14 p HC $4.00 CSCL 08B
N74-18021
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THE USES OF ERTS-I IMAGERY IN THE ANALYSIS OF LANDSCAPE CHANGE

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Abstract

The NASA-ERTS Geography Remote Sensing Project has been delimiting, monitoring, and mapping photomorphic regions of landscape dynamics in Tennessee through the analysis of ERTS-I imagery. The analysis of strip mining from ERTS data has resulted in the mapping of landscape changes for the Cumberland Plateau Test Site between the dates of April 1972 and October 1972. Several mapping experiments utilizing ERTS data have been established for the mapping of state-wide landuse regions. The first incorporates 12 frames of ERTS-I imagery for the generalized thematic mapping of forest cover for the state of Tennessee. In another mapping effort, 14 ERTS images have been analyzed for plowed ground signatures to produce a map of agricultural regions for Tennessee, Kentucky, and the northern portions of Mississippi and Alabama. Generalized urban landuse categories and transportation networks have been determined from ERTS imagery for the Knoxville Test Site. Finally, through the analysis of ERTS imagery, short-lived phenomenae such as the 1973 Spring floods on the Mississippi River in western Tennessee, have been detected, monitored, and mapped.

Introduction

Since July 1972, NASA's Earth Resources Technology Satellite (ERTS-I) has been orbiting the earth at an altitude

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Performed under contract NAS5-21726 issued by the National Aeronautics and Space Administration.

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of 560 miles and providing two essential capabilities for the analysis of landscape change from a regional perspective: (1) a timely, sequential, and cyclic, coverage on an 18 day basis; and (2) a region-wide view encompassing 13,225 square miles in each image frame.

The purpose of this paper is to illustrate the applications of ERTS-I imagery to the analysis of landscape change within five selected areas of landscape dynamics. These include: (1) strip mining areas on the Cumberland Plateau of Tennessee; (2) agricultural regions in Tennessee, Kentucky, and portions of northern Alabama and Mississippi; (3) forest regions of Tennessee; (4) urban-suburban growth areas in Knoxville, and (5) flooded areas within the Mississippi River floodplain (Fig. 1).

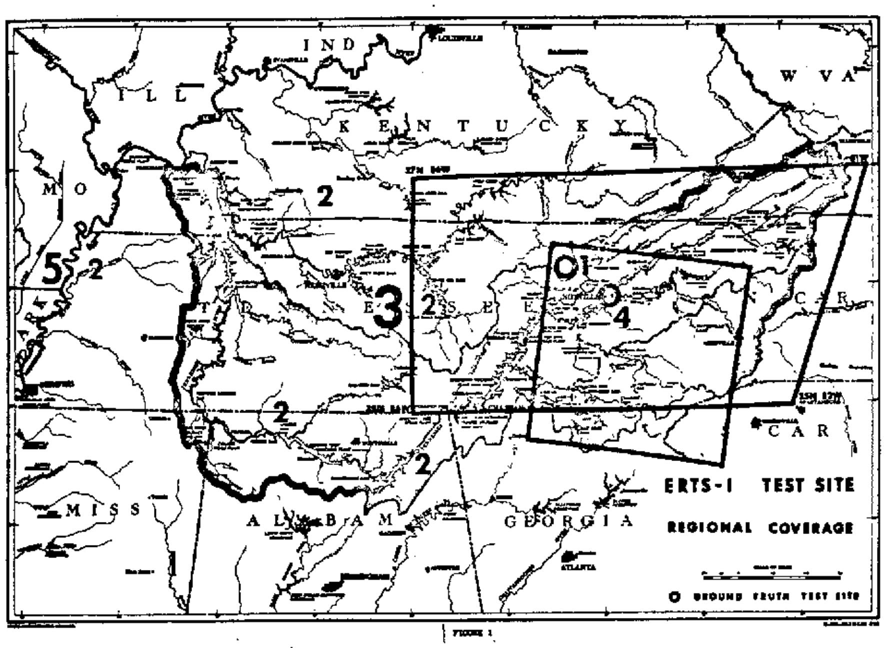

Fig. 1. Test Site Map. Regions under specific investigation are indicated by numbers.

Strip Mining Landscape Change

The applications of ERTS-I imagery to the detection and monitoring of strip mining landscape change are positive and capable of becoming operational. The strip mining landscapes on the Cumberland Plateau of Tennessee are excellent examples of dynamic landscape modification representing several states of change: (1) recently cleared/deforested; (2) actually stripped or mined for coal; (3) current reclamation; and (4) reclaimed.

From ERTS imagery and RB-57 high altitude aircraft imagery, a map of strip mining changes between April 1972 and October 1972 has been produced (Fig. 2). To facilitate the legibility of the mining changes, the map was prepared at a scale of 1:120,000 which is the scale of the high flight imagery. The darkest tones on the map represent the strip mines as of April 18, 1972 and mapped from the high flight imagery. The light gray tones represent additional strip mines and mining expansion as mapped from the ERTS imagery dated October 15, 1972.[1]

The analysis of ERTS imagery for strip mine detection and monitoring depends on the ability of the interpreter to identify strip mining signatures on the imagery. Strip mines on an original band 5 black and white transparency from ERTS register as light toned, jagged lines on a dark forested background. By negative print enhancement the same image can be printed so that mining signatures appear as dark, solid, jagged lines on a light toned background as illustrated in figure 3.

No single remote sensing platform (stage), scale, or sensor can be expected to provide all the information necessary for the analysis of strip mining from a remote perspective, thus it is imperative that a multi-stage, multi-scale procedure be utilized. Using the RB-57 high flight imagery as a data base and identification medium, strip mines are identified as irregular, jagged lines which follow the contours of the mountains (Fig. 4). Unlike local dirt roads, strip mines do not form linkages between each other and other geographical points. In the negative print of figure 4, the mines are enhanced in dark tones on a white forested background. Note the extent of cleared, stripped land in April 1972 indicated at the mine north of the arrow. By comparison in figure 3, one can see not only the configuration of the same strip mine, but can also detect from the July 1973 image additional dark tones immediately north of the arrow. Of considerable importance is the capability of the negative print to enhance and display strip mines in dark tones. Such enhancements aid in the detection and identification of newly cleared lands and favor the mapping of cleared, stripped, or otherwise deforested landscapes.

Fig. 2. Map of strip mining changes on the Cumberland Plateau Test Site. April–October 1972. ERTS I.D. No. 1084-15431.

Agricultural Landscape Change

The agricultural landscapes of East and Middle Tennessee are dominated by a chaotic pattern of tiny fields measuring from one-third acre to usually not more than 50 acres in size. With landscape cells as small as these, one might doubt the feasibility of detecting agricultural changes from the ERTS perspective at an altitude of 560 miles. ERTS imagery has

Fig. 3. ERTS band 5 negative print. Note extent of strip mining indicated by the arrow. I.D. No. 1354-15431. July 12, 1973.

Fig. 4. RB-57 high flight negative print. Note extent of strip mining indicated by the arrow. Apr. 18,1972.

been analyzed at our lab since October 1972, but it was not until the analysis of ERTS imagery taken during the Spring months of April and May that the agricultural scene began to emerge. The agricultural landscape of Tennessee then emerged as a significant dynamic surface exhibiting plowing signatures and cleared fields.

The detection and mapping of plowed fields from ERTS forms the basis of agricultural landscape change. From the April 14, 1973 ERTS band 5 imagery of Sand Mountain, Alabama, the initial detection and identification of plowed ground signatures began (Fig. 5). This negative print of band 5 enhances normally light toned, cleared earth signatures into black dots and blocks and thus provides a high contrast mapping medium from which to detect and map bare earth surfaces in agricultural areas. The image in figure 5 represents an almost ideal condition for detecting plowed earth signatures. The dark elongated feature in the southwest portion of the image is Sand Mountain, Alabama, an agricultural region based upon truck garden vegetables and fruit grown on sandstone based soils.

Perceived as aggregates, the dark tones form a photomorphic region of similar tones. The interpretive value of the photomorphic region is that like-tones can be assumed to reflect similar landscape characteristics.[2] In this case, the Sand Mountain area forms a most dramatic photomorphic region which exhibits plowed earth signatures — surrogates for potential agricultural crop activity. Southeast of Sand Mountain, additional photomorphic regions in the Gadsden, Alabama and Rome, Georgia area can be seen.

Using the plowed ground signature as a surrogate for both potential crop activity detection and photomorphic regionalization, 14 ERTS band 5 negative prints were mosaiced for the states of Tennessee, Kentucky, and the northern portions of Alabama and Mississippi (Fig. 6). The interpretive value of any mosaic is that it presents an even larger perspective and region-wide view than its individual components (i.e. single ERTS frames).

Beginning in the southeastern corner of the mosaic below Chattanooga and east of Huntsville, one can again see the Sand Mountain agricultural region (1). Immediately north and west of Huntsville, a large irregularly shaped plowing region denotes the southern portion of the Highland Rim of Tennessee (2). Northward the Highland Rim continues into the subregion known as the Plateau of the Barrens here at Tullahoma (3).

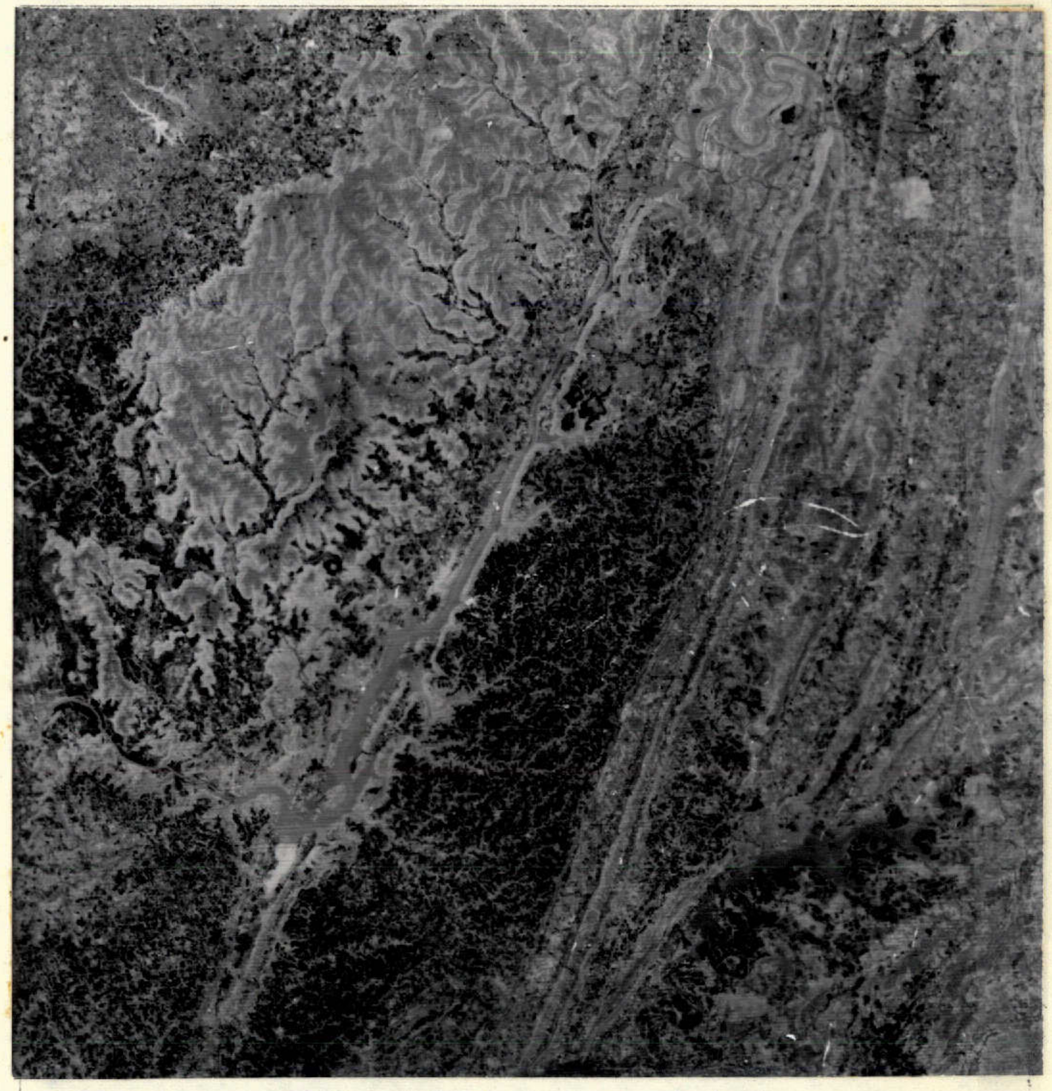

Fig. 5. ERTS-I band 5 negative print of Sand Mountain, Alabama. I.D. No. 1265-15501. April 14, 1973.

Although this area, too, has relatively small farms, fewer areas here appear with the dark plowed signatures. This is an indication of a temporal-spatial difference in the timing of plowing practices between here and farther south. West of region 3 near Nashville, is the Nashville Basin, a physiographic region of limestone soils and a rich agricultural heritage. Note, however, the absence of dark plowing signatures. The Nashville Basin today is characterized by a predominance of pasture lands for the grazing of cattle and horses, hence the lack of plowed earth signatures.

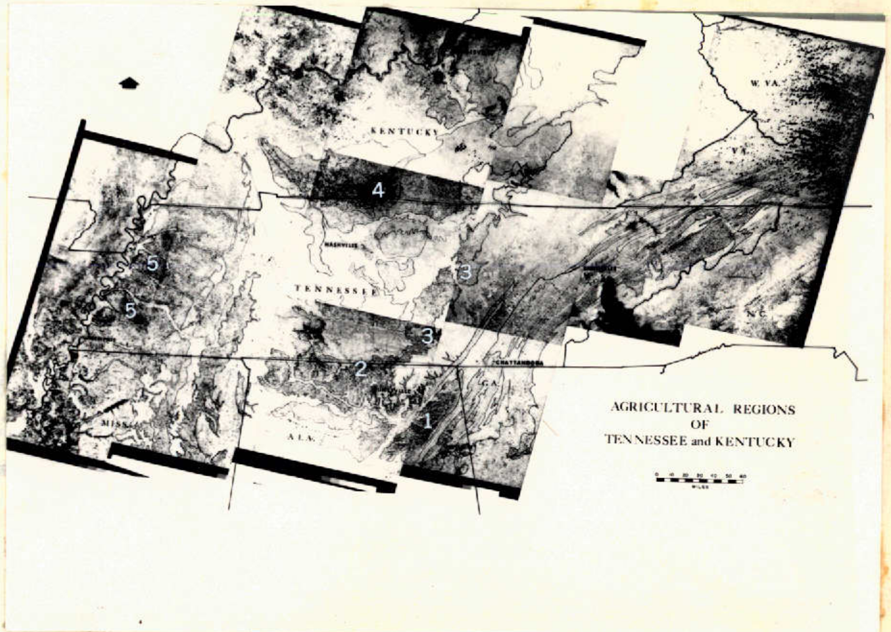

Fig. 6. Agricultural regions of Tennessee and Kentucky derived from ERTS-I imagery, April-May 1973.

Region 4 is marked by the strongest returns of dark tones and represents the Burley Tobacco Region of southern Kentucky. Small farms, intensive tobacco cultivation, and a crop calendar of remarkable continuity mark this area as a significant agriculturally active region. The final region (5), as mapped from the ERTS mosaic, is the soybean region of western Tennessee. Alluvial soils, level topography, and a relatively recent conversion from cotton to soybeans form the basis of this area of plowed fields.

An analysis of ERTS imagery for two successive dates for adjacent areas reveals the capabilities of detecting agricultural landscape change. Figure 7 illustrates two negative band 5 prints for May 4 and May 21, 1973 in south central Tennessee and northern Alabama. The temporal distance is only one ERTS cycle apart (18 days) yet significant changes can be detected. In the Muscle Shoals - Florence, Alabama area (1) for the two dates there is a direct transformation from dark plowed earth signatures for May 4 into lighter tones for May 21. This represents a change from plowed conditions into an initial flourishing or greening of the spring crops. Northward in the Lawrenceburg, Tennessee area (2), the field signatures of light tones for May 4 indicate a dormant state.

Plowing conditions have not yet begun. However, by May 21, the dark tones appear in the same area indicating a freshly plowed condition.

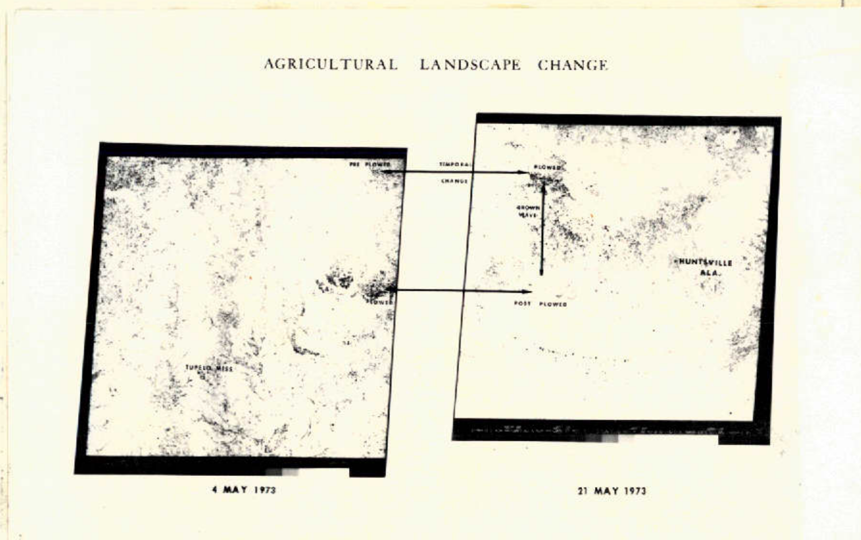

Fig. 7. Agricultural landscape change derived from ERTS-I band 5 negative prints. I.D. Nos.1283-16013 and 1302-15554. May 4 and May 21, 1973.

As indicated by the arrows on the two images, a temporal change can be detected between the two dates of May 4 and May 21 in terms of plowing signature changes. Area 1 changes from plowed to post plowed signatures, whereas area 2 changes from preplowed to plowed signatures. Furthermore, a brown wave effect can be detected spatially in a south-to-north movement. Unlike a phenological brown wave, this wave represents the northward migration of plowing practices as a response to a variable crop and plowing calendar.

Forest Cover Mapping

Unlike the previous sections, the topic of forest cover is treated thematically and cartographically but not temporally in terms of landscape change. As an experiment in thematic land cover mapping, the forest cover of Tennessee was chosen to test the applications of ERTS imagery in rapid reconnaissance and simple mapping. Using 14 ERTS band 5 frames in their original black and white transparency format, we proceeded to map general forest signatures for each image. Then by a mosaic and scale reduction method, the forest signatures were reduced to the map product as shown in figure 8.

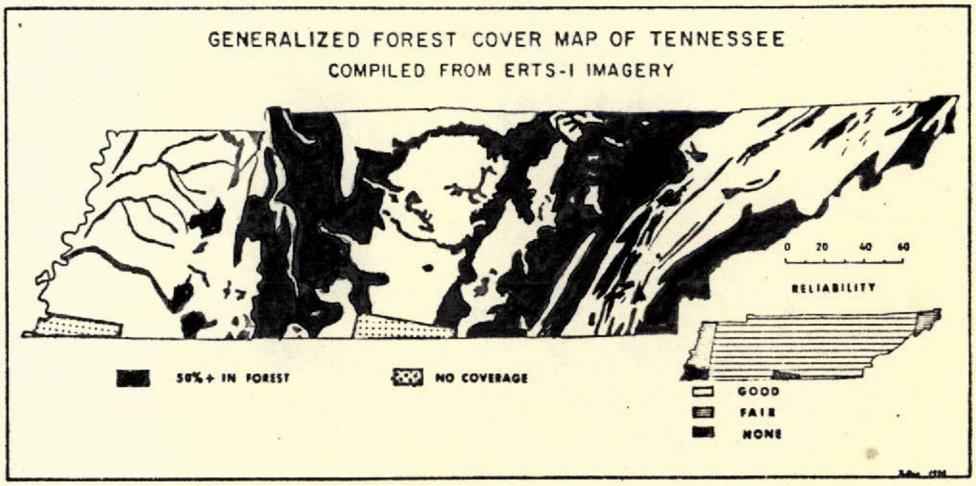

Fig. 8. Map of Forest Cover of Tennessee derived from 12 ERTS-I images. Various dates, 1972-1973.

Forest signatures for full foliage periods appear collectively (deciduous and evergreen) on band 5 imagery in dark relatively uniform tones. Conversely, non-forested areas appear in lighter tones of gray to white. Thus the detection and mapping of forest signatures is facilitated by extreme contrasts in signature reflection.

To complete the map in figure 8 required a total of six man hours. Such time efficiency as this can only lead to a cost benefit ratio of considerable proportions. Compared to the $49 worth of ERTS imagery, an RB-57 high flight data base would have required more than $150,000 worth of imagery and at least 10 man days to complete the mapping of Tennessee's forest cover.

Urban-Suburban Change Analysis

The analysis of landscape change in or near urban areas has been as perplexing as it has been fruitful. From the ERTS perspective, the urban scene is amalgamated into almost continuous tones of gray. The small areal size of urban places and their extreme density of settlement and high reflectance characteristics do not easily allow for the effective discrimination of change detection. Certainly, the spider web of roads and routes leading from the city can be detected and mapped, but the cell for cell land units ranging in size from 2 to 25 acres are often obscured on the original imagery.

The multistage-multiscale approach thus became essential to the analysis of urban-suburban change in Knoxville and west Knox County, Tennessee. Paramount to this effort was the use of RB-57 high flight imagery as a comparative data base to which the ERTS imagery was adjusted and compared. Three high flight images of the Knoxville area were negatively printed and mosaiced. A band 5 negative print from ERTS was enlarged to a scale of 1:140,800 and then projected through a vertical projecting system to fit the 1:120,000 scale of the high flight data base. The landscape units which appeared on the ERTS image as dark tones but which were absent on the high flight imagery were thus outlined and mapped on the mosaic.

The information shown in figure 9 outlines the areas which changed from light tones in April 1972 into dark tones by July 1973. The tonal changes identify landscape changes but offer little or no information about the landuse character of the change. Although tonal change is the signature of significance, the question remains — what are the varieties of landuse and landscape change represented by dark tones on the ERTS negative print? With strip mines, the identification was simple. But for the urban-suburban scene, dark tones of dots, blocks, or any geometric shape except linear can mean anything from a bare earth surface to a full scale and functioning shopping center complete with shoppers!

Despite the identification problems, several areas are experiencing significant changes and thus provide patterns of landscape dynamics. Note in the western and northern portions of the map, the clustering of dynamic areas associated with commercial and residential development along interstate routes I-40 and I-75. The changing areas represent a variety of states of change and development from recently cleared construction sites to current shopping center and apartment construction. In the far western portion of the map, the construction of the Oak Ridge - Knoxville highway connector is visible. In the center of the image, urban renewal work is taking place near the CBD (Central Business District). To the south of Knoxville, subdivision developments continue to emerge but to a lesser degree than the northern and western growth areas. These same patterns can be seen on the ERTS band 5 negative print in figure 10 where landuse areas have been labeled on the image.

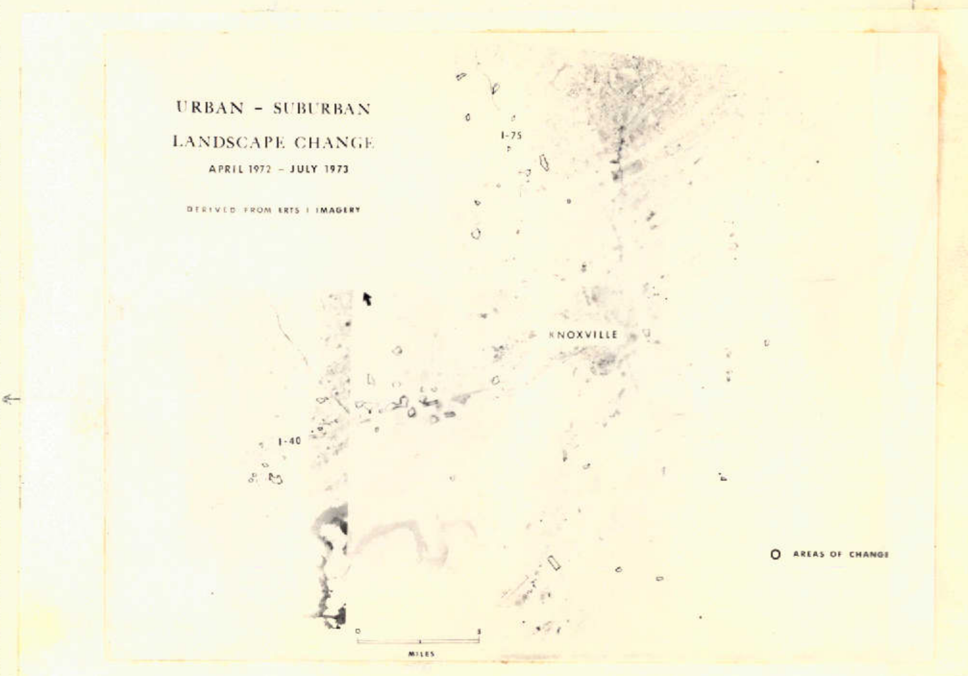

Fig. 9. Urban-suburban landscape changes in the Knoxville-West Knox County area. April 1972-July 1973.

Mississippi River Floods - 1973

During the spring of 1973, torrential winter and spring rains caused the Mississippi River and its tributaries to flood to record proportions. Thousands of acres were covered by flood waters and millions of dollars in property losses were suffered. To record the disaster by low altitude aircraft imagery would have been nearly impossible. Even high flight coverage would have been difficult. However, on three frames from ERTS the Mississippi River floodplain from above Cairo, Illinois to as far south as the Arkansas River was covered. Figure 11 illustrates in a change detection and mapping coverage the areas affected by the spring floods. The darkest tones represent the river system during normal to low water levels as of October 1, 1972. The lighter tones represent the floods on the Mississippi as of May 5, 1973.

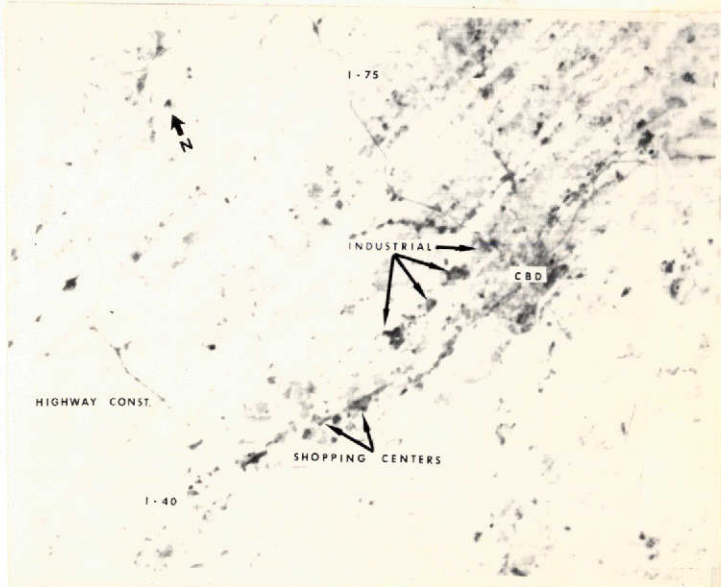

Fig. 10. ERTS-I band 5 negative print of selected landuse areas for the Knoxville, Tennessee area. I.D. No. 1354-15431. July 12, 1973.

From above Cairo to just above the Tennessee/Kentucky border, the floods on the upper Mississippi and Ohio River areas cover less land area than the section immediately south. In the southwest Kentucky area and particularly in northwestern Tennessee the full flood effect can be detected. This represents the crest of flooding for this date of 5 May, 1973. From Memphis southward, the flood areas are again lesser in areal extent but are expected to receive more floodwaters as the crest continues downstream.

One final note, the areal extent of flood of additional water covered area as shown on the map and detected and mapped from ERTS was approximately 1.7 million acres.

Conclusion

The results of this investigation are only a preliminary step in the direction of operational applications of ERTS imagery. ERTS provides region-wide perspectives and significant temporal coverage. It is indeed a remote sensing system of remarkable capabilities. Yet without it, the kinds of change detection and mapping utilization which have been demonstrated here could not have been accomplished within any reasonable amount of time let alone within the one year time period in which the majority of this research was produced.

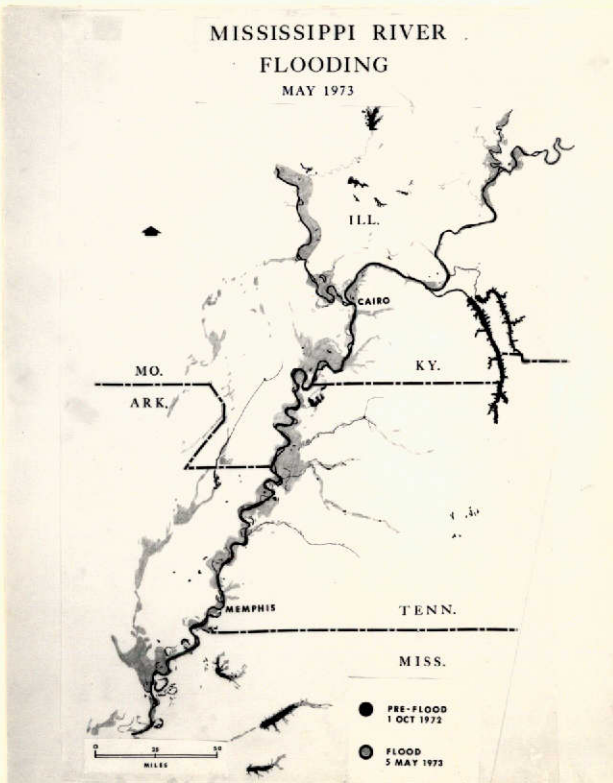

Fig. 11. Map of spring floods on the Mississippi River derived from ERTS band 7 imagery. October 1, 1972 - May 5, 1973.

References

[1]Rehder, John B., Geographic Analysis of Landscape Change from ERTS-I Imagery. Type II Report to the National Aeronautics and Space Administration, No. E73-10661, June, 1973. Springfield, Virginia: U.S. Department of Commerce, National Technical Information Service. 25 pp.

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