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16. Abstract

Changes in land use in the Phoenix (1:250,000-scale) Quadrangle in Arizona have been mapped using only the images from ERTS-1, tending to verify the utility of a land use classification system (USGS Circular 671) proposed for use with ERTS images for nationwide mapping. The change was between November 1970 and summer 1973. Seasonal vegetation changes studied in successive ERTS color composite transparencies, aided delineation of land use boundaries. Image enhancement was performed on a color additive viewer, a twenty-power magnifier, and a density slicer. Change detection by quick flip and overlaying procedures was attempted with the color additive viewer and a Zoom Transfer Scope. The latter was used for photogrammetric corrections. Types of changes detected included new residential areas, new cropland, and a new reservoir. A 1970 map of land use was updated. ERTS underflight photos were used to check accuracy of the new map, but it was found that the air photos and ERTS images complemented each other in revealing spatial and spectral change. The new land use data were inserted in a previously existing data bank where they were compared with land ownership, soils, drainage, and census information as an aid to planners and resource managers. Color illustrations EDC-010023 and EDC-010024 are available for purchase from the EROS Data Center.

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Figure 2A. Technical Report Standard Title Page. This page provides the data elements required by DoD Form DD-1473, HEW Form OE-6000 (ERIC), and similar forms.

SUMMARY (PREFACE)

Objective

As stated in the original proposal, the basic objectives of the program of computerized mapping and modelling of land use was (1) to test the interpretability of ERTS-A images for use in the mapping of generalized land use, and (2) to test the applicability of ERTS-A images for use in up-dating existing maps and in detecting changes.

Scope of Work

The land use change in the Phoenix (1:250,000 scale) Quadrangle in Arizona has been mapped, and in doing so generalized land use mapping in the Phoenix area has been tested. Transparencies of the ERTS color composite images have been used for the interpretation. In order to check the accuracy of the ERTS interpretation, land use change in the Quadrangle has also been mapped using NASA high-altitude aerial photography. Density slicing and color additive viewer enhancement have been tried as aids to ERTS image interpretation. Land use and land use change have been geo-coded to UTM coordinates and included with previously existing data in a computer model. The data are aggregated to cells spaced 1,000 meters apart. The automated output has consisted of maps and tabular listings from the computer.

Conclusions

The mapping of generalized land use (Level I) from ERTS-1 images has been shown to be feasible with better than 95% accuracy in the Phoenix (1:250,000 scale) Quadrangle. The accuracy of Level II mapping in urban areas is still a problem. The terms Level I and Level II refer to categories proposed in USGS Circular 671 (Figure 1).

Updating existing maps has also provéd to be feasible, especially in water categories and agricultural uses, however, expanding urban growth has presented some problems with accuracy. ERTS-1 film images have indicated where areas of change were occurring, thus aiding a "focussing-in" for more detailed investigation. ERTS color composite transparencies provide a cost effective source of information for land use mapping of very large regions of United States and for the entire nation at small map scales.

The use of Level I of the USGS Circular 671, proposed for use with ERTS-type imagery, has proven successful in this type of region, i.e., the arid Southwest. In fact, the mapping of some of the second level categories may be feasible. For example, extractive industries, airports, or the separation of residential, commercial/industrial, and large open areas within cities may be mapped from ERTS composites.

The use of seasonal views from ERTS allowed delimitation of certain types of land use with greater accuracy than would be possible with a single view per year, that is, monitoring of seasonal changes in vegetation and water areas facilitated more accurate mapping. It was discovered that ERTS seasonal images and "one-shot" aerial surveys were mutually complementing.

LAND-USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

Level I	Level II
01. Urban and Built-up Land.	
	01. Residential.
	02. Commercial and Services.
	03. Industrial.
	04. Extractive.
	05. Transportation, Communications, and Utilities.
	06. Institutional.
	07. Strip and Clustered Settlement.
	08. Mixed.
	09. Open and Other.
02. Agricultural Land.	
	01. Cropland and Pasture.
	02. Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas.
	03. Feeding Operations.
	04. Other.
03. Rangeland.	
	01. Grass.
	02. Savannas (Palmetto Prairies).
	03. Chaparral.
	04. Desert Shrub.
04. Forest Land.	
	01. Deciduous.
	02. Evergreen (Coniferous and Other).
	03. Mixed.
05. Water.	
	01. Streams and Waterways.
	02. Lakes.
	03. Reservoirs.
	04. Bays and Estuaries.
	05. Other.
06. Nonforested Wetland.	
	01. Vegetated.
	02. Bare.
07. Barren Land.	
	01. Salt Flats.
	02. Beaches.
	03. Sand Other Than Beaches.
	04. Bare Exposed Rock.
	05. Other.
08. Tundra.	
	01. Tundra.
09. Permanent Snow and Icefields.	
	01. Permanent Snow and Icefields.

Figure 1. This land use classification system used in the investigation is taken from USGS Circular 671, available from the U.S. Geological Survey upon request. Level I was intended for use with ERTS images.

The ERTS images lacked geometric accuracy sufficient to meet normal map accuracy standards at 1:250,000 scale, however, the information from ERTS could be transferred to an accurate base map if one exists and if enough common features were recognizable in both the image and the map, e.g., streams or roads.

Summary of Recommendations

ERTS film transparencies should be used for both (1) generalized land use mapping at scales of 1:250,000 and smaller and (2) for detecting changes over large areas of the United States in a 1:250,000-scale land use mapping program, or elsewhere in the world where geometrically accurate maps exist to serve as plotting bases. ERTS imagery also should be used to detect generalized change in more complex urban areas. These areas can then be selectively studied with high-altitude aerial photography or other more intensive survey techniques. Greater study should be made of spectral analysis possible from the four MSS bands, such as use of the computer compatible tapes from ERTS.

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Illustrations originally in color are identified in their caption by EDC-0100__ number. Copies of the original color illustrations are available for purchase from the EROS Data Center, Sioux Falls, South Dakota 57198, using the EDC number. Prices are available on request.

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

ERTS-A - Pre-launch designation for the first in a series of Earth Resources Technology Satellites.

ERTS-1 - Post-launch designation for the first in a series of Earth Resources Technology Satellites.

I^2S - International Imaging Systems, a private corporation that manufactured the color additive viewer used in this investigation.

LARS - Laboratory for Applications of Remote Sensing, located at Purdue University, West Lafayette, Indiana.

MSS - Multi-spectral Scanner; a four band scanner, one of the two imaging systems in ERTS.

RBV - Return Beam Vidicon; one of the two imaging sensor systems aboard ERTS, an electron beam imager made by RCA corporation.

UTM - Universal Transverse Mecator; a rectangular grid coordinate system designed for mapping world wide.

HISTORY OF OVERALL PROJECT

Prior to the start of the ERTS investigation, a land use map of the Phoenix Quadrangle had been prepared at a scale of 1:250,000 in 1970 from high-altitude aerial photography. This map was used as the base of reference for the change-detection work done under the current investigation.

After the start of the investigation, but prior to the receipt of the ERTS imagery, experiments were conducted using ERTS-simulation photographs of the test site mounted in an I^2S Color Additive Viewer. Different intensities of light were tried in each of the ERTS wave length bands in order to find the optimum enhancement setting for interpreting different types of land use. A map was compiled showing land use changes within the test site detected in the ERTS simulation photographs.

The first ERTS images were received in Fall, 1972. MSS bands 4, 5, and 6 images were examined on an I^2S Color Additive Viewer and other magnifying equipment. An initial map of land use changes detected from ERTS was compiled for the entire test site.

The only set of RBV imagery covering the test site was received in the Fall of 1972. Resolution poorer than comparable MSS imagery limited the usefulness of RBV imagery to an insignificant role in the experiment. The RBV had been expected to provide geometric accuracy, but previously-existing base maps were used instead.

Nine-inch MSS black and white transparencies were used to prepare ERTS color composite transparencies for the test site (Figure 2). Both photographic and diazo methods were used to prepare the composites. At this stage of the investigation, the products of both methods were often of nearly comparable interpretive value. Diazo allowed hard-copy color products to

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Figure 2. May 1973 MSS 4, 5, 7 composite image of Phoenix and the adjacent area is representative of the ERTS images used in the investigation, but shown here in black and white rather than color.

be made quickly and at very small cost. In later phases, the quality of the photographic composites had been improved to the degree that they were clearly superior to diazo. Other hard-copy false-color composites were obtained by photographing the viewing screen of an I^2S Color Additive Viewer which contained 70 mm chips cut from nine-inch images. This latter technique provided an image on the I^2S display scope of similar scale as the base map.

During the first four months of 1973, imagery from the Fall and Winter seasons was used to improve and update the map of land use change already compiled from earlier ERTS data. This was done using magnified color composite and black and white single band transparencies. Imagery was examined to establish possible relationships between seasonal changes in vegetated areas and detection of changes in land use.

A Spatial Data Systems Data Color System 703-32 density slicer was used to examine portions of MSS images. Urban, agricultural, and rangeland areas were examined separately and in combination to determine to what extent color enhancement of density differences aid in determining land use or detecting changes in land use. Results were interesting, but not conclusive. They showed that relatively homogeneous areas, urban or rural, gave the best results.

MSS nine-inch images were also examined on a Bausch and Lomb Zoom Transferscope. By using an optional 4x magnification lens, a composite image was formed at a scale of approximately 1:250,000. Two images in the same spectral band from different time periods were viewed using a "quick flip" technique to alternately examine identical areas on each frame. This allowed land use changes in complex urban fringe areas to be detected quickly, although illumination difficulties combined with excessive image clutter tended to limit the effectiveness of this technique. Similar "quick flip" and overlaying techniques had been tried with the I^2S viewer, but displacement of the principal points caused clutter.

A revised Product Order Form was submitted in the Spring of 1973. This resulted in imagery being furnished in all MSS bands in both nine-inch and 70 mm positive transparency formats. ERTS Data Request Forms were also submitted to acquire MSS band 7 imagery to complete earlier ERTS coverage over the test site.

Photographically-prepared color composite transparencies were made from ERTS images which covered the eastern section of the test site in October, 1972, February, 1973, and May 1973. Color print enlargements at a scale of 1:100,000 covering that portion of the Phoenix metropolitan area within the test site were prepared from the three transparencies. These were used for further updating of the map of land use changes detected from ERTS in early summer, 1973.

Land use changes were also mapped from recently received NASA high-altitude aerial photography taken over the test site in November, 1972. The two land use mapping efforts, i.e., from ERTS imagery and from air photos, were done independently and the results from the photo interpretation have been compared with the ERTS results to measure the accuracy of the ERTS interpretation (Figure 3 and 4), and to determine what advantages the ERTS image interpretation might have over the air photo interpretation. Using the ERTS results, an initial approximation of the number of square kilometers of land which changed in use was made and the net gain or loss in area by land use category was calculated. Area measurements of land use change were also conducted using the November 1972 ERTS-underflight aerial photography.

The MSS nine-inch image of the Phoenix metropolitan area taken on August 18, 1973 was compared with the first MSS nine-inch image of that area taken on August 23, 1972. Natural vegetation appears to be more lush in the 1973 image (Figure 5). This could be attributed to the abnormally large amount of precipitation received during the Winter 1972-73. Reservoir levels were also higher in the 1973 image. The most noticeable land use changes were the filling of Painted Rock Reservoir (Figure 6), which resulted in the change of agricultural and rangeland to water near the southern border of the test site and a major residential addition to the Sun City development, which has been expanding northward resulting in a change from agricultural to urban land use. No changes were detected in areas devoted to mining in the test site.

A map overlay showing Level II land use was made that covers much of the eastern third of the test site. The overlay was compiled on a 1:100,000-scale print base made from a portion of an ERTS color composite image. Land use in the area around metropolitan Phoenix was mapped with as much detail, i.e., second level, as possible, although all Level II categories were not interpreted. For example, the Level II categories of Commerical, Industrial and Institutional had to be combined into a non-residential urban category. The other urban categories were generally distinguishable.

In connection with the review of ERTS-1 Investigations by the Land Use Panel at Goddard Space Flight Center on October 25, 1973, two overlays were prepared for the 1:250,000-scale land use map of the Phoenix Quadrangle. The overlays covered the eastern half of the test site, including the metropolitan Phoenix area within the quadrangle. Land use changes were mapped. The first overlay showed land use changes detected from ERTS imagery for the period November 1970 to May 1973. The second overlay showed land use changes detected from high-altitude aerial photography for the period November 1970 to November 1972.

A presentation of accomplishments and current status of ERTS work in the Phoenix Quadrangle was given at the NASA/ERTS-1 Third ERTS Symposium at Washington, D.C., on December 11, 1973. In connection with the preparation of the report, twenty-five graphics were prepared which should be of continuing value to the research effort.

The changes in land use were digitized by square kilometer cells and read into a previously-existing data bank for the Phoenix Quadrangle where they not only updated the land use records but were combined with information on land ownership, soils, drainage, and census codes which were hung on the same cells. Each cell was located at even 1,000 meters on the UTM coordinate system. The UTM coordinates had been converted to latitude and longitude automatically by the computer. This allowed analysis of the change data in a variety of ways, as well as for automated plots of updated maps of land use (Figures 7 and 8).

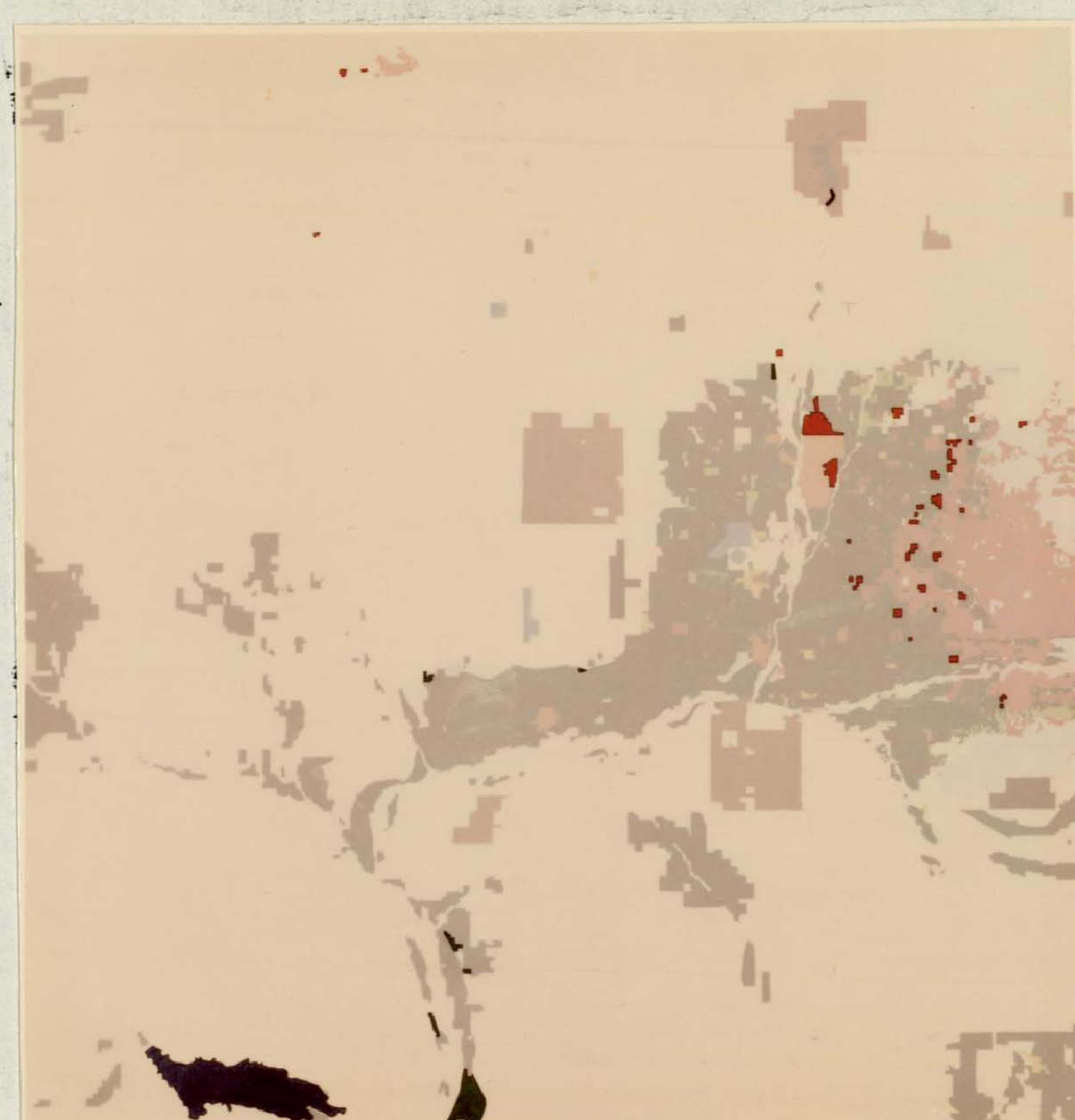

Figure 3. Polygons of land use change (Nov. 1970 - May 1973) detected from ERTS data are superimposed as dark patterns on a muted 1970 land use map of eastern Phoenix Quadrangle. Red is new residential; dark blue is new water areas; and dark green is new cropland. EDC-010074

Figure 4. Polygons of land use change (Nov. 1970 - Nov. 1972) detected from 1972 high altitude aerial photography are superimposed as dark patterns on a muted 1970 land use map of eastern Phoenix Quadrangle. Red is new residential; dark blue is new water areas; and dark green is new cropland. EDC-010075

Figure 5. Seasonal differences in rangeland vegetation and reservoir size are evident in the October (above) and May (below) scenes north of Phoenix. The dark area in the upper right quadrant of the lower photo is lush desert grass during the winter rainy season.

Figure 6. ERTS allows the timely detection of rapid land use change over large areas. These are before (November 1972) and after (May 1973) views of a filling of a new reservoir on the Gila River near Gila Bend.

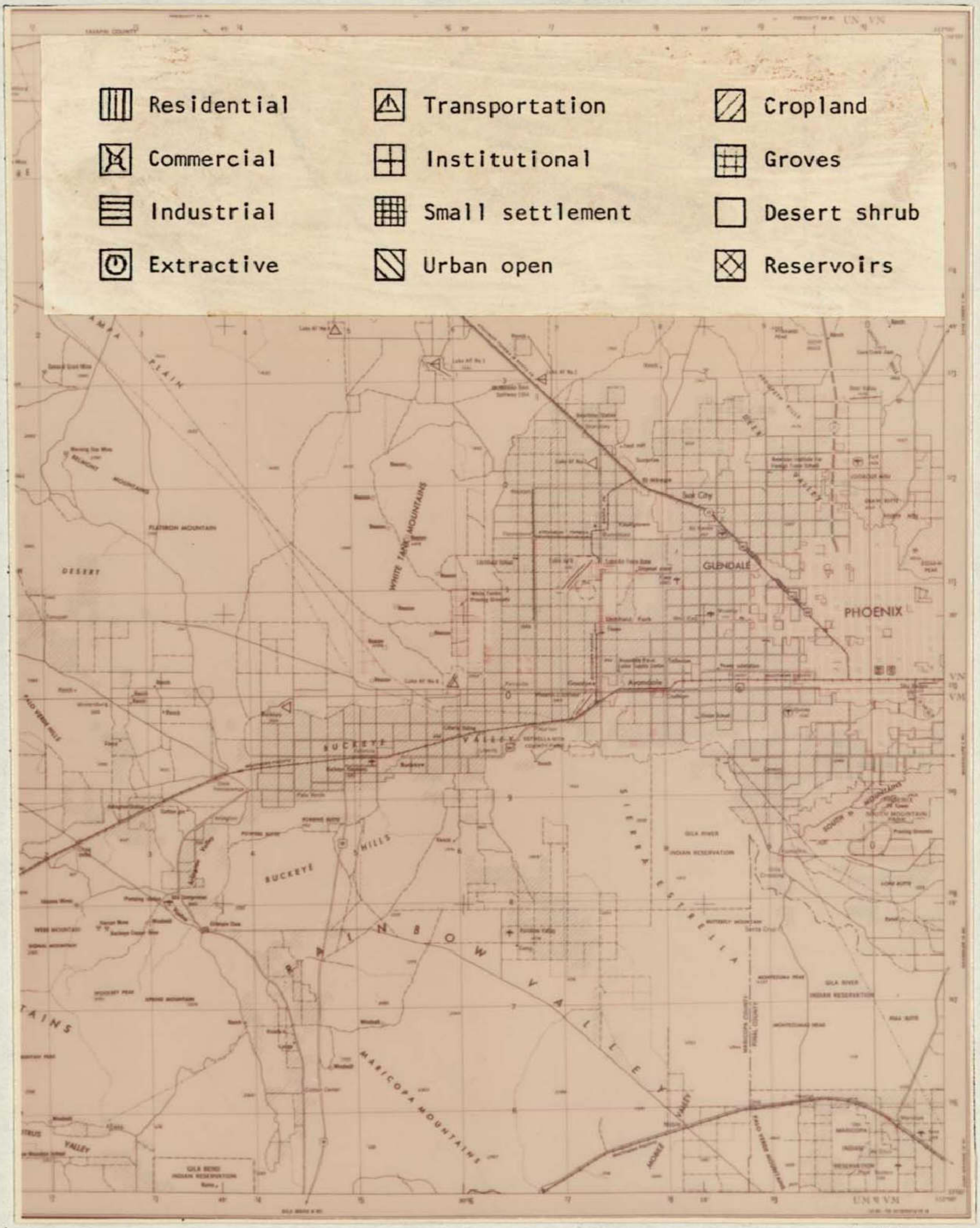

Figure 7. Computer-generated plot of land use by cells in the Phoenix Quadrangle as of November, 1970. Such computer plots overlay the standard topographic quadrangle for place names and linear patterns. EDC-010023

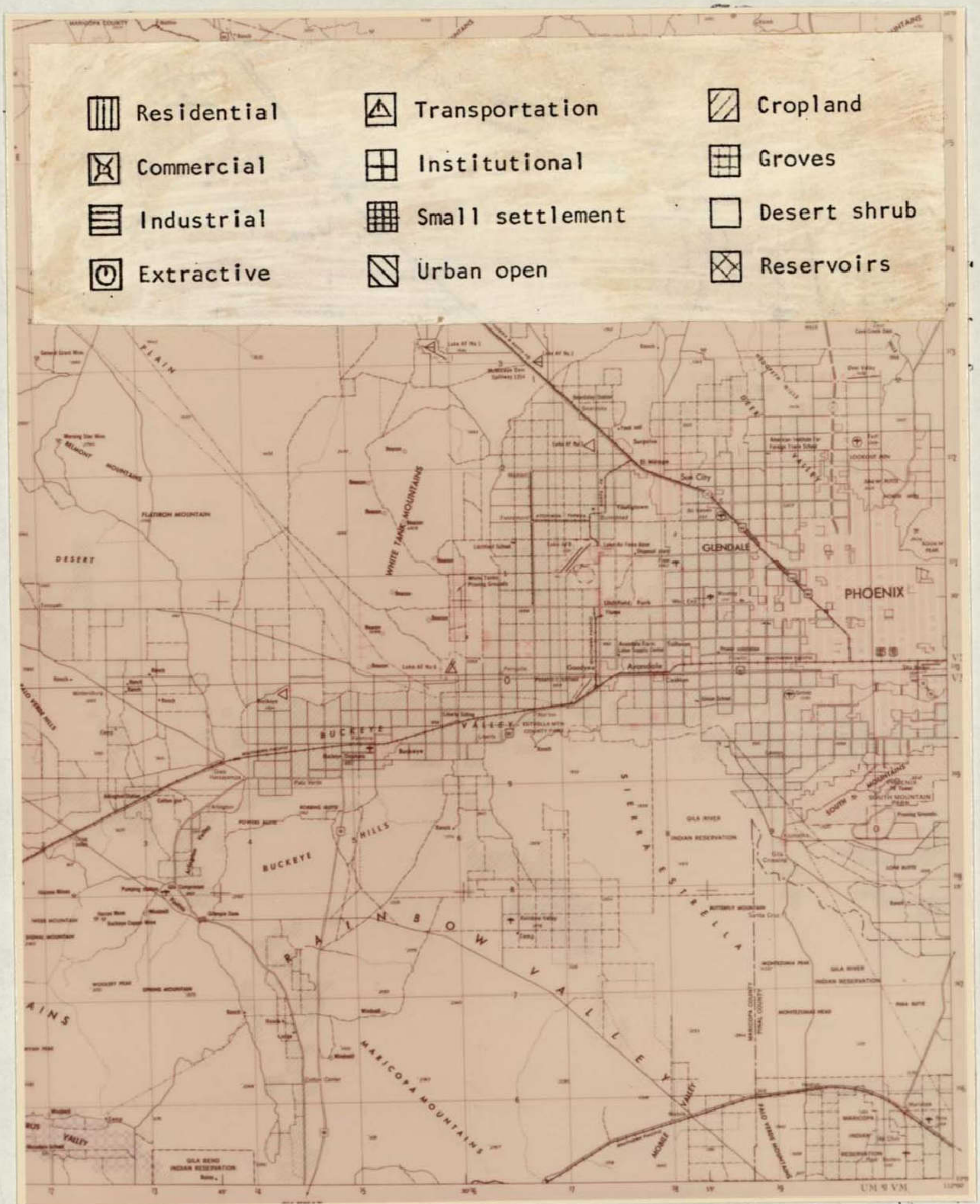

Figure 8. Computer generated plot of land use by cells in the Phoenix Quadrangle, reflecting changes detected from ERTS as of May 1973, e.g., the reservoir in the southwest corner. EDC-010024

NEW TECHNOLOGY

In the first months of this investigation, experimentation with multiband ERTS-simulation photographs in an I^2S Color Additive Viewer indicated that high intensities of light in the infrared band greatly enhance the interpretability of vegetation patterns, including landscaping within urban areas. Non-vegetative, man-made patterns were emphasized in the red and green bands of the visible spectrum. Interpretation of those ERTS simulations allowed development of procedures for interpreting ERTS-type multiband images on an I^2S viewer.

Experimentation with 70 mm squares cut from ERTS MSS nine-inch transparencies (bands 4, 5, and 6) in an I^2S Color Additive Viewer and other magnifying devices indicated that band-5 images provide the most useful interpretable data. In the I^2S viewer, high intensities of blue and red light in combined bands 4 and 6 enhanced faint vegetation patterns, not easily detectable. Examination of MSS imagery during the ensuing year indicated that seasonal changes affect accurate detection of agricultural land use change. Comparisons of nine-inch MSS black and white images and color composites made from bands 4, 5, and 6 showing agricultural areas near Phoenix during the summer, fall, and winter seasons aided in verifying that certain land areas were being used for cropland and not as rangeland (Figure 9). Agricultural land which was without crops during certain seasons, especially if on the margin of the desert, often became more readily identifiable through monitoring of seasonal vegetation changes.

Experimentation with a Spatial Data System density slicer on portions of a nine-inch MSS band-7 transparency showing the central urban core of Phoenix (Figure 10) enabled dense commercial and industrial areas to be discriminated from less dense urbanized land uses; however, excessive clutter produced results of limited usefulness. The best results in agricultural areas near Sun City were obtained using band-5 imagery. Discrimination of different land uses in both urban and agricultural areas which were density sliced was not possible to the degree of accuracy necessary to make mapping feasible. Density slicing techniques may be useful in identifying areas which merit further study with more definitive methods, such as processing by ERTS computer compatible tapes.

During the early spring of 1973, experimentation with the Bausch and Lomb Zoom Transferscope using nine-inch MSS imagery of identical areas in the same spectral band from different time periods, using a "quick flip" method of alternately viewing the same areas, enabled rapid detection of a particularly large land use change from agricultural to urban use on the northwest fringe of the metropolitan Phoenix area. The best results in this case were obtained when comparing MSS band-5 imagery. Because of clutter caused by vegetation differences, small areas of land use change were difficult to distinguish.

During the latter part of the reporting period, a more up-to-date version of the map of land use change was made using the photographically-prepared color composites of the test site for fall 1972, winter 1973, and spring 1973,

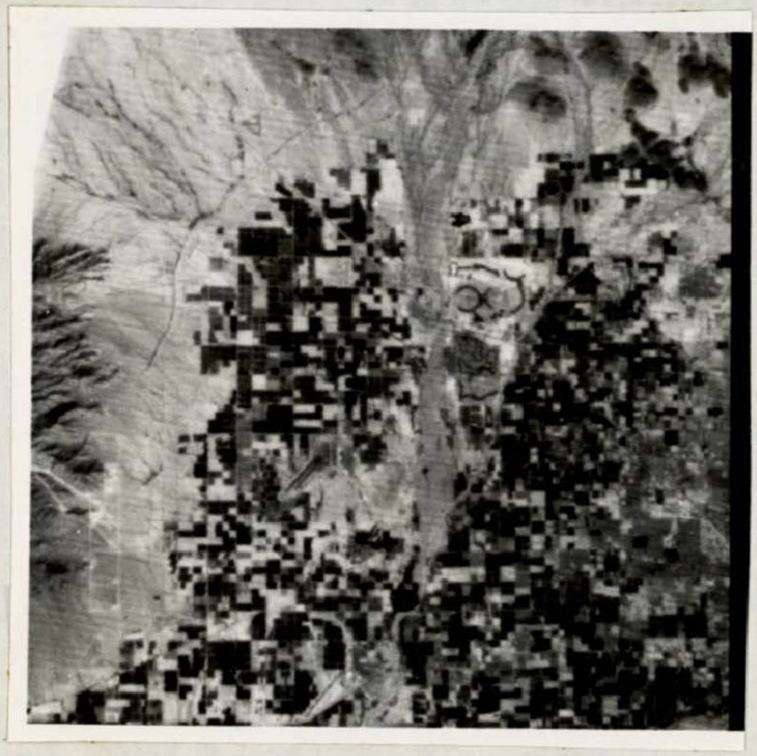

Figure 9. Increased visibility of natural vegetation in the February image (above) allows the sharp delineation of the rangeland-cropland boundary, not feasible with the October image (below).

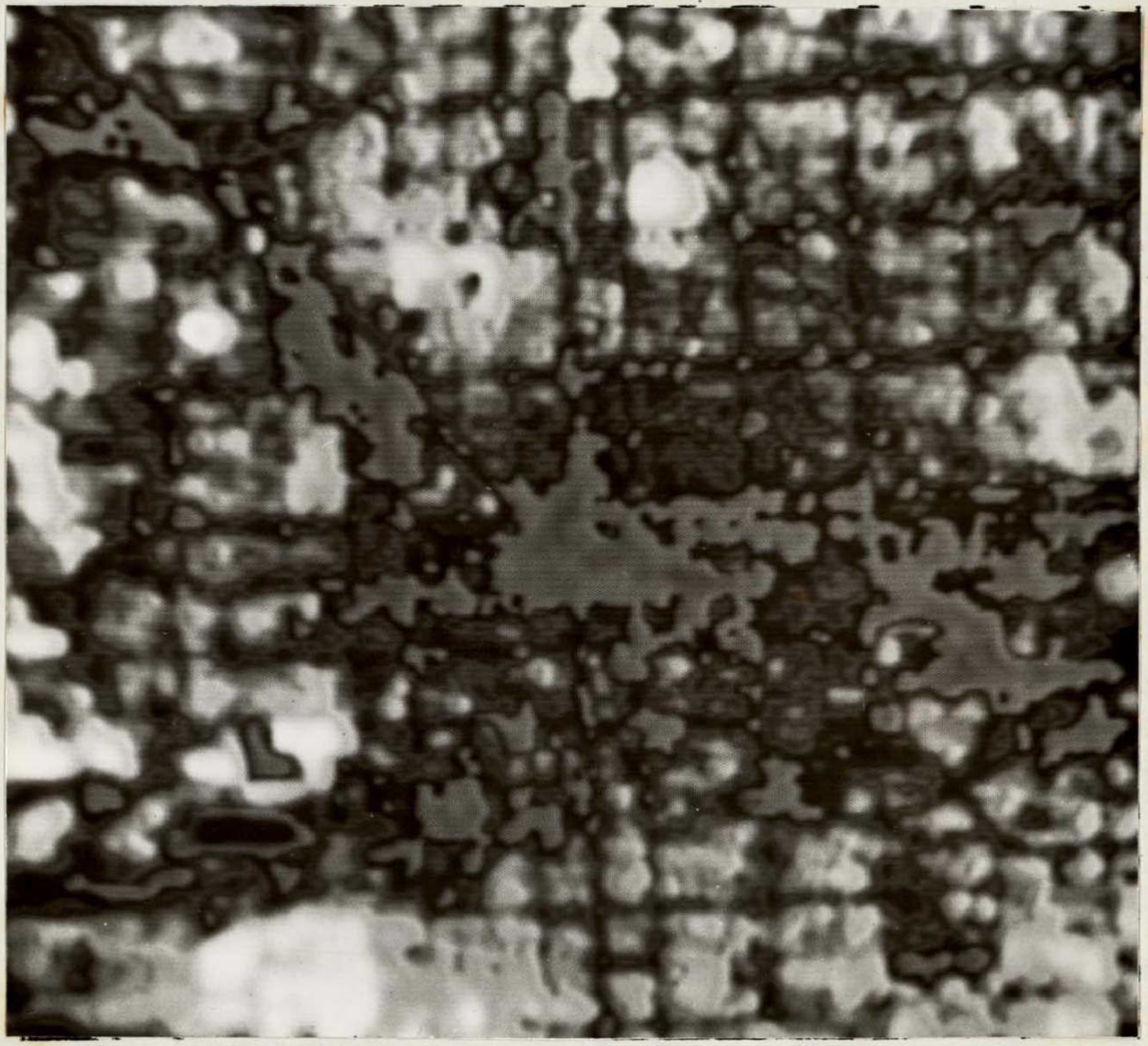

Figure 10. A density slice using a Data Color System 703-32 of a portion of a MSS band 7 transparency shows central Phoenix. The industrial districts and central business district appear gray, the business streets black, and the residential area as white.

some scenes enlarged to 1:100,000 scale. Land changing from agricultural or rangeland to urban residential use usually could be accurately identified only when landscaping vegetation was established to the point that a distinctive pink color was visible on the color composite. Due to the size, location, and rapidly-changing shape, one area adjacent to the northern edge of Sun City undergoing change from agricultural to urban use was readily detectable without relying on the color change previously mentioned. One case of change from agricultural to urban use was detected from the appearance of white and blue-black patterns which correspond to large buildings and parking areas.

As to mapping other second level categories of an urban or built-up type, extractive industries could be delineated where open pit or strip mining was practiced and where tailings, dumps or ponds were visible on the imagery. In the transportation, communications, and utilities category, larger airports and railroad yards were usually the only mappable features. Highways, although often visible (Figure 11), were rarely delineated as land use categories because the corridor they occupied was below minimum mapping width. Highways can be shown as overlays on computer map plots and updated by hand.

Separation of citrus from other agricultural land was moderately successful in the ERTS 1:100,000-scale Level II land use mapping around Phoenix, due to a characteristic brownish red color of citrus groves in ERTS color composites. No feeding operations were detected from ERTS. Commercial and services, industrial, and institutional land were not reliably separable from each other using present image interpretation techniques. Urban open areas, such as parks and golf courses, were readily detectable, particularly when local maps were consulted even though out-of-date. Strip and clustered settlements could often be detected depending upon their size and contrast with the surrounding area on the ERTS image.

Land areas which were inundated in the Salt and Gila River Valleys were evident in late winter and spring 1973 imagery. The large land area inundated with the sudden filling of the Painted Rock Reservoir in the extreme south central section of the test site resulted in a significant amount of land use change in relation to the entire test site. Rapid detection and measurement of land use change caused by sudden natural and man-made situations was found to be quickly detectable and measurable using ERTS data.

The amount of water area within the test site increased by about 72 square kilometers, which resulted in a loss of about 16 1/2 square kilometers of agricultural land and 55 1/2 square kilometers of rangeland to the new use. Urban land increased by about 19 1/4 square kilometers, with about 18 1/4 square kilometers changing from agricultural and about 1 square kilometer changing from rangeland. Agricultural land increased by about 27 3/4 square kilometers by change from rangeland, but changes of 18 1/4 square kilometers and 16 1/2 square kilometers to urban and water uses respectively resulted in an overall decrease of about 7 square kilometers for land in agricultural use. Rangeland decreased about

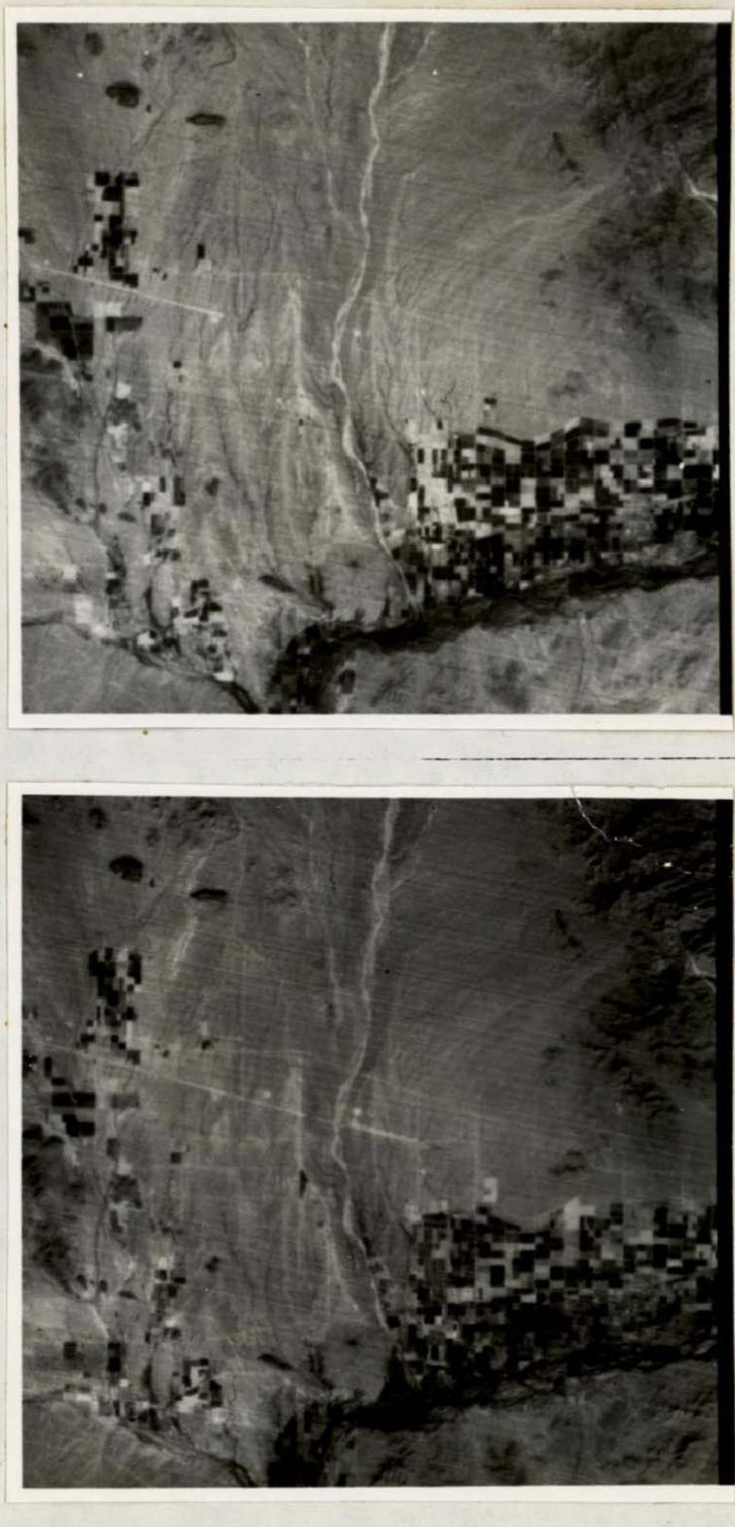

Figure 11. Repetitive ERTS coverage shows construction progress between May and October 1973 on Interstate 10 west of Phoenix. The highway is a white line extending southeastward from the left edge of the photo. In the later (October) ERTS image (below), it has crossed the Hassayampa River.

84 1/4 square kilometers with losses of 55 1/2 square kilometers, 27 3/4 square kilometers, and 1 square kilometer to water, agricultural, and urban uses respectively. The above results, which were obtained by manual dot counting, indicate that agricultural land is being urbanized, but that new agricultural land is being developed from rangeland at a greater rate. Cleared land was more easily detectable from surrounding naturally-vegetated rangeland at certain times of the year on ERTS imagery.

In comparing the land use changes detected from ERTS and the changes compiled from the November 1972 aerial photography, the total areas of change were found to be of the same magnitude. The clusterings or distributions of changes on both of the overlays were quite similar. The greatest variations were a result of differences in dates between ERTS images and aerial photographs. The greatest accuracy was obtained in the water classification, where interpretations were virtually identical. Land use changes from rangeland to agricultural land were normally detectable, although ERTS images did not always show new agricultural land which was not yet in crops. Land changing from agricultural to urban use presented more problems. Individual land units changing were usually smaller than the types previously mentioned. Lack of landscaping vegetation in newly-developed residential areas often caused them to be overlooked during interpretation of ERTS images. In the larger parcels and in those with characteristic vegetation present, the Level II changes were mapped with more than 90% accuracy. ERTS was found to be a useful tool in monitoring urban advance on the western fringe of Phoenix.

The land use change polygons were then overlaid with one-kilometer-square grid on the Universal Transverse Mercator projection. Grid intersections falling within change polygons were then recorded as changed cells, and the information was entered into a previously compiled data bank for the test site. Information relating land uses and other factors was produced by computer in the form of automated plots and tabular listings, often in the form of matrices. Table 1 shows the status of general land use during the existence of the data bank. The change figures show increases in urban and water uses and decreases in agricultural and rangeland uses. Gain and loss figures show a balance when comparing urban with agricultural and rangeland with water. A better understanding of the use change trends can be gained from Table 2. Here the large amount of change due to the filling of a major reservoir may be separated from other factors. When examining only the residential, cropland, and desert shrub categories, one can see the trend of land use change following a pattern of movement upward step-by-step in use intensity. Desert shrub land changes to cropland and cropland to residential. The only exception is the two cells which went from desert shrub to residential. Table 3 shows that nearly all the land which has changed in use was in private hands. Small amounts of change have occurred in other categories, but most of this was a result of the filling of a large reservoir. Most of the land in the test site is still in some form of non-private ownership. Table 4 shows the ability of the data bank to be related to census information. Users are able to identify the census tracts where change has occurred since the 1970 census. These data are of interest to many

TABLE 1

LEVEL I LAND USE IN THE PHOENIX QUADRANGLE (Square Kilometers)

LAND USE	1970	1973	CHANGE
Urban	647	677	+30
Agricultural	1890	1861	-29
Rangeland	18080	18004	-76
Water	16	91	+75
Total	20633	20633	

TABLE 2

LEVEL II LAND USE CHANGE BETWEEN 1970 and 1973 IN THE PHOENIX QUADRANGLE (km^2)

		T O		
		Residential	Cropland	Reservoir
F R	Cropland	28	-	22
O M	Desert Shrub	2	21	53

TABLE 3

DATA FOR CHANGED LAND USE CELLS IN THE PHOENIX QUADRANGLE (km^2)

1970 OWNERSHIP versus 1973 USE

Ownership	Residential	Cropland	Reservoir	Total
Private land	28	19	68	115
State land	1	2	3	6
Public land	1	-	3	4
Indian land	-	-	1	1
Total	30	21	75	126

TABLE 4

DATA FOR CHANGED LAND USE CELLS IN THE PHOENIX QUADRANGLE (km^2)

CENSUS TRACT versus 1973 USE

Census Tract	Residential	Cropland	Reservoir	Total
Not tracted	2	6	–	8
0303	3	–	–	3
0405	2	–	–	2
0506	–	2	22	24
0715	7	–	–	7
0718	2	–	–	2
0820	3	–	–	3
0923	1	–	–	1
0927	1	–	–	1
1042	5	–	–	5
1125	4	–	–	4
6233	–	13	53	66
Total	30	21	75	126

users. Table 5 shows that residential land seems to be using soils that are well suited to agriculture. The problem of good agricultural soils being lost through urban expansion is not confined to the Phoenix area and is a cause of concern to many land use managers. Good agricultural soils have also been lost through inundation when the large reservoir filled. Also of interest would be the one cell which indicates that residential development took place in an area reported to have alluvial soils subject to flooding. The ability of ERTS data to aid in detecting land use changes quickly and relating these to other factors in the data bank provides users with information needed to shape future land use and planning decisions.

Attempts to arrive at a precise accurac ent have been handicapped by the fact that ERTS is unique. There is no other source of information like it, hence, we have nothing with which to compare as a check. Aerial photographs provided for ERTS underflight "ground truth" were provided on a "one-shot" basis only; it took months to fly all of Arizona to approximate ERTS coverage. This test site, the Phoenix Quadrangle, was covered in November 1972. Yet one cannot fairly compare ERTS images for November 1972 with those photos because much of the informational content of ERTS products is derived from its monitoring of seasonal changes in vegetation or in water. Not enough seasonal ERTS coverage had been obtained before November 1972.

Nevertheless, it was apparent that air photos, because of their better spatial resolution, could detect smaller man-made features. However, ERTS could detect seasonal changes in vegetation and water which aided land use delineation in a way that single surveys by air could not. It became very evident that ERTS and aerial surveys complement each other as aids to land use mapping. ERTS also provided currency as exemplified by the ERTS mapping of a large new reservoir in the test site, more recent than the aerial photography flight.

Efforts to arrive at an accurate estimate of cost effectiveness have also been handicapped by the fact that ERTS was unique. One cannot compare the cost of broad regional land use mapping using ERTS images against the cost of previous methods when the previous methods did not exist. Surveys of this size done every eighteen days would have been prohibitively expensive whether done by aerial survey, ground survey, or questionnaire. The best we can do is to estimate the cost of contracted aerial surveys for the Phoenix Quadrangle every eighteen days, or even once a season. This could be compared with the cost of purchasing from the EROS Data Center in Sioux Falls, the best ERTS transparencies of color composites obtained each season. Admittedly more detailed land use mapping at a larger scale would have been possible with the air photos. However, this experiment was intended to aid a <u>nationwide</u> program of land use mapping. The information must be generalized for economical processing and presentation at such a scale, i.e., 1:250,000. Hence, the ERTS informational content might be closer to what is needed than would be the hypothetical air photo taken from 10,000 meters altitude showing an area about 9 x 9 kilometers in size in each frame.

TABLE 5

DATA FOR CHANGED LAND USE CELLS IN THE PHOENIX QUADRANGLE (km^2)

SOIL versus 1973 USE

Soil Type	Residential	Cropland	Reservoir	Total
Data not available	2	6	-	8
Typic Torrifluvents	8	6	67	81
Typic Haplargids	12	-	-	12
Typic Calciorthids	7	9	3	19
Shallow soils over unweathered and/or weathered bedrock	-	-	2	2
Shallow and moderately deep soils over geologic materials	-	-	3	3
Alluvial soils subject to flooding	1	-	-	1
Total	30	21	75	126

To guess at the cost of such an aerial survey, assume $3,000 per day as the cost of a photo mission. Assume good flying weather every other day. This is conservative for Arizona, but very optimistic in most places. If the survey could fly the entire quadrangle in eight hours and only four hours per day had high enough sun angles, then each survey of the quadrangle would cost about $12,000. This could be compared to about one hundred dollars for ERTS color composite transparencies (two or three scenes to cover the quadrangle) from the EROS Data Center. For four seasons each year, a total of nearly $48,000 could be saved. The smaller number of images to be handled and stored using ERTS would also save some money, but we could assume generally that further processing costs would be similar. Hence, we save approximately $50,000 per quadrangle in mapping the 674 quadrangles (1:250,000 scale) in the United States, or over $3,000,000 for each yearly update. This is a compromise between several rough approximations, e.g., most quadrangles are smaller than the Phoenix Quadrangle, but in most areas of the country, the probability of good weather or high sun angle is much less.

The above calculations assumed that no recent areal photography already existed, and this is reasonable. It also disregarded the cost of launching and maintaining the satellite and also did not consider the value of any aerial photographs to other users who might share the cost of obtaining them.

An important question is, "How much value are land use maps and land use analyses?" Land use planning is presently recognized as an important part of intelligent resource development and management as well as environmental protection. The land use planning cycle normally starts with mapping and taking inventory of current land use--as shown to be possible on a generalized scale with ERTS film-type images. Monitoring of land use change helps to detect trends which sometimes can be projected into the future. Other planning factors besides land use, e.g., air or water pollution, harmful sedimentation, loss of green areas, absence of vegetation in some inner-city residential districts, can sometimes be detected in ERTS images; these can supplement the land use mapping. If the land use data were read into a computerized data bank, as was done in this investigation, other factors can be compared with land use by computer analysis as an aid to planning and management. The near-real-time monitoring, possible for the first time with ERTS, is well suited for use with computerized information systems for land use managment of large regions.

APPENDICES

Publications from Project

Place, John L., and Wray, James R., 1972, "Automated Plotting and Update of Land Use Maps and Related Information in South Central Arizona," Proceedings of the Conference on Remote Sensing on Arid Lands, Tucson, Arizona, November 8-10, 1972.

Place, John L., "Change in Land Use in Phoenix (1:250,000) Quadrangle, Arizona, between 1970 and 1972: Successful Use of a Proposed Land Use Classification System," Proceedings of the Symposium on Significant Results Obtained from ERTS-1, New Carrollton, Maryland, March 6, 1973.

Place, John L., "Change in Land Use in the Phoenix (1:250,000) Quadrangle, Arizona Between 1970 and 1973: ERTS as an Aid in a Nationwide Program for Mapping General Land Use," Proceedings of the NASA Symposium on Significant Findings from ERTS-1, Washington, D.C., December 10-13, 1973.

GLOSSARY

DIAZO - An ozalid-type process which allows reproductions to be made in transparency format in any one of a number of colors.

LEVEL I - The most general classification of land use, designed to be used with satellite data, as set forth in USGS Circular 671.

LEVEL II - The second-most general classification of land use, designed to be used with high altitude aerial photography, as set forth in USGS Circular 671.

TEST SITE - The USGS 1:250,000-scale 1^{o} x 2^{o} quadrangle, entitled Phoenix, Arizona Quadrangle.

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