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REMOTE SENSING AND CHANGES IN LAND USE IN CENTRAL ARIZONA

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REMOTE SENSING AND LAND USE PLANNING

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I. INTRODUCTION

Statistics indicate that the U.S. is losing about one million acres of prime farmland to urban sprawl each year. Once fertile fields are being converted to non-agricultural uses; the loss to agriculture is irreversible. The rapid conversion of farmlands to urban uses has spurred widely concerns on the long-term availability of enough high quality agricultural land to sustain the level of agricultural production needed in the years to come.

Concern for the availability of agricultural land has prompted many states, counties and local communities to initiate programs aimed at stopping or slowing down the conversion of agricultural land to other uses. As Lester Brown, President of Worldwatch Institute, points out, prime farmland can be protected from competing nonfarm demand only through land use planning efforts (Brown, 1978). Sound land use planning efforts and management programs, however, rely upon adequate information. Detailed and systematic information on the rate and kind of change in land use, in particular, is essential to proper planning, management and regulation of the use of such land resources.

In responding to the needs of timely and detailed information on changes in land use, the U.S. Department of Agriculture and the U.S. Geological Survey of the Department of Interior have been engaged in monitoring and inventory of land use for selected areas. In the past, however, information on changes in land use was either incomplete, fragmental or expensive to obtain. Moreover, since changes in land use occur at highly variable rates from place to place, a timely systematic and relatively inexpensive process for measuring these changes is urgently needed for the production of necessary facts appropriate for varying needs at county, state, regional or national levels.

The rapidly developing technology of remote sensing offers an efficient and timely approach to mapping and collection of land use data. At the present time, the remote sensing technology offers a wide range of capabilities including: (1) multispectral scanner data are available from LANDSAT over extensive areas on a repetitive basis as frequent as 9 to 18 days, (2) both black and white and high resolution color-infrared imageries as well as RBV paper products are also available at various prices; each of them has comparative advantages over the other. Their combined usage produces more information than that by using either one alone.

For those who are particularly interested in the spatial location of land use information over a relatively large area, remote sensing seems to be an efficient and timely approach. However, remote sensing alone may not be adequate for monitoring changes in land use. For detecting the nature and degree of land use changes, the degree of effectiveness in using remote sensing technology largely relies on the capability of the investigator to interprete the LANDSAT information and his familiarity with the use of computer software system. Whenever alternative sources such a high-resolution aerial photos and local land use maps are available, they should be obtained and used to supplement the effort. As Anderson suggested, the statistical estimation and scientifically designed sampling procedure ought to be considered as alternative approaches for selected area needing much more detailed attention (Anderson, 1977).

II. Purpose of the Study

The previous section has demonstrated the need for the development of new methodology and framework that would provide timely, systematic and inexpensive approach for the monitoring of multi-temporal changes in land use and the collection of land use data. For the past several years, experimental studies have been undertaken in the U.S. Geological Survey to determine how data acquired from LANDSAT and high altitude aircraft can be interfaced for the efficient updating of land use changes and the collection of land use data. Useful findings have been obtained. Guidelines and suggestions for further research have been itemized (Anderson, 1977; Milzaao, 1973). At about the same time, the Statistical Research Division, Economics, Statistics and Cooperative Service of the U.S. Department of Agriculture equipped with an information system capable for inputting, storing, retrieving and manipulating data spatially or geographically on an electronic computer and with an established area frame sampling procedure, began to experiment with the usage of remote sensing techniques to measure and estimate the crop acreage for areas as small as one square mile with considerable statistical precision.

As a part of the effort for the continuation and broadening of these experimental studies, this study attempts to develop measures of changes in land use pattern in south central Arizona, one of the fastest growing areas in the United States. It is designed to provide ample information on where and to what degree changes in land use pattern have happened. Policy implications in terms of proper land use planning will be examined and presented.

III Land Use Classification

This study uses a land use and land cover classification system developed by the Office of Chief Geographer, U.S. Geological Survey (U.S.G.S.) upon the initiative of an Interagency Steering Committee on Land Use Information and Classification in early 1971.

The classification system was developed under several assumptions and guidelines. To begin with, land use refers to "man s activities on land which are directly related to the land" (Clawson and Stewart, 1965); and land cover, on the other hand, describes, "the vegetational and artificial constructions covering the land surface" (Burley, 1961). Remote Sensing image-forming devices do not record activities on the land directly. The remote sensor acquires a response which is based on many characteristics of land surface, including natural or artificial cover. Using patterns, tones, textures, shapes and site associations, interpreters are able to derive information about land use activities from what is basically information about land cover.

The system is receptive to inputs of data from both conventional sources and remote sensors on high-altitude aircraft and satellite platforms. The approach embodied in the system is "resource oriented," in contrast, for example, with the "people oriented" of the "Standard Land Use Coding Manual," developed by the U.S. Urban Renewal Administration and the Bureau of Public Roads (1965).

The system has two levels of land use classification. Level I defines major categories of land uses, while Level II gives detail description of each of the category defined in Level I. Only four of the major land use categories at Level I are being used in this study. These are: Agricultural land, urban or build-up land, range, forest, barren land, water and wetland. A brief description of these four major land use categories are as follows:

1. Agricultural land: Agricultural land is defined broadly as land used primarily for production of food and fiber. This includes cropland and pasture, including summer-fallow and idle cropland and land on which crop failure occurs; orchards, nurseries and horticultural areas, including nut crops and vineyards; confined feeding lots, chiefly beef cattle feedlots and large poultry farms; and other agricultural land such as farmsteads, farm lanes and roads, ditches and ponds. On LANDSAT imagery, the chief indications of agricultural land will be distinctive geometric field and road patterns on the landscapes.
2. Urban or build-up land: This comprises areas of intensive use with much of the land covered by structures. Included in this category are cities, towns, villages, new subdivisions, transportation and communication facilities, industrial and commercial complexes, and airports and institutions that may, in some instances, be isolated from urban areas. New subdivisions with plotted building lots and areas on which over 60% of the land have been developed are also included in this category.

3. Range, forest and barren land: Historically, rangeland has been defined as land where the natural vegetation is predominantly grasses, forbs, or shrubs and various forms of cactus. Forest are lands stocked with trees capable of producting timber or other wood products, and exert an influence on the climate. Barren land is, in general, an area of thin soil, sand or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the category of rangeland. Areas of strip mines, quarries and gravel pits are also included in this category.
4. Water: Water is defined as major water bodies sich as lakes, reservoirs or dams, canals and streams. Generally, they are easy to identify. The delineation of streams, rivers and canals, however, depends on the scalp of data presentation and the scale and resolution characteristics of the LANDSAT imagery.

IV. MAPPING

By overlaying a "mylar" film paper on either a black-or white or a flase color-inflared photography, one can easily trace out boundaries of different land use category with a pencil. Generally speaking, black-wbite imagery gives better picture of roads, highways, canals, and various residential, commercial and industrial facilities; while color-inflared photos give better view of various types of vegetation and, in particular, geometric farm fields and landscapes. Supplementary materials such as county highway maps and municipal land use planning maps are helpful in identifying these boundaries. This is true in particular when one has some doubt in mind about the identification of a particular segment of land.

In conducting mapping the following guidelines have been used:

1. The minimum level of categories is at least 85 percent. For

land use planning and management purposes, data generated at such a level of accuracy has been found satisfactory. (Anderson, 1976).

2. Repeatable results should be obtainable from one interpreter to another and from one time of sensing to another.
3. Efforts should be devoted to obtain data or other land use maps that would complement or increase the accuracy of interpretation of LANDSAT data.

V. LANDSAT Data Registration and Digitization

In order to estimate acreages of changes for various land use categories, LANDSAT data have to be registered and digitized. Registration can be accomplished in the following manner.

A. Select control points such as road and/or rail intersections and other topographic features from a 1:1,000,000 LANDSAT positive transparency.
B. Overlay the transparency on an USGS index map or a 1:1,000,000 World Aeronautical Chart map (WAC) and digitize the control points.
C. Obtain grayscales (magnified portions of the LANDSAT scene) from a line printer using information on computer compatible tapes.
D. Determine corresponding points on grayscales and index maps. This is done either by overlaying grayscales on maps or by visual identification of topographic features.
E. Enter control points on both the maps and grayscales into a file by the process of digitization.
F. Using a computer processing system known as EDITOR, predict row and column coordinates by means of regression analysis.

After registration is completed, a digitizer is used to trace boundaries of various land use strata. Again, the computer system EDITOR is used to estimate acreage of each distinct land use field as well as the area of various land use strata.

V. Major Findings

With the completion of mapping and digitization, information on changes in land use in Maricopa County, Arizona have been obtained. Map 1 shows the location as well as magnitude of land use changes. Table 1 gives the relative land use changes measured in acreage. Table 2 gives a matrix of gains and losses in acreage by major land use categories.

As is expected, total areas of urban and build-up land have more than doubled, from 136 thousand acres in 172 to an estimated 304 thousand acres in 1979, representing 122% increase in a period of seven years. Most of the growth are in suburban communities adjacent to the city of Phoenix such as Mesa, Scottsdale, Tempe, Glendale and Youngtown-Sun City areas.

The growth of urban and build-up areas takes a heavy toll on both agricultural land and range and other land; about 65% of the urban growth come from range and other land, and 35% from agricultural land (Table 2).

The completion of Salt River Water Project and the Painted Rock Dam along the Gila River makes more water available for irrigation purposes. As a result, total acreage of agricultural land has increased. However, the loss of agricultural land to urban expansion has more than offset its increase because of the availability of water for irrigation.

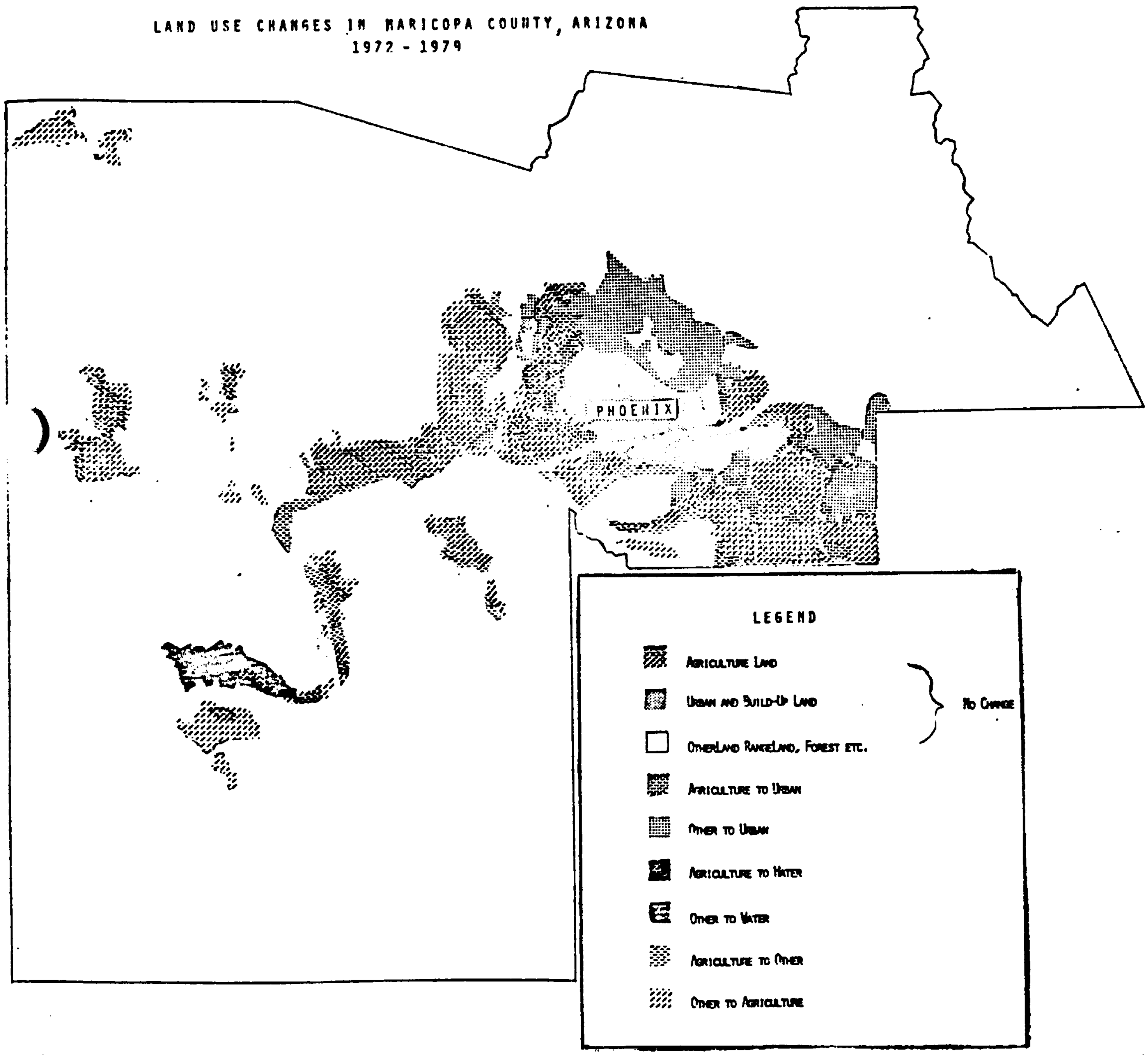
LAND USE CHANGES IN MARICOPA COUNTY, ARIZONA
1972 - 1979
PHOENIX
LEGEND
AGRICULTURE LAND
URBAN AND BUILD-UP LAND
OTHERLAND RANGELAND, FOREST ETC.
NO CHANGE
AGRICULTURE TO URBAN
OTHER TO URBAN
AGRICULTURE TO WATER
OTHER TO WATER
AGRICULTURE TO OTHER
OTHER TO AGRICULTURE

Table 1: Land Use Changes In Maricopa County, Arizona, 1972-1979

Land Use Category	Years		Change (1972-1979)	
	1972	1979	Acres	Percentage
	(Acres)	(Acres)		
Agricultural Land	472,681.9	457,502.6	- 15,179.3	- 3.2
Urban or Build-Up Land	136,670.8	303,782.4	- 167,111.6	+ 122.3
Range, Forest and Other Land	5,364,172.5	5,177,901.5	+ 186,271.0	- 3.5
Water	0	34,464.4	+ 34.464.4	-
Total	5,970,014.9	5,973,650.9	+ 3,636.0	0

Table 2: Matrix of Estimated Gain or Loss in Acreages by Land Use Category, Maricopa County, Arizona, 1972-1979

Change From / To	Agricultural Land	Range and Other Land	Urban and Build-up	Water and Westland	Total Gain	Net Gain
		(Acres)				
Agricultural Land	(457,502.6) a/	55,319.5	θ	θ	55,319.5	θ
Range and Other Land	8,540.0	(5,177,901.5) a/	θ	θ	8,540.0	θ
Urban and Build-Up	58,190.4	108,921.2	(136,670.8) a/	θ	167,111.6	167.111.6
Water and Wet Land	3,768.4	30,570.3	θ	(θ) a/	34,338.7	34,338.7
tal Loss	70,498.8	194,811.0	θ	θ	265,309.8	
Net Loss	- 15,179.3	-186,271.0	θ	θ		θ

a/ Numbers in parenthisis indicate acreages remaining unchanged.

VI. The "Ground Truth" data

One way to check the accuracy of the mapping and the classification is through the use of the "ground truth" data obtained by field offices of the U.S. Department of Agriculture. In June each year, the U.S.Department of Agriculture in cooperation with States and local governments, conducts a survey of sample segments. A segment is an area ranging from about 80 acres in towns or cities to about 600 acres in agricultural and rangeland areas. The survey is done by trained enumerators who interview households and property owners and record all information concerning acreages of various crops and land uses within the sample segment. These information were then processed and stored on computer tapes.

By locating the segments on 1:500,000 base map for detecting land use changes, it has been found that 69 segments fall in agricultural land category and 16 in urban and build-up land category in Maricopa County, Arizona. Acreages of various crops and land cover were tabulated and shown in Table 3. It can be seen that about three-fourth of agricultural land was used for growing crops with cotton being the predominant crop in Maricopa County. Only about one-fourth was used for non-agricultural purposes such as roads, residential, commercial facilities and forest. In contrast to agricultural land, onely one-fifth of the urban and build-up land was used for growing crops and non-agricultural uses accounted four-fifth of urban and build-up land. This demonstrates that the mapping in this study has attained a high level of accuracy.

VIII. Conclusions

The loss of farmland and the ever increasing population have spurred a globe concern on the availability of enough high quality agricultural land to sustain the level of food and fiber production needed in the years to come. As a result, officials at various levels of governments began to initiate programs aimed to stopping or slowing down the conversion of agricultural land to other uses. Sound land use planning efforts and management programs, however, rely upon adequate information.

Estimated Acreages of Land Cover Obtained from June Enumeration Survey, Maricopa County, Arizona, 1979

Land Cover	Major Land Use Categories			
	Agricultural Land N=69		Urban and Build-up Land N=16	
	Acreage	Percent	Acreage	Percent
Agricultural Uses	29,983.9	71.5	1,376.3	19.6
Cotton	18,108.7	43.1	521.2	7.4
Hay & Alfalfa	4,595.3	10.9	137.6	2.0
Wheat	799.9	1.9	-	-
Pasture	642.0	1.5	78.3	1.1
Salflower	459.4	1.1	-	-
Barley	341.5	0.8	17.0	0.2
Sugarbeets	452.7	1.1	133.2	1.9
Sorghum	210.8	0.5	-	-
Corn	187.1	0.4	124.0	1.8
Potatoes	156.7	0.4	-	-
Citrius	646.7	1.5	229.3	3.3
Other Crops	1,297.3	3.1	135.7	1.9
Summer Fallow	2,085.8	5.0	-	-
Non-agricultural Uses	11,994.0	28.5	5,634.1	81.4
Total Number of Acreas	41,977.9	100.0	7,010.4	100.0
Total Acreage of Segments	40,518.0		6,746.0	

In responding to the needs of information on changes in land use, the U.S. Department of Agriculture and the U.S. Geological Survey of the Department of Interior began to experiment with the usage of remote sensing techniques to monitoring and inventory of land use for selected areas as early as in 1973. As part of the effort for the continuation and broadening of these experiments, this study is designed to generate information on changes in land use pattern in Maricopa County, Arizona, one of the fastest growing areas in the United States.

As is expected, total areas of urban and build-up land where the city of Phoenix and its suburban communities are located, have more than doubled, from 136 thousand acreas in 1972 to an estimated 303 thousand acreas in 1979, representing a 122% increase in a period of seven years. The growth of urban and build-up areas takes a heavy toll on both farmland and rangeland; about 65% of the urban growth came from rangeland and 35% from farmland. It has been found that water plays a major role in changes of land use pattern. About 55 thousand acres of rangeland have been converted to farmland because water is made available for irrigation purpose. However, the loss of agricultural land to urban expansion has more than offset its increase due to the availability of water. As a result, Maricopa County has experienced a net loss of 15,000 acres of farmland and 186,000 acres of rangeland to urban expansion in seven years.

The framework developed in this study for monitoring land use changes using remote sensing and computer information system is a viable approach to provide timely information for land use planning purpose. It may not be a viable approach to generate information for purposes requiring a higher level of accuracy. Since total costs of conducting such an investigation have not been accounted, the feasibility of using such a framework for monitoring land use changes by states and local communities remains to be explored.

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