

BIOGRAPHICAL SKETCHES

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REGIONAL LAND USE MAPPING: THE PHOENIX PILOT PROJECT

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INTRODUCTION

Regional land use mapping and inventory should be a major component of effective regional analysis. Land use maps, topographic maps, soil maps, as well as other kinds of maps can be effective tools in the planning and management of land resources. However, if land use maps are to be used effectively in making planning and management decisions at local, state, and national levels, such maps and inventories should be accurate and up-to-date, and should provide the appropriate information in a format most useable for planning and management purposes.

Numerous examples of national, regional and local programs which have utilized aerial photographs effectively in land use inventory and mapping can be cited. A few are briefly mentioned here to illustrate how widely the aerial photograph has been accepted as a tool in carrying out inventory and mapping programs at different scales of refinement and detail.

Currently Canada is conducting a land inventory for all of Canada that has been settled, which is approximately 800,000 square miles. In this inventory an effort is being made to assess and map land "according to its capabilities for various uses" and then relate these uses to various social and economic conditions. To do this in an intelligent manner there is "a need to collect a mass of information on the land's characteristics, and to organize this knowledge so that it can be put to good use."¹ The inventory is a cooperative project between the several provinces and the federal government, which is being conducted under the Agricultural and Rural Development Act.

¹The Canada Land Inventory, Department of Forestry and Development - Canada, Ottawa, 1966, p.1.

Recognizing that conventional maps have data limitations which need to be complemented by other analytical techniques, a geo-information system has been developed in order to cope effectively with the storage, analysis, and presentation of many different kinds of data about the many characteristics of land and the numerous physical, social, economic, and other conditions affecting the use of land resources. Aerial photography is being used extensively in collecting the great variety of information inputs for the Canadian land inventory and airphoto interpretation is being used as an analytical tool. However, the use of the computer is the major new dimension in land inventory presently being carried out in Canada.

Another example of an integrated survey which made extensive use of aerial photographs and of the techniques of airphoto interpretation in a semi-detailed land use mapping program was the Proyecto Aerofotogrametrico OEA-Chile. This survey covered nearly all of the agricultural land of Chile. Land use information was needed more or less simultaneously for a number of different purposes including (1) the design of a new taxation program for rural areas; (2) research and planning for land reform; and (3) for agricultural development and conservation of soil resources. By sharing the costs of the survey among several related programs it was possible to make the land use survey economical.²

In the late 1940's Francis J. Marschner, working in the former Bureau of Agricultural Economics of the U.S. Department of Agriculture, undertook the compilation of land use information at a scale of 1:1,000,000 by using aerial mosaics, which had been prepared as index sheets for the aerial photography then available for the United States. These unpublished maps, now preserved in the National Archives, constituted the most comprehensive single attempt to make a thematic map of land use for the United States. The map, which was a generalization of the unpublished maps compiled by states, was published in 1950 under the title,

²Physical Resource Investigations for Economic Development: A Casebook of OAS Field Experience in Latin America. General Secretariat, Organization of American States, Washington, D.C. 1969, pp. 288-293.

Major Land Uses in the United States at a scale of 1:5,000,000.³ Thus the use of airphoto interpretation in making a definitive study of the major uses of land on a national scale was firmly established by the publication of this map.

Another current example of land use and natural resource inventory is being carried out with major reliance upon the technique of airphoto interpretation and computer compilation, storage, retrieval, and mapping and tabular analysis by the Office of Planning Coordination of the State of New York. This inventory was designed specifically to "identify and record how the State's land resources are being utilized" in order to provide the necessary information for the "long range planning of the State's physical resources."⁴

Several aspects of the methodology of the New York land use and natural resource inventory are worth noting. In the first place, the scale of the aerial photography has been specifically keyed to the 1:24,000 scale of existing topographic maps for the State, thus making effective use of earlier large-scale maps. Secondly, the land use classification represents a compromise between the anticipated data requirements of various potential users and the main source of information which was aerial photographs. Thirdly, both land use areas and point data have been identified and mapped. For example, an agricultural area being identified is orchard land. "Active farmsteads" is an example of point data being obtained through airphoto interpretation. In order to make a meaningful generalization of the massive amount of information contained in the 989 maps at a scale of 1:24,000 necessary for total State coverage, a summarization of data by grid cells is being employed. By using appropriate referencing units, such as political subdivisions, several different statistical analyses can be made by use of the computer. Thus there is a clear recognition of the importance of the prompt analysis of inventory data if such information is to be used effectively for a wide variety of existing needs.

³Marschner, Francis J., Major Land Uses in the United States, U.S. Department of Agriculture, Washington, D.C., 1950.

⁴Land Use and Natural Resource Inventory of New York State, Office of Planning Coordination, State of New York, 1969, p. 1.

The Phoenix Pilot Project, which is being carried out under the Geographic Applications Program in the U.S. Geological Survey, has been designed to make effective use of past experience in making land use maps and collecting land use information. The first specific objective of the Phoenix Pilot Project is to make a land use map at a scale of 1:250,000 by using Apollo 9 and aircraft imagery as well as some other supplemental information. In making a land use map at this scale from the sources indicated, it was hoped that at least eight major categories and several subcategories could be identified and mapped. A second major objective in the pilot project is to create a geographically oriented data bank of land use information. It is hoped that a workable scheme can be developed for digitizing land use data on the basis of a one-kilometer grid on the Universal Transverse Mercator Projection and for programming of the electronic computer to print out on call, land use maps, land use information in tabular format, and to make several different kinds of analyses of land use.

Land use information and maps are widely used for a number of purposes, a few of which are cited here as examples.

- (1) In regional and local planning an inventory and mapping of the present uses of land furnishes the most effective base from which to plan needed changes in land uses.
- (2) Officials charged with making assessments for the collection of taxes on land and improvements are very interested in locating uses of land by ownership units. Changes in the use of land and improvements made to land must be carefully assessed if taxes are to be fairly levied.
- (3) State and Federal agencies charged with land management and environmental planning functions must have information about the present use of land resources.
- (4) Utility companies, banks, and other private industries and businesses are interested in land use changes.
- (5) Effective prediction of sediment loads and flood hazards on streams is dependent upon having current information about the distribution of the several different uses of land and the changes in land use that occur. Clearing of forests,

increasing the area of cultivated land, and the expansion of urban areas are examples of changes that greatly affect stream flow.

Among the reasons for selecting the Phoenix quadrangle of the 1:250,000 series of topographic maps of the U.S. Geological Survey were the following:

- (1) Rectified photographs from the Apollo 9 mission of March 1969 have been converted by the U.S. Geological Survey into a photo map which could be effectively used as a base map for land use plotting and analysis.
- (2) Considerable analytical work has already been done in the Phoenix area by the U.S. Geological Survey during the past five years. This meant also that a large collection of recent imagery was available.
- (3) Clear skies and low latitude make it more certain that additional imagery from future manned and other satellite missions will be available for comparative purposes.

SELECTION OF SENSORS

The types of sensors used on NASA aircraft to obtain the images in the Phoenix area were mostly conventional aerial cameras utilizing a variety of film-filter combinations, but some experimental testing was also done with side-looking radar. A very large number of pictures were taken from airplanes flying at altitudes as low as several hundred meters to as high as 18,000 meters above the Earth's surface. Of additional interest were the many color photographs taken from orbital altitudes by astronauts using hand-held Hasselblad cameras. After experimentation, it was determined that the most useful sensor image for geographic research was the color infrared photograph. This was found to be true for studies for both rural and urban areas.

One of the cameras used to photograph the Earth from the Apollo 9 spacecraft contained color infrared film. Another finding from the NASA aircraft program was that multiband photography could be of assistance in the study of man-made features, especially surfaces of concrete, asphalt, and roof materials.

In order to verify the interpretations obtained from the color and multiband photographs, ground information was collected by field teams and from low-flying aircraft. In some cases the airplanes were equipped with metric cameras with long focal lengths which were intended to collect spot type of information as samples of prevailing conditions on the ground. This served as an additional check in the interpretation of the lower-resolution, satellite-type photographs.

DATA COLLECTION

Data being used in the Phoenix Pilot Project include Apollo 9 imagery, photographs taken from both high-flying (17,000 to 19,000 meters) and low-flying aircraft (1,500 to 4,500 meters), and results of ground observation and enumeration. Much pertinent information was also collected from government and commercial offices. The Apollo 9 mission took place in March 1969. The high altitude and low altitude photography, although not taken simultaneously with the Apollo 9 mission was taken sufficiently close in time to be used effectively for preparing a land use map at a scale of 1:250,000 for 1969. Complete photographic coverage from high-altitude flights was not available for the Phoenix Pilot Area, but such photography was available for Phoenix and vicinity where it was most needed. Mosaics of aerial photographs (1:62,500) taken on lower altitude flights were used for selected areas where more detailed information was necessary for effective delineation of land use categories. Ground observations were made in June 1970 to check the actual land use situation against the available imagery. Some use was also made of the Phoenix urban area.

DATA ANALYSIS

A Land Use Classification Scheme for Use with Orbital Imagery

Although it is very unlikely that the one ideal classification of land use will ever be developed or universally accepted, there is a growing appreciation for the advantages of more standardized approaches to land use classification for urban and regional planning and other purposes. In developing a land use classification scheme for application in the Phoenix Pilot

Project, several working criteria were established for the purpose of giving guidance in adopting a workable scheme of classification for mapping land use in the Phoenix area.

Among the criteria used were the following:

1. A minimum level of accuracy of about 85 to 90 percent or better should be approached in the interpretation of the imagery being used.
2. A well-balanced reliability of interpretation for the several categories included in the classification scheme should be attained.
3. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
4. The classification scheme should be useable or adaptable for use over an extensive area.
5. The categorization used in the classification scheme should permit vegetative and other cover types to be related to be activity-oriented categories whenever possible.
6. The classification scheme should be suitable for use with imagery taken at different times during the year.
7. The classification scheme should permit effective use of sub-categories that can be obtained from ground surveys or from the use of imagery available at a larger scale or with the use of color photography.
8. A need to collapse the categories of the classification scheme into a smaller number of categories must be recognized.
9. Comparison with land use information compiled at earlier points in time and with data that will be collected in the future should definitely be possible.
10. The classification scheme should recognize the multiple-use aspects of land use whenever possible.

The following classification scheme was adopted for use in the Phoenix Pilot Project.

Land Use Classification Scheme for Mapping
Land Use from High-Altitude Imagery in the
Phoenix Area

I. Agricultural

- A. Cropland (All cropland except orchards, groves, and vineyards. All cropland will be irrigated in the Phoenix area.)
- B. Orchards, Groves, Vineyards (A more permanently established cover type than generally exists for other cropland.) All of this use will be irrigated in the Phoenix area.

II. Grazing

- A. Rangeland
- B. Pasture (irrigated) may need to be included as part of cropland (IA)

III. Forestry

- A. Arid woodland (Generally of little commercial value for timber or wood products but may be of value for watershed protection, grazing, wildlife habitat, and recreation.)
- B. Forest Land (Very little such land will be found on the Phoenix Quadrangle.)

IV. Mining and Quarrying (There is no oil or gas production on the Phoenix Quadrangle.)

V. Transportation, Communications, and Utilities

- A. Highways
- B. Railroads
- C. Airports

VI. Urban Activities

- A. Urbanized Areas (1970 definition not yet determined by the Bureau of the Census)
 - 1. Industrial

2. Commercial
3. Residential
4. Other

B. Other Urban (Populated places of more than 2,500 but not including urbanized areas)

VII. Towns and Other Built-Up Areas (With a lower areal limit which is identifiable through interpretation)

VIII. Recreational Activities

- A. Mountain Oriented
- B. Desert Oriented
- C. Water Oriented

When this adopted land use classification scheme was evaluated against the established criteria, it was obvious that all of the criteria could not be satisfied immediately by the classification scheme. Some of the criteria are not always satisfactorily met in classification schemes used in conjunction with field or enumerative surveys. It has been possible to meet some of the criteria more easily than others. Generally, however, the adopted land use classification scheme has worked satisfactorily when used with Apollo 9 as well as aircraft imagery available for the Phoenix Pilot Area.

In developing the land use classification scheme for the Phoenix area, it seemed highly desirable to maintain effective rapport with existing schemes of land use classification that are currently in widespread use. The more basic the categorization used in a classification scheme, the more variable the uses that can be made of the classification. Categories containing a combination of two or more discrete land uses have been avoided, since a grouping of uses during the interpretation stage would prevent alternative groupings from being made later.

Interpretation of Imagery

The preparation of the land use map of the Phoenix quadrangle in Arizona was done in the following steps.

First, two of the Apollo 9 photographs were put together to fit the existing map of the Phoenix area. These photographs served as the base for the land use map. Study of the Apollo photographs permitted the selection of areas with more intensive land use, such as settled areas and irrigated cropland. For these areas, aerial photographs were procured. For most of the area, the Apollo photographs are the best quality recent photographs available. To supplement the Apollo photographs, mosaics of aerial photographs taken by the U.S. Department of Agriculture during February 1970 were used. The aerial photographs and orbital photographs were found to be mutually supporting, especially for delimiting cropland boundaries and the urban fringe of Phoenix. The clutter in the aerial mosaic is clarified by the Apollo photograph and aided in the delimiting of the urban fringe. Rangeland, a category of grazing, could not be uniformly isolated at a desirable level of reliability. This problem was particularly noticeable when arid woodland types were being used for grazing, as they frequently are in southwestern United States.

It was found that, where choices of film types were available, color infrared photographs proved to be the most useful for the interpretation of land use. For the Phoenix metropolitan area, NASA had provided multispectral photography, including color infrared, conventional color, and multiband photography. Of the multiband photographs, the red band of the spectrum produced the clearest pictures of urban areas. The photographs that were taken from satellites or from very-high aircraft were so small in scale that it was difficult to separate the residential from the commercial districts. Some differences in texture were detectable between urban and commercial districts; however, lower altitude photographs, or other supplemental data, were needed for accurate identification of commercial districts of Phoenix.

Since it is improbable that a complete well-balanced land use map can be compiled solely from orbital and aerial imagery, it seems desirable to supplement these useful sources of information with other land use data when available. Use of inference by knowledgeable persons, which is based on such supplemental information, will probably continue to be much needed at least until further technological improvements have been made in remote sensors and until a more standardized approach to interpretation has been developed.

The actual drawing of the land use map was done on a

sheet of transparent plastic which was overlain first upon the Apollo photographs and verified by overlaying upon the published topographic map of the Phoenix area at this same scale. In this way, the boundaries of the land use patterns could be aligned more accurately with the roads, streams, canals, and other topographic features, and with governmental boundaries. The land use patterns were then represented in color on the finished map. It should be noted that this map was not intended for publication; it was intended as a working tool in reading off the land use data into a computer.

After the land use map was completed, a grid overlay of lines spaced one kilometer apart was placed upon the map. The land use at each grid intersection was identified and recorded on computer tape for future analysis, automatic updating, and print out in map form.

Auto-Processing of Interpreted Imagery

In addition to making a land use map of the Phoenix area at a scale of 1:250,000 by combining the use imagery from high altitude aircraft and satellites, the Phoenix Pilot Project was designed to devise a system for land use data collection, storage, retrieval, and up-dating. Such a digitized data bank is almost absolutely necessary if large masses of data are to be handled efficiently and economically. Since the analysis of land use changes is considered to be a prime objective of any future national program of land use mapping and inventory, it will be important to employ prompt and accurate data processing techniques.

One of the important components of electronic computer handling of data will be a means of geographically isolating cells of information about land use. In the pilot project it was decided to use a 1 km² cell keyed to the Universal Transverse Mercator grid. Since each UTM grid unit is a square of constant size, the use of this grid makes computer handling of data easier. In order to compare data obtained mainly from the use of remote sensing techniques with information available from other sources, several different identification codes are being keyed to the 1 km² cells. Thus it will be possible to group these cells by counties, census tracts, watersheds, land management agency areas, and in other ways that may be needed.

Highways will be read from photographs and recorded as changing line patterns in the computer data bank. Other line patterns such as railroads, which rarely change significantly at this scale and within a short time frame, will be shown as a fixed overlay on the printed map output. Each of the land use categories and line patterns will be shown in a different color. In order to increase the value of the data bank for purposes of planning and management, a soils map is also being placed on computer tape. These soils data will be allocated to the same one-kilometer grid points.

At each kilometer grid point the date of the photograph from which the land use was interpreted is also recorded. Presumably, the land use information in the data bank will be updated at intervals of one to five years, depending on how rapidly changes in land use are occurring. If good geometric control is maintained, the computer can report changes occurring at each grid point at each updating. Thus, a map of land use change could be printed out automatically on the computer.

This spatial identification of interpreted uses of land will form an important basis for further study of land changes that are occurring. Prompt, efficient, and flexible analysis of the changes is necessary if a data bank of land use information is to be an effective tool in regional land use mapping and inventory. It will also be essential to have the capability to relate the present land use situations and the changes that occur from time to time to other characteristics of land. Some examples of influences on land use are natural soil, slope, and climatic conditions; assessed and sale values; size and type of ownership units; distance from centers of population of various size; and access to different types of transportation.

CONCLUSIONS

Some conclusions reached from the Phoenix Pilot Project are:

- (1) Land use maps and accompanying statistical information of reasonable accuracy and quality can be compiled at a scale of 1:250,000 from orbital imagery.
- (2) Orbital imagery used in conjunction with other

sources of information when available can significantly enhance the collection and analysis of land use information.

- (3) Orbital imagery combined with modern computer technology will help resolve the problem of obtaining land use data quickly and on a regular basis, which will greatly enhance the usefulness of such data in regional planning, land management, and other applied programs.
- (4) Agreement on a framework or scheme of land use classification for use with orbital imagery will be necessary for effective use of land use data.

GLOSSARY

Data bank is a term used to indicate the information stored in the electronic computer.

Mosaic is a composite of aerial photographs.

Print out in map form refers to the capability of the electronic computer to make a map by printing symbols of various kinds on a sheet of paper.