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A LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE-SENSOR DATA

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ABSTRACT

New demands on our land resources require more stringent controls and management practices. The administration of these controls requires better and more frequent information concerning land use. Although new tools became available to aid in acquiring and processing the data, a major lack in uniform techniques for identifying the land use was a major problem. Creation of a more standard form of classification of land use, based on the capabilities inherent in the various forms of remote sensors and other data sources was a necessary step.

A classification has been created, and published in preliminary form, by the Geological Survey of the United States Department of Interior. It is presented as Geological Survey 671, entitled "A Land Use Classification System for Use With Remote-Sensor Data". This paper discusses the origin, development, and controlling influences of that classification system.

The desire for information about land use is not a new phenomenon. In fact, the concept of the Cadastral Survey dates back to early mideastern settlement and includes information about land use as a major part of the Cadastral Survey. Land use and land capability were associated, even then, in developing a sound basis on which to establish taxation policies.

What is new is the fact that we, in this country, and several others have used land lavishly, and are now faced with difficult decisions that require more information than we now have readily available. The pressure on our land resources stems from a number of sources, but includes at the top of the list increased population and an economic system that provides the highest profit to those who exploit our best resources first.

Other new things relevant to the problem include an awareness at many levels of government of a need for a new approach to management of the land resource. Attempts at the local level to control land use through zoning have been less than effective in most areas. But there is a genuine reluctance in all parts of the country to undertake regulated zoning at the higher levels of government. This is due to the historical precedent of giving zoning powers to the local government units. Some notable exceptions are just now starting their long struggle for validation through the court systems. Examples include the new concept of state agencies with New York State's Adirondack Agency and the Coastal Zone legislation now operative in New Jersey, some of the New England states, and along parts of the eastern seaboard. Others are the Agricultural Districts legislation of New York State, permitting land owners to create their own areas of land use control, and in some states such as Vermont statewide legislation is being used as a source of land use control.

All of these examples have at least two things in common. First, they seek to control and guide the development and use of the land resource. Second, they need, in fact require, a great volume of information about land use to meet their objectives.

Two new fields of science, apparently completely unrelated to the above situations, now provide opportunities to gain the information needed in solving our land use problems. They are

remote sensing and data processing. Early research projects on the suitability of remotely sensed data for land use classification were revealing and generally quite successful. A study sponsored by the USDA and undertaken at Cornell University showed the possibility that remotely sensed data obtained at scales of up to 1:3,000,000 could provide suitable data for certain kinds of land use information.[1]

Although this paper will not deal with either topic specifically, it does present information on the background, origin, and performance of a land use classification system that allows remotely sensed data to be managed in a manner suitable to the needs of machine processing. This is the proposed Land Use Classification System for Use With Remote Sensor Data, published in Geological Survey Circular 671 in 1972 and submitted for general review by users as a necessary catalyst between data acquisition from remote sensors and data processing by machine methods.

It is not difficult to understand our need for more information concerning land use. We need it frequently, at quite high levels of accuracy. It is not difficult, either, to understand how remote sensing can play a major role as the prime source for this kind of information. Airphotos, scanners, and satellite hardware can all contribute to the solution of the problem. And in like manner, we readily understand the need for rapid processing of the data, and we recognize the significance of the part machine processing plays at this point.

What is less easily understood is the failure of the performance of the remote sensors and the data processors in acquiring the needed information without a firm or basic understanding of certain levels of standardization. A solution to this point of failure can be found in the development and application of a classification system based on the capabilities of the remote sensors and manageable within the format constraints of automatic or semi-automatic data processing techniques.

The new tools have been tested and found productive, if not yet satisfactorily efficient. It is time now to provide the missing ingredients necessary for the system to perform satisfactorily.

Land use classification systems have been developed in the past. The suggestion to simply adapt one of the existing, more or less accepted, classifications was frequently offered. But that was not an easy or satisfactory solution to the problem. Most classifications of the past are based on knowledge that is not available from remote sensors. Also, many are patterned after biological classification systems, where fragmentation into suborders and classes is the basic technique used to accommodate information. In land use classification, a more usual step is to aggregate groups into larger categories rather than rely on continual subdivision.

There were very few experienced people to call on for assistance. Few have actually developed and applied a land use classification system for as large an area as a whole state. Far fewer have considered the problems inherent in developing a land use classification suitable for nationwide application.

As these problems were becoming evident, researchers were attempting to test the utility of the imagery provided by satellites and high altitude aircraft. It was evident to the various groups working on imagery from various parts of the country, that a major barrier to progress in their research efforts was the lack of any form of a standard land use classification suitable to their needs. This was strong evidence that effective use of the new tools in generating a nationwide land use inventory would not be possible until the problem of land use classification was resolved.

INTER-AGENCY STEERING COMMITTEE ON LAND USE INFORMATION AND CLASSIFICATION

In 1971 an Inter-Agency Steering Committee on Land Use Information and Classification was formed under leadership provided by NASA and the EROS program of the United States Department of Interior. Representation on this committee was obtained from the United States Department of Agriculture, the Geological Survey of the United States Department of Interior, Earth Observations Program of the National Aeronautics and Space Administration, the Soil Conservation Service, as well as the Association of American Geographers, and the International Geophysical Union. Chairman of the Inter-Agency was Dr. Arch C. Gerlach, Chief Geographer of the Geological Survey, until his death in May, 1972. Shortly before this, Dr. James R. Anderson was appointed acting chairman of

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[1] Belcher, D. J., E. E. Hardy, and E. S. Phillips, "Land Use Classification with Simulated Satellite Photography", Agriculture Information Bulletin No. 352, Washington, D. C., 1971.

the committee, and since that time has been appointed Chief Geographer of the Geological Survey.

The Inter-Agency Committee had two objectives. One was to sponsor a national conference on Land Use Information and Classification in order to bring together federal, state, regional, and local land use planners to discuss their mutual land use data and classification needs. A conference to meet that objective was held in Washington, D. C., in June, 1971.

The second objective of the committee was to review and analyze existing land use classification schemes and to develop a classification system capable of using high-altitude aircraft and satellite data. This classification was to serve as the basis for the preparation and rapid updating for national and regional inventories which could provide an overview of land use changes, trends, and potential environmental impact of policy decisions.

The conference was attended by 153 invited representatives of agencies from federal, state, and local levels. After presentations from a number of experts in various fields including airphoto interpretation, computer sciences, remote sensing, etc., the participants formed group discussions recording what their agencies needed in the way of land use information to perform their functions. This large group developed a list of eleven land use categories they would like in Level I of the classification. They were:

I Urban and built-up
II Transportation, communications, and utilities
III Farming (agriculture)
IV Grassland (grazing)
V Forest land (forestry)
VI Extractive
VII Water
VIII Marshland
IX Tundra
X Barren land
XI Permanent snow fields

The outline for Level II as approved at the conference varied somewhat from the original Level I categories. This problem was later resolved by the Conference Steering Committee. The Conference approved Level II classification was:

I Urban and built-up

A. Residential
B. Commercial (trade)
C. Industrial (manufacturing)
D. Services
E. Recreational
F. Transportation
G. Other

II Transportation, Communications, and Utilities
No subcategories proposed at the time.

III Farming (agriculture)

A. Cropland
B. Pasture
C. Orchards, vineyards, horticultural areas

IV Grassland (grazing, rangeland)
No subcategories proposed at the time.

V Forest Land (forestry)
No subcategories proposed at this time.

VI Extractive (mining and quarrying)
No subcategories proposed at the time.

VII Fishing
No subcategories proposed at the time (dropped at later date).

VIII Water

A. Lakes
B. Streams
C. Ponds
D. Reservoirs

IX Low Activity Land

A. Marshland
B. Tundra
C. Barren land
D. Permanent snow fields

This was the final state of the classification categories as prepared by the conference. Dr. Gerlach closed the conference with the reminder that the land use classification scheme must be decided on soon because there was a need to utilize the NASA high altitude flights and satellite coverage as rapidly as possible for optimum results.

Through the discussions and talks presented at the conference, a rather natural ordering of levels of input, complexity, and acquisition became apparent. It was soon realized that a Level I classification system could be accomplished through the use of satellite imagery. Level II would be produceable through the use of a combination of satellite and high altitude imagery. A limited amount of back-up data in the form of 1:250,000 maps might be available. Level III could be accomplished through the use of high altitude photography, regular aerial photography, and a substantial amount of supplementary information. Subsequent levels, such as IV and V would require larger scale photography and increased amounts of supplemental data.

In similar manner, each level in the classification would serve users with various "levels" of interest. (In a general way, Level I would be of interest to people wanting data on a national basis, while Level II would serve the same purpose for those interested in state or regional data. Levels III and IV are expected to be of use primarily to users of local information and will be developed and tailored to more nearly meet their specific needs.) It would be desirable for the detailed levels (III, IV, and possibly V) to be aggregatable to the higher levels, I and II. In this way, highly accurate, detailed information may also be incorporated into the data used for national surveys.

The classification scheme was to be developed in a systematic way, based on levels, each of which had particular application or had parameters defined by technological restraints. A four-level system was devised in which Levels I and II can be used with satellite imagery and imagery procured by high altitude aircraft. These two levels, after compromises, meet many of the demands of the federal agencies included in the Inter-Agency Steering Committee for land use information. Levels III and IV are expected to be developed by the state and local users of land use data and should be tailored to closely fit their needs.

After the National Conference of June, 1971, the Inter-Agency Committee met and appointed a subcommittee headed by Dr. Anderson to prepare a tentative land use classification scheme for Levels I and II with definitions for the land uses classified in those categories. That committee published its preliminary report in the spring of 1972. Suggestions for alterations were welcomed and each was carefully reviewed and tested.

PREPARATION OF THE LAND USE CLASSIFICATION SCHEME, LEVELS I AND II

Work on the classification scheme was undertaken by Dr. J. R. Anderson, Dr. E. E. Hardy, and John T. Roach. The Inter-Agency Committee had assisted in making a number of decisions that became major guidelines in preparing the classification. Some of the parameters of restraint included:

1. The classification must serve the needs of the federal agencies that had requested it.
2. It must be operable at economic levels of input.
3. It should make use of the numerous sources of data from high altitude and satellite sensors.
4. It should be applicable by use of manual or automated techniques.

5. It must be comprehensive for the whole of the United States including Alaska and Hawaii.

6. The classification must be based on direct interpretation criteria. There can be no prediction of future development in land use.

The subcommittee, through previous experience in developing classification systems, recognized a number of other guidelines to adhere to. These included:

1. Recognition of the user's needs as the major guide in developing a classification.

2. Understanding the capabilities of remote sensors in terms of detecting differences in land use.

3. Realization that land use and land cover are not identical but that land cover is an excellent indicator of land use.

There are a number of firm requirements that, if met, allow a classification system to be more valuable over time. Therefore, we deemed it necessary to think of the classification as being flexible, to allow a certain amount of change as time progresses and to accept new information and new techniques. It must be repeatable to guarantee its continued value over time. This allows trends to be determined. Also, it must be comprehensive in terms of area coverage.

In addition, the classification unit descriptions received detailed attention. A classification should be designed to provide three major characteristics:

Unique description - Each unit should be thoroughly described in terms relative to the source of information about the unit. If airphotos are to be the source of information, then the unit should be described in terms relative to what can be identified from aerial photos at the scale to be used. A good description describes what the unit is and also what it is not. The description should be so thorough that there is little opportunity to make incorrect assignments. In a situation where the mapping units are formed by a partitioning of a continuum, the "exact" location should be specified.

Discreet assignment - Each land use should have one and only one proper or acceptable designation within the classification system. There should be no room for confusion concerning which classification unit a land use area should be assigned to. There should never be any doubt that what is called forest in one part of the country will be called the same in other parts of the country. The greatest aid to discreet assignment is a good description. It should be as long as necessary to help the classifier in his decision making process.

Comprehensive assignment - There should be a place in the classification system for every land use type encountered by the classifiers. In most cases there is a need for a unit called "other". But even the items to be included in "other" should be specified in detail and limited in number within reason.

With the guidelines well defined, a small committee undertook the analysis of the directives from the conference and the preparation of the Level I and Level II classification system. Potential users were contacted, and exhaustive discussions were held regarding the classification units and descriptions that would satisfy the users' needs. This effort was applied to all the items in the levels of the classification that have been developed.

After the discussions, airphotos and other forms of remotely sensed data were examined to guarantee the land use unit could, in fact, be identified and that the description of that unit was at least adequate for the identification process. Many compromises were made. But after a number of visits to a great many agency representatives, a tentative land use classification was published. The original paper was 97 pages in length. From that paper, a condensed revision was prepared and published by the Geological Survey as Circular 671. It is entitled "A Land Use Classification System for Use With Remote Sensor Data". Some of the historical perspective and system constraints are treated at greater length in the original document. Of course, the land use definitions are in abbreviated form.

APPLICATION OF THE CLASSIFICATION SYSTEM

Circular 671 has received wide circulation, and the predictions made by attendees at the conference of June, 1971, have been borne out. Although it is a preliminary version of a classifi-

cation system, it has received widespread experimental use and attention. The publication is not final. There are opportunities for changes to be incorporated into the system, provided they meet the rigid restraints imposed by the use of remote sensors as a source of data, and others related to the guidelines established at the 1971 Conference.

We are constantly reminded by users that they do not have any areas of permanent ice and snow cover. And we agree, but a lot of the country does have. Or a western office might express concern that we have not given rangeland an exclusive listing. But it is not possible, from a remote sensor, to distinguish western rangeland from eastern pasture or from wildlife habitat. Consequently, all must be accommodated in the same unit.

Two other illustrations of application technique problems should be pointed out. It is not possible to identify land ownership from a remotely sensed source of data. Consequently, attempts to accurately identify such categories as publicly owned land, recreation land, etc., at Levels I and II are bound to be failures. And another problem occurs when more than one use is made of the same resource, such as forestry and recreation. Consequently, the most logical approach to use, when restricted to only remotely sensed data, is to identify the land unit only in terms of what can be seen from the source of data. This often calls for an arbitrary decision, but it is required if the goal of uniformity is to be maintained.

Several research projects within federal agencies are applying the classification as currently described in Circular 671. In addition, a number of Principal Investigators reported on its use at the NASA Symposium on the use of ERTS-A data in March of this year.

Although there is not complete agreement among the users of the classification, the majority of comments seem very favorable. Many report very good successes with the Level I categories, and this appears to hold up reasonably well for both automatic processing and manual applications.

Not as many researchers have reported as much success at Level II. However, in discussions with the ingestigators it was evident they are trying to obtain the Level II classification with essentially the same techniques as they applied for Level I. The classification is not designed to be used in that manner. Also, it is evident there is more success at Level II with higher inputs of human skill in preparing the data. Several researchers have indicated success at generating selected data for the III and IV levels from satellite imagery. This is encouraging. But it should be remembered that Levels III and IV have not been generated yet, and are expected to be developed by local users to more nearly fit their specific needs.

There are many applications already in discussion or underway that will rely on the current classification. The system has not been finalized. And it should be kept in mind that the classification, as currently presented, is preliminary.

SUMMARY

In summary, the goals established by the cooperating agencies have been fairly well met. A classification system for use with remote sensor data has been prepared, and is currently being tested in many parts of the country. It is still in the experimental phase, but current indications are that it is a reasonably satisfactory classification for the uses for which it was designed. It is still undergoing revision, and your suggestions are welcomed so that the scheme will constantly be proceeding toward the goal of an accurate, useful classification system.