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Land-Use Classification Schemes

—used in selected recent geographic applications of remote sensing.

ABSTRACT: *The author is concerned primarily with the problem of developing land-use classification schemes which can be used with orbital imagery for making thematic maps of land use in the United States ranging generally in scale from 1:250,000 to 1:2,500,000. Briefly, some background on approaches to land-use classification based mainly upon aerial photographs that have been used in the United States gives a perspective to the review of the recent attempts to develop systems of land-use classification that would be useable with imagery from remote sensors placed in orbiting spacecraft.*

To provide a framework for review and evaluation of some attempts that have been made at developing a suitable land use classification scheme for use with orbital imagery, several criteria are proposed. These criteria are not intended to be all-inclusive or precise enough to give a highly refined evaluation. A review and evaluation of the land use map prepared by Prof. Norman J. Thrower and colleagues at U.C.L.A. from Gemini and Apollo imagery, which has been made against the standards set forth, hopefully will serve to direct attention to some of the serious problems that must be resolved before effective classification schemes can be developed for use with orbital imagery. Several recommendations are then presented as guidelines for further study. Finally, two tentative land-use classification schemes are proposed for further testing with orbital imagery.

BACKGROUND

THE COMMISSION ON Geographic Applications of Remote Sensing of the Association of American Geographers has undertaken during the past three years to study some of the implications of making thematic maps of land use from remote-sensor information such as that expected to be available from future spacecraft missions. An integral part of any land use mapping program is the selection of a suitable classification scheme for use at a specified scale, for a designated area, and within the capability of the information-gathering techniques being used.[1]

Past efforts of land use classification research are strewn with many valiant attempts to find an all-purpose classification scheme for mapping land use which would satisfy the great variety of needs that exist for land-use maps. Although it is very unlikely that the one ideal classification of land use will ever be developed, 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 the context of the present concern with making a land use map with major reliance upon orbital imagery, the land classification scheme employed by the Tennessee Valley Authority in the 1930's has considerable significance.[2] This significance stems from the detailed attempt to develop a technique which would permit several important or major characteristics of land to be related to one another and from the extensive use made of aerial photographs in a major effort to deal with land use problems.

With sophisticated computer technology now widely available, it may be appropriate

[1] These studies have been conducted under contracts with the Geographic Applications Program of the U. S. Geological Survey.

[2] *The Rural Land Classification Program: A Summary of Techniques and Uses*, Land Classification Section, Division of Land Planning and Housing, Tennessee Valley Authority, December, 1935.

for geographers to re-examine carefully the possibilities of identifying and classifying land uses in relation to other major attributes of land which are associated with its use. Often such relationships need to be identified and classified. Thus today, a scheme for the classification of land use should be developed and tested in the context of the greater need to provide a more comprehensive approach to the analysis of land resources. Computer technology and much more refined approaches to remote sensing are now available for such an analysis.

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 was published in 1950 under the title, *Major Land Uses in the United States* at a scale of 1 :5,000,000.[3] Thus the use of aerial photographs in making a definitive study of the major uses of land on a national scale was firmly established by the publication of this map.

In compiling the map of major land uses mainly by using air-photo index sheets available for most counties in the United States at a scale of one inch to one mile, Marschner developed a classification to fit this main source of information which he was using. However, he was also careful to retain comparability with existing land use classification schemes being used in the Census of Agriculture and by various Federal land-management agencies such as the Bureau of Land Management and the Forest Service.

The resulting classification was predominantly morphological, yet the categories were selected and defined to permit a generalized transfer to a functional classification of land use. Terms such as grassland, marshland, and swamp were used. As Marschner relied mainly on air photo mosaics, it was not possible to determine with confidence the actual use of areas having such vegetative cover. Use of supplemental information from other sources would have permitted a more functional approach to the classification of land use. For example, records available from various Federal land management agencies give some indication of the use being made of the land for which these agencies are responsible.

Statistical information from the Bureau of the Census also permits at least a generalized translation of a morphological classification to a functional orientation. A more refined and compatible approach to using information available from air photos and other imagery sources in conjunction with statistical data should be developed. Use of computer technology now available could greatly facilitate the use of different data sources for purposes of gathering and analyzing information about the use of land resources.

In the 1950's and 1960's much attention was being directed to urbanization and its impact on patterns of land use in the United States. Many city and local planning groups have been very busy preparing maps of existing land use in order to plan more effectively for further expansion of the urbanized areas. In 1965 a *Standard Land Use Coding Manual* was prepared and published jointly by the Urban Renewal Administration and Bureau of Public Roads. In the foreword to the joint report it was recognized that "this edition is only the initial effort to develop a uniform coding system." It was further strongly recommended "that where appropriate the detailed system of categories presented in this publication be used for the collection and coding of information describing land use activity."[4]

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."[5] The inventory, which is relying heavily on aerial photography, is a cooperative project between the several provinces and the federal government, which is being conducted under the

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

[4] *Standard Land Use Coding Manual*, Urban Renewal Administration and Bureau of Public Roads, Washington, D.C., 1965.

[5] *The Canada Land Inventory*, Department of Forestry and Rural Development, Ottawa, Canada, 1966, p. 1.

Agricultural and Rural Development Act.

Another current example of a land use and natural resource inventory is being conducted with major reliance on the technique of air-photo 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."[6]

Concern is growing about the timeliness of mapping efforts, because agencies and groups financing projects are interested in the resulting analysis for planning and other action-type purposes. In the past one of the most difficult problems to resolve has been to complete maps of land use so that they are still of current value. Hopefully, the use of remote sensors from spacecraft might help to solve this problem at least for the preparation of land use maps at scales ranging from 1 :250,000 to 1 :2,500,000.

Criteria for Evaluation

A set of working criteria against which to evaluate land-use classification schemes for use with orbital and other high altitude imagery is presented here. Use of such criteria is suggested as one approach to gaining a better understanding of current problems related to developing effective classification schemes for use with remote sensor imagery. These criteria apply mainly to classification schemes developed for use at intermediate scales ranging from 1 :250,000 to 1 :1,000,000 for the United States. Furthermore, the potential users of maps and data which might be made available at the above-indicated scales are assumed to be state, federal, and other agencies or users needing information for regional and national planning purposes.

Criteria which seem appropriate for evaluating such land use classification schemes are:

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.

If this level of accuracy can be reached the results would be nearly comparable with the level of accuracy attained by the Bureau of the Census in obtaining information about land use by enumeration in the Census of Agriculture, which is taken every five years. Generally, under-enumeration has been running between 5 and 10 percent as shown by post-enumeration checking. There is also considerable difficulty in enumerating certain land use categories properly. Particularly difficult have been such categories as cropland used only for pasture, cropland not harvested and not pastured, and other pasture.

2. A well-balanced reliability of interpretation for the several categories included in the classification scheme should be attained.

Closely related to the requirement of a minimum over-all level of accuracy is the matter of varying levels of accuracy which can be attained for the several categories of the classification being used. Irrigated land can be recognized with a high degree of reliability in Arizona but greater difficulty is experienced in differentiating dark, bare, rock areas from low, dark green, desert shrub areas. Therefore separate categories for dark bare rock and green desert shrub areas should not be attempted, but a combined category would yield a level of reliability in interpretation approaching that possible for irrigated land in Arizona.

3. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.

Also associated with the accuracy problem is the need to have clear and sharp definitions of land use categories which can be used without major modifications from one time to another. It must be assumed that many persons will be involved in the interpretative process. It will also be very important to have a scheme of classification that can yield comparable results each time the monitoring or sensing is repeated for a given area.

4. The classification scheme should be useable or adaptable for use over an extensive area.

An open-ended approach which will permit a great deal of flexibility will be highly desirable. Categories will need to be added as the classification is applied over a larger area. Thus the classification for the United States should be adaptable for use on a world-wide basis by adding appropriate categories. Where varying combinations of land uses are included in the same category, it is very difficult to extend the application of the scheme of classification beyond the area for which it was originally intended. The classification used by Marschner for the map of *Major Land Uses in the United States* has this disadvantage.

This is a very difficult requirement to attain satisfactorily in a land-use classification scheme to be used over a wide range of physical and cultural conditions. Either the categorization may become highly generalized and rather meaningless or so detailed that comparisons from one set of physical and cultural circumstances to another will not be possible. A recognition of the need for different classification schemes for such contrasting circumstances as are present in the high latitudes, humid mid-latitudes, dry lands, and wet tropics is a possible solution. Such an approach to the classification of land uses over an extensive area would of course need to accommodate problems of overlapping categories in transitional situations.

5. The categorization used in the classification scheme should permit vegetative and other cover types to be used as surrogates for activity-oriented categories wherever possible.

[6] *Land Use and Natural Resource Inventory of New York State*, Office of Planning Coordination, State of New York, 1969, p. 1.

This standard will be a difficult one to meet uniformly but in a number of important instances information available from other sources can be used to make such a transfer possible. For example, in an area where statistical information available for a given areal unit, such as a county, indicates that nearly all short grass rangeland is being grazed, it will be possible to use the vegetative cover type of short grass as a surrogate for land used for grazing. However, mixing of categories from morphological and functionally oriented classification schemes should be avoided.

6. The classification scheme should be suitable for use with imagery taken at different times during the year.

Although imagery taken in the winter over North Dakota would probably have little value in classifying land use, it is probable that imagery for Florida made during the winter months would be far more useful than that taken during the summer months when cloud cover would be a problem. Thus winter imagery for Florida might be used in conjunction with summer imagery from North Dakota for the most effective interpretation. Therefore, the classification scheme being used should accommodate such a situation.

Much more study of this seasonality problem will be needed in order to permit effective use of the same classification scheme over an extensive area. Just what is the probability at various times of the year of getting satisfactory imagery for the identification of as many land uses as possible? This is a question that needs an answer for differing weather situations which markedly affect effective remote sensing operations. Of course, for some areas there may be little likelihood of obtaining any imagery at all.

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.

Generally, this standard will not be a difficult one to meet. However, care will need to be exercised in using categories having combinations of uses in order to permit meaningful sub-categories. For example, in revising the map of *Major Land Uses in the United States* for inclusion in the *National Atlas of the United States*, it was necessary to have a category designated as "cropland with grazing land." This is not a satisfactory category if a further breakdown is contemplated at a larger scale, because it will probably be possible to establish sub-categories of cropland much more easily than sub-categories for grazing land can be derived.

8. A need to collapse the categories of the classification scheme into a smaller number of categories must be recognized.

A pattern of cultivated summer fallow which might be easily identified along with irrigated cropland as separate categories of cropland in the western United States might be appropriately collapsed into a cropland or arable land category on a worldwide scale of generalization.

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.

In order to permit the careful analysis of the dynamics of land use, it will be extremely important to have as much refinement as possible in the definition of categories.

10. The classification scheme should recognize the multiple-use aspects of land use whenever possible.

This has been an extremely difficult criterion to meet in developing classification schemes for use with ground or field surveys. Therefore, it is perhaps expecting too much to assume that initial efforts in developing a classification scheme for use with imagery obtained from spacecraft-based sensors will yield very concrete results. Yet a growing need exists for this kind of information about land use in the context of both local and regional studies. Therefore, this criterion should be recognized as a standard to be met at least partially if possible.

Obviously the criteria outlined above cannot all be met initially in classification schemes being developed for use with spacecraft-based imagery. Some of them have not always been satisfactorily met in classification schemes being used in conjunction with field or enumerative surveys. It will be possible to meet some of the criteria more easily than others. It is also quite likely that other criteria should be added to this selected list presented here and it will also probably be desirable to make further refinements in the criteria.

By applying selected criteria for preparing a unified scheme for the classification of land use, it is possible to review and evaluate some of the recent exploratory research in developing classification schemes that are useable with remote-sensor imagery such as that which may be obtained from sensors placed in orbiting spacecraft. In conducting a review and evaluation of this kind, it is extremely important to bear in mind that the research so far has been largely exploratory in nature and that no refined system of classification has yet been presented by any of the researchers working with orbital imagery.

Furthermore it should be emphasized that even though the present conclusions about a workable classification are tentative and incomplete, this should not be a cause for undue concern. The early attempts of the Bureau of the Census at enumerating land use were beset with many problems. Even more recent efforts to obtain more information about land use and its relationship to other characteristics of land have not always yielded the desired results until after survey and enumeration procedures have been altered. Thus it must not be assumed that the procurement of data on land use for enumerative and field surveys is necessarily of the

highest quality. The techniques of conducting such surveys have been frequently altered and refined. Undoubtedly, the technology of remote sensing for gathering land use information will need to undergo a series of revisions.

Land-Use Mapping of Southwestern United States

Geographers from the University of California at Los Angeles recently made use of Gemini and Apollo imagery to prepare a map of land use for part of southwestern United States.[7] The objectives of this research project were to: "(1) determine what land uses are visible on satellite photography; (2) devise a land use classification system compatible with data obtainable from such imagery; and, (3) construct land use maps at scales of 1:250,000 and 1:1,000,000."[8]

Among the significant conclusions reached are the following which are cited from the abstract of the report:

> "Various land use categories are interpretable from the photography, although some are difficult to distinguish (e.g., unimproved grazing land and woodland). Accuracy was found to be a function of the degree of dependence on spectral characteristics and consequent amount of inference necessary for an interpretation. Nevertheless, the photography proved a useful data source when supplemented by limited field investigations and the geographical knowledge of the investigators. Such imagery certainly would be a valuable tool for mapping and analyzing land use in developing countries, where it would be difficult, expensive, and in some instances impossible to conduct such a survey utilizing conventional techniques of data acquisition."[9]

If placed in the context of land use classification schemes which are currently being used at scales of generalization similar to those used in this study, very little difficulty seems to occur in comparing the land-use map that has been prepared with others that might be made from conventional sources of land-use information.

Using the above selected criteria, an evaluation of the classification scheme used in preparing the map of *Land Use in Southwestern United States from Gemini and Apollo Imagery* is presented here in order to highlight some of the problems being encountered and to emphasize possible future uses of orbital imagery. Numbers used refer to the numbered criteria discussed previously.

1. A clear recognition exists for some serious problems of accuracy or reliability of interpretation for extensive areas covered by this research activity. In assessing their work, the authors make the following significant statements about accuracy of interpretation of orbital imagery:

> "There is a definite relationship between reliability of land use identification and dependence on spectral signatures. At orbital altitudes a single photographic resolution cell represents the integration of a variety of spectral responses associated with a number of phenomena and their condition—i.e., a resolution cell represents a gross generalization (or aggregation) of the area it is imaging. Consequently, generalizing a variety of such cells into land use categories requires sophisticated interpretation and inference."[10]

2. The table showing levels of reliability of land use identifications that is included in the research report for this activity reveals a low level of reliability for unimproved grazing lands, unproductive land, and woodland. Similar problems are also encountered with conventional aerial photographs, particularly on levels of improvement to grazing land. Arid woodland as a land use category should not be difficult to identify, however, on low altitude photography. If non-irrigated cropland had been a more widespread land use type in the area covered by this study, could it have been identified separately from irrigated cropland at a reasonably high level of reliability? This will be an important question to be answered when a land use classification scheme for the entire United States is developed for use with orbital imagery.

3. Concern is expressed by the authors about obtaining repeatable results from one interpreter to another and this reviewer concurs with the conclusion reached about the present use of the available technology in interpreting orbital imagery. The conclusion reached was:

> "Geographical knowledge and interpretation skills are important here, but, since it is doubtful that any two people would discriminate boundaries at exactly the same loci, such identifications will probably be the best possible compromise that judgement permits. Automation techniques would be useful for the high reliability categories, but the other categories will probably require a man-machine interface until their identification can be standardized by a presently non-existent system."[11]

[7] Norman J. W. Thrower assisted by Robert H. Mullens II and Leslie W. Senger and with cartography by Carolyn Crawford and Keith J. Walton, "Land Use in Southwestern United States from Gemini and Apollo Imagery." Map Supplement Number 12, *Annals of the Association of American Geographers*, Vol. 60. No. 1, March 1970.

[8] Association of American Geographers, Commission on Geographic Applications of Remote Sensing. Technical Report 69-3—*Satellite Photography as a Geographic Tool for Land Use Mapping of the Southwestern United States 1 July 1968–31 January 1970*. Prepared by Norman J. Thrower and Leslie W. Senger assisted by Robert H. Mullens II and Keith J. Walton, abstract.

[9] *Ibid.*, abstract.

[10] *Ibid.*, p. 12.

[11] Ibid., p. 12.

4. The classification scheme used in this study of Gemini and Apollo imagery is adaptable for use over a more extensive area. However, categories which have been designated as "grazing land (unimproved)" and "unproductive" will cause considerable trouble where extended to other areas with diverse conditions. Using the level of improvement as a basis for categorization of grazing land as a land use in the United States has caused a great deal of difficulty. In 1954 the Bureau of the Census started to enumerate improved and unimproved grazing land. The results have not been satisfactory and comparability from one enumeration to another has not been achieved.

Terms such as "unproductive," "miscellaneous," "wasteland," "unused," and "other" are widely used in land-use classification schemes as a convenient means of classifying the residual which is generally difficult to classify. The connotation of the terms "unproductive" and "wasteland" is too restrictive. For example, in the context of the classification presently being reviewed, land not useable or not being used for agriculture, grazing, or forestry has been designated as "unproductive." Yet the sandy beaches of Florida, which are practically worthless for such activities, are the State's most prized and most used land. Similarly, the rough, unvegetated or sparsely vegetated mountain peaks and ridges of southwestern United States have an aesthetic value that is very difficult to measure in economic terms. Certainly if the term "unproductive" is to be used, it will be better to use it as a part of a phrase such as "unproductive for agriculture" or "unproductive for forestry."

5. In this classification scheme vegetative or other cover types have been used as surrogates for "unimproved grazing land" and "unproductive land." The use of inference has been clearly acknowledged and effectively applied in this initial effort to make a land use map from orbital imagery.

6. No inherent problems seem to occur in using this classification scheme with imagery taken at different times during the year.

7. Sub-categorization will be possible without difficulty.

8. Collapse of the categories into a smaller number can be easily accomplished if needed.

9. Except for the two categories of "grazing land (unimproved)" and "unproductive," the classification scheme should permit ready comparison with land use information compiled at earlier points in time as well as with data gathered at a future time.

10. Multiple-use aspects are not recognized. Had the authors chosen to do so they might have attempted using inference as an approach to recognizing multiple use in the scheme of classification. For example, both domestic livestock and wild game graze over extensive areas such as the Kofa Game Range of southwestern Arizona. Therefore use could have been made of a particular vegetative cover type and a known landform situation to introduce a category into the classification such as "grazing land used by wildlife and domestic livestock."

In summary, the classification scheme which was used in preparing this land use map from orbital imagery satisfactorily meets most of the selected criteria, but a more consistent attention to an activity orientation in the designation of categories seems desirable. Certainly the preparation of this land use map has given some very helpful initial insights into the problems of making land use maps from orbital imagery.

Remote Sensor Imagery and Existing Schemes for Classifying Land Use

Recently Nunnally and Witmer[12] conducted a land use interpretation experiment to test an interpretation and classification system which would permit interpreting land use in as great detail as possible and which would accommodate the development of classification systems for use with the interpreted data that would allow each researcher to employ an hierarchial arrangement appropriate to his particular needs.

It is often very difficult to fit interpretations of land use from remote sensor imagery into existing land use classifications. Therefore, it is quite logical to identify uses of land on an activity basis in as small an areal unit as possible and with as much separation of uses as possible. By using such an approach, a classification scheme can be developed to fit a variety of possible uses which might be made of interpreted data. The search for a single land-use classification system which will serve all users for all time is a fruitless one. Such an accomplishment is not likely to be attained. However, a need exists for recognizing some common ground that will permit the interchange of data from one classification system to another. The careful identification, as recommended by Nunnally and Witmer, of as many distinguishable uses as possible will offer the best approach to the effective interchange and recombination of data to be obtained from orbital imagery.[13]

Even though the point is well taken by Nunnally and Witmer that it is difficult to fit interpretations of land use from remote sensor imagery into existing land use classifications, it does not seem to this author that an effective classification can necessarily be developed from a specific interpretation of imagery that has been made. An hierarchial arrangement appropriate to a particular need

[12] Nelson R. Nunnally and Richard E. Witmer, "Remote Sensing for Land Use Studies," PHOTOGRAMMETRIC ENGINEERING, May 1970, pp. 449–453.

[13] Ibid., p. 450.

for a land classification system seems almost a necessity to guide the interpretation of remote sensor imagery. It is indeed quite probable that gaps will not be properly filled by using a preconceived classification scheme. Yet the other alternative seems to be the risk of misdirected efforts which may not be needed for a particular purpose. For example, if a prospective user is only interested in identification of 10 major uses of land, it is likely that he will not be willing to bear the expense of an interpretation of remote sensor imagery that will yield 30 categories of land use. The approach to interpretating remote sensor imagery proposed by Nunnally and Witmer seems expecially appropriate for use in developing a data bank of land-use information which would be available to several users rather than for the use of a single user whose needs have not been carefully assessed before interpretation begins.

Directions for Further Research

Several suggestions are made here which hopefully may serve as guidelines for further study into some of the perplexing problems associated with the mapping of land use by using imagery available from remote sensors placed in orbiting spacecraft. Certainly the challenge to perfect a land-use classification scheme which will be useable with orbital data is a very great one. The development of an effective approach to mapping land use at least to a substantial degree from sensors placed in spacecraft can result in a considerable reduction in the costs of preparing land-use maps and in obtaining timely statistical information about land use.

The following suggestions are directed to the development and testing of a land-use classification system that will be useable with orbital imagery for the preparation of land use maps at scales ranging from 1:250,000 to 1:2,500,000.

1. After evaluating initial attempts to prepare land-use maps at intermediate scales from existing or simulated imagery, it is quite apparent that it will not be possible to duplicate categories generally used for the classification of land use from surveys involving enumeration, ground observation, large-scale aerial photographs or a combination of these data-gathering approaches. Although some categories comparable with those used in existing schemes can be identified and delineated effectively, others cannot be isolated satisfactorily with imagery comparable in quality to that obtained from the Gemini and Apollo missions.

2. Further careful study will be needed before a land-use classification scheme which will be useable for the entire United States can be firmly accepted. Exploratory studies indicate that problems of identification and delineation of land use in the relatively dry areas of southwestern United States may differ markedly from those that may exist in eastern United States. The number of discrete uses found within a locality which may comprise a "resolution cell" may be significantly greater in the humid East. Certainly the sharp contrast between irrigated and non-irrigated land will not always be found; however, underdeveloped areas having poor drainage such as the Everglades will contrast effectively with land used for agriculture and other uses. More study is needed to determine the appropriate size of interpretation units for use with differing "mixes" of land uses. A large contiguous area with similar land uses requires a different approach to interpretation and classification than would be used for areas having a considerable diversity of land uses.

3. Inasmuch as it is improbable that a complete, well-balanced land-use classification scheme can be developed in the near future which places sole reliance upon orbital imagery, it is strongly suggested that a scheme be adopted which will be adaptable to supplementing orbital imagery with other readily available information about land use in order to avoid difficult gaps in the categories that will be needed for an acceptable classification system. Use of inference (which is based on such supplemental information) by knowledgeable persons 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.

4. Because more timely analysis of the dynamics of land use will be one of the significant benefits of the remote sensing of land use, it seems desirable that the classification scheme that is used be compatible for making comparisons with information previously obtained by the Bureau of the Census and other data collecting agencies. Although complete compatibility will not likely be necessary, it should be possible to retain comparability for some of the main categories that are already in use. Attainment of comparability will of course include a scheme for data processing that will recognize county and other areas units previously used in compiling data.

5. It will be highly desirable to retain as much flexibility as possible in any land use classification developed for use with orbital imagery. This will be important in order to permit the classification to be expanded or collapsed for various uses. It also will be desirable to have a system that will permit a recombination of various categories within the system. Certainly flexibility will be very important also from the standpoint of developing rapid and effective computer processing of land use data, even to the point of having maps made with auxiliary computer equipment now available or likely to be perfected soon. *The more basic the categorization is in a classification scheme, the more variable the uses that can be made of the classification.*

6. Categories containing a combination of two or more discrete land uses should be avoided wherever possible. It is generally desirable to have a minimum of grouping of land uses during the stage of enumeration, field observation, or interpretation from remote sensor imagery, as a

grouping of uses at that time will prevent alternative groupings being made later.

7. A land use classification system should be activity-oriented. Such a classification should ideally not employ "references to natural qualities of the land, nor to improvements on the land."[14] The classification should be oriented only to those activities that take place on the land. Thus vegetal cover would properly be used mainly as a surrogate for an activity making use of land resources.

8. The classification system should permit the ready comparison with information about other characteristics of land such as natural conditions, assessed and sale value, and distance from centers of population of various size. Such comparisons will involve accurate location of parcels or data cells that would need to be used in making such comparisons.

Two Tentative Land-Use Classification Schemes

In proposing the following tentative land-use classification schemes, it is clearly recognized that deficiencies and inconsistencies will be discerned in these schemes. The two schemes proposed are meant to serve mainly as guidelines for further discussion and research into the ways of using orbital imagery eventually as a viable means of getting much-needed land use information at less cost to the user. The first scheme that is presented is an attempt to devise a more activity-oriented or functional categorization which will be compatible with some of the classification systems that are currently in widespread use. Placed in parenthesis after appropriate items are category designations such as are commonly encountered in vegetal cover or morphologically oriented classifications. In many instances the morphological and functional terminology employed is similar, yet it is important that a clear distinction be made between land use and land cover in a classification scheme. Furthermore, this scheme hopefully will be useable with orbital imagery *if the interpretation of such imagery is carried out in conjunction with the use of information available from other sources.*

The second scheme that is presented represents this author's assessment of what seems to be a possible scheme for use solely with orbital imagery for the United States as a whole. It is assumed that such imagery would be of comparable or better quality than that available from the Gemini and Apollo missions. This assessment results primarily from the review and evaluation of selected research activities sponsored by the Commission on Geographic Applications of Remote Sensing plus a partial survey of other research efforts directed toward the classification and related problems associated with the use of remote sensor imagery.

SCHEME I

A Tentative Classification Scheme for Use with Orbital Imagery and with Some Supplementary Information for Making Land Use Maps for the United States Ranging in Scale from 1:250,000 to 1:2,500,000

(This scheme assumes availability of some supplementary information from other sources. Vegetal cover terminology is given in parenthesis where applicable)

I. Resource Production and Extraction
- *A. Agricultural*
  - (*1*) *Crop Production* (*Cropland*) (Cropland harvested except for orchards, groves, and vineyards; cropland used only for pasture; and cropland not harvested and not pastured)
    - (*a*) *Irrigated Crop Production*
    - (*b*) *Non-Irrigated Crop Production*
  - (*2*) *Fruit and Nut Culture* (*Orchards, Groves, Vineyards*)
    - (*a*) *Irrigated Fruit and Nut Culture*
    - (*b*) *Non-Irrigated Fruit and Nut Culture*
- *B. Grazing* (*Grassland and Shrubland*)
  - (*1*) *Rangeland Grazing* (*Rangeland*) (Native grasses, shrubs and brushland including sagebrush, scattered mesquite and some other shrub types in the West)
  - (*2*) *Livestock Pasturing* (*Pasture*) (Tame grasses and legumes and scattered brushland in the East)
- *C. Forestry*
  - (*1*) *Non-Commercial Tree Raising* (*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)

[14] As a member of a special Committee on Land Use Statistics organized by Resources for the Future, this author participated in a series of meetings which dealt with a wide range of problems related to the collection and use of land use data. The report of the deliberations and recommendations of this Committee were prepared by Marion Clawson and Charles L. Stewart and was published under the title: *Land Use Information: A Critical Survey of U. S. Statistics Including Possibilities for Greater Uniformity*. Resources for the Future Inc., 1965. Distributed by Johns Hopkins Press, Baltimore. (The citation is from page 114 of the report.)

(2) *Lumbering and Pulping* (*Forest Land*)
D. *Mining and Quarrying*
II. *Transportation, Communication and Utilities*
A. *Motoring* (*Highways*)
B. *Railroading* (*Railroads*)
C. *Flying* (*Airports*)
D. *Communication and Utility Activity* (*Communication and Utilities*)
III. *Urban Activities*
A. *Urbanized Livelihood Areas* (*Urbanized Land*) (*1970 definition not yet determined by the Bureau of the Census*)
(1) *Industrial* (*Industrial Land*)
(2) *Commercial* (*Commercial Land*)
(3) *Residential* (*Residential Land*)
(4) *Other Livelihood* (*Other Land*)
B. *Other Urban Livelihood* (*Other Urban Land*) (Populated places of more than 2,500 but not including urbanized areas)
IV. *Towns and Other Built-Up Livelihood Areas* (*Town and Built-Up Land*) (With a lower areal limit which is identifiable through interpretation.)
V. *Recreational Activities*
A. *Mountain Oriented* (*Mountains*)
B. *Water Oriented* (*Water Bodies*)
C. *Desert Oriented* (*Desert*)
VI. *Low-Activity Areas* (*Other Land*) (Excluding land of these types on which land using activities are found)
A. *Low-Activity Marshland Oriented* (*Marshland*)
B. *Low-Activity Tundra Oriented* (*Tundra*)
C. *Low-Activity Barren Land Oriented* (*Barren Land*) including lava flows and mountain peaks above timber line.
VII. *Water Using Activities* (*Water Bodies*)

SCHEME II

A Tentative Classification Scheme for Use with Orbital Imagery but with Little or No Supplementary Information for Making Land Use Maps Ranging in Scale from 1:250,000 to 1:2,500,000

(This scheme assumes little or no supplementary information from other sources but the assumption is made that vegetal cover surrogates can be effectively used to identify these activity-oriented uses.)

I. *Agricultural* (with no distinction attempted between cropland and orchards, groves, and vineyards and between irrigated and non-irrigated)
II. *Grazing*
III. *Forestry*
IV. *Mining and Quarrying*
V. *Transportation, Communications, and Utilities* (first order only)
VI. *Urban Activities*
VII. *Recreational* (only if mountains, water bodies, desert, etc., are used as surrogates and only if inference by knowledgeable persons is employed)
VIII. *Low Activity Areas* (*Other Land*) (marshland, tundra and barren land excluding those classified by use of surrogates and inference as recreational)
IX. *Water Using Activities* (*Water Bodies*)

Notice to Contributors

1. Manuscripts should be typed, double-spaced on $8\frac{1}{2}\times11$ or $8\times10\frac{1}{2}$ white bond, on *one* side only. References, footnotes, captions—everything should be double-spaced. Margins should be $1\frac{1}{2}$ inches.
2. *Two* copies (the original and first carbon) of the complete manuscript and two sets of illustrations should be submitted. The second set of illustrations need not be prime quality.
3. Each article should include an abstract, which is a *digest* of the article. An abstract should be 100 to 150 words in length.
4. Tables should be designed to fit into a width no more than five inches.
5. Illustrations should not be more than twice the final print size: *glossy* prints of photos should be submitted. Lettering should be neat, and designed for the reduction anticipated. Please include a separate list of captions.
6. Formulas should be expressed as simply as possible, keeping in mind the difficulties and limitations encountered in setting type.