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Remote Sensing for Land-Use Studies

An experimental group provided data for evaluating a modified system of photo interpretation.

INTRODUCTION

LAND-USE CLASSIFICATION systems, like other types of classifications, are designed to fit specific needs. Although numerous attempts have been made to standardize land use classifications,[1] no single system exists which is generally suitable for all purposes.[2] A lack of standardization in terminology among systems in use compounds the problem for both compiler and user of land-use data.

The report proposes to develop a system for classifying land use as interpreted from remote sensor imagery. This will be accomplished by examining, in detail, the various types of problems the interpreter faces and recommending a basic system for resolving them.

THE PROBLEMS

The image interpreter who tries to interpret land use is placed in a difficult situation because he is " . . . confronted by persistent problems of terminology and classification as well as problems of image identification."[3] It is beyond the scope of this paper to deal with image interpretation problems as they are of a special type and are treated abundantly in the literature. Rather, we will focus our concern on the problems of terminology and classification systems.

Problems in terminology appear to be two kinds—those associated with the incompatibility of terms used in different systems, and those where the same term may be used differently in several systems. A good example of the former is the use of such words as *arable, cultivated* and *cropland;* all of which are similar but do not necessarily mean exactly the same thing. The latter problem is illustrated by the varying meanings that are attached to a word like *idle* in agricultural land use. This category may or may not include

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[1] Perhaps the best example is the standardized classification presented in the *Standard Land Use Coding Manual* prepared by The Urban Renewal Administration Housing and Home Finance Agency and Bureau of Public Roads, Department of Commerce, Washington, D. C., 1965. Even this system was developed primarily for use in urban areas and for planning purposes. Investigators at the Cornell University Center for Aerial Photographic Studies found the SLUC system " . . . particularly unsuited for a remote sensing operation," Ronald Shelton, "Air Photo Interpretation and Computer Graphics for Land Use and Natural Resources Inventory," *American Society of Photogrammetry, Papers from the 34th Annual Meeting,* March, 1968, pp. 198–204.

[2] Robert Colwell, editor, *Manual of Photographic Interpretation,* American Society of Photogrammetry, Washington, D. C., 1965, p. 563.

[3] *Loc. cit.*

NELSON R. NUNNALLY

fallow cropland, abandoned land and land in conservation reserve programs.

Even though interpretation involves assigning land parcels to use categories, the process of identification and its associated problems can be separated from those involved in establishing classification systems. Classification enables us to name things, transmit information, and make inductive generalizations,[4] but classification systems with their hierarchies of classes are required only for the latter. A classification system cannot be derived without establishing orders or hierarchial categories, but this is not a necessary prelude to identification. For example, an image interpreter may recognize corn without having to classify it into a land-use classification system.

ABSTRACT: *The most common problems associated with interpreting land-use data are (1) incompatible and inconsistent use of terminology, and (2) developing useful and comparable classification systems. The interpretation and classification system proposed and tested here has two basic parts: land-use interpretation in as great detail as possible; and devising a classification system using the interpreted data which is specifically suited to the problem at hand. Sixteen photo interpretors participated in an experiment to test the validity and utility of the proposed system. They were divided into a control group which used any interpretation and classification system, and an experimental group which used the proposed system described in this report. Preliminary sampling analysis of these interpretations indicate that the members of the experimental group had the most detailed interpretations, produced more specific land-use data with less ambiguity, had fewer non-use classes, and employed more compatible classification systems.*

The process of classification can be defined as the creation of classses based on common properties or relationships.[5] As thus defined, classification systems can be developed deductively through logical division or inductively by grouping objects according to similarity or relationship.[6] Most land-use classification systems are produced by the former method. Admittedly, logical division has the advantage that the system needs to be no more detailed than the immediate problem demands. However, certain disadvantages are inherent in the approach: (1) the utility of the data is severely limited because the classes are likely to be incompatible with other systems; (2) the system may have built into it subconscious cultural and personal bias; and, (3) by nature, logical division must exhaust all possibilities, thus there must be a *miscellaneous* category.[7]

Land use is a functional concept. In a strict sense it may be defined as ". . . the end to which land is allocated, assuming a conscious decision to use it for a desired end."[8] The Committee on Land Use Statistics ". . . would like to confine the term *land use* to mean man's activities on land which are directly related to the land. . . . Thus, while natural qualities of land, improvements, tenure, intensity of use, and other factors are related, they are not a part of the central core."[9]

Interpretation of use from photos or imagery must be accomplished from image forms because function is seldom shown. Therefore, few deductively-derived land-use classifications are appropriate for use with imagery. Even those deductive systems that have been formulated specifically for use with photos are not generally applicable for a wide variety of uses due to variations in scale, resolution, time, location and imaging system.

Table 1 contains the land use classes used by four persons in collecting use statistics from photos. The first three of these studies were part of a series written for the Rural Land Use Working Party of the Commission on Interpretation of Aerial Photographs, In-

[4] David Grigg, "The Logic of Regional Systems," *Annals of the Association of American Geographers*, 55 (1965), p. 469.

[5] *Ibid.*, p. 466.

[6] *Ibid.*, pp. 466–469.

[7] On this point Clawson makes the following comment: "However, as we have noted, most sources of data have a *miscellaneous* category, which in practice becomes a waste basket for errors and omissions, as well as undefined uses or activities, such as *idle*." Marion Clawson, with Charles S. Stewart, *Land Use Information*, Resources for the Future, Inc., Baltimore, The Johns Hopkins Press, 1965, p. 124.

[8] Marion Clawson, "Land Use and the Demand for Land in the United States," in *Modern Land Policy*, edited by Harold Halcrow, *et al.*, University of Illinois Press, Urbana, Illinois, 1960, p. 4.

[9] Clawson and Stewart, p. 29.

TABLE 1. LAND USE CLASSES

Munn, McClellan and Philpotts	*Board*	*Stridas*	*Avery*
horticulture		horticulture	
cropland	cultivated land	cropland	cultivated land
orchards and vineyards	orchards and vineyards	trees and other perennials	
improved pasture and range	grassland	improved permanent pasture	
		grassland and scrub	
productive woodland	clumps and unplanned woodland	woodland	pine forest
unproductive woodland	unplanned forest and dense bush		hardwood forest
unproductive	scattered bush	unused	idle
swamp, marsh and bog		swamp and marsh	water

ternational Geographic Union.[10] The other comes from a study measuring land use changes on USDA photographs.[11] Although there are some classes common to more than one of the studies it would be difficult, if not impossible, to compare data collected by the different systems.

THE SYSTEM PROPOSED

In an attempt to resolve the problems discussed in the preceding section we are presenting a two-part system for land use classification from imagery. We believe that this system, which is based on an inductive approach to establishing classes and hierarchies, has more to offer in terms of accuracy, utility and compatibility than do systems based on logical division.

STEP ONE: INTERPRETING AND RECORDING LAND USE DATA

The first step consists of interpreting land use data and recording it in map form. It is suggested that this be done in as great detail as possible. To facilitate this phase orthophotos could be used.

In accomplishing this first step the interpreter should follw the recommendations of the Committee on Land Use Statistics and record the use "with maximum detail."[12] Also the identification should be based on land use alone and not include concepts such as intensity, improvements, tenure, ownership or natural qualities of the land which are often confused with use.[13] And, finally, data should be separately recorded for each land parcel.[14,15]

We feel that this recommended approach will clear up much of the confusion in terminology since most of these problems arise from the naming of hierarchial groups or classes of uses.

The real difficulty in this first phase is in identifying *functional* use from observable form. As mentioned earlier, however, we will not treat problems in interpretation in this paper.

Land use is dynamic. Some changes are cyclic, some are not; some changes are short term, and some occur slowly over long periods of time. In many cases involving short term cycles, land is intensely used for a time and then is simply reserved until the next period

[10] C. Board, "Land Use Studies by Air Photographs in Southern Africa," *Photogrammetria*, 20 (1965), pp. 163–170. S. Sridas, "Interpretation and Mapping of Rural Land Use from Air Photographs in Ceylon," *Photogrammetria*, 21 (1966), pp. 77–82. L. C. Munn, J. B. McClellan and L. E. Philpotts, "Airphoto Interpretation and Rural Land Use Mapping in Canada," *Photogrammetria*, 21 (1966), pp. 65–76.

[11] Eugene Avery, "Measuring Land Use Changes on U.S.D.A. Photographs," *Photogrammetric Engineering*, Vol. 31 (July, 1965), p. 621.

[12] Clawson and Stewart, p. 5 (see also p. 162).

[13] *Ibid.*, pp. 2–4, 114, 161.

[14] *Ibid.*, p. 5.

[15] Eric Moore and Barry Wellar, "Urban Data Collection by Airborne Sensor," *Journal of American Institute of Planning*, January, 1969 (Vol. 35, No. 1), p. 39.

of the cycle occurs. A good example is that of cropland in mid-latitudes where, once the crop is harvested, the land may not be used again until the next crop is planted. In other cases such as crop rotation, the land may undergo different but related uses during different parts of the cycle.

To avoid problems of misidentification we agree with Clawson that the classification "be based, as far as possible, upon what the field enumerator or surveyor actually sees or observes on the gound or on aerial photographs."[16] Needless to say, if imagery is used as the source of data, what can be seen on the image (and therefore the detail which can be enumerated) will depend to a large extent on the resolution and scale of the image. It is our opinion that land use should be identified as the existing use at the time of identification, whether the identification is made from imagery or in the field, and nothing should be inferred by the investigator except that which is based on observable evidence.

Traditionally, land use inventories have attempted to identify and map completely the extent of uses within the area of interest. Exhaustive inventories of this type are time-consuming and expensive for large areas and are virtually impossible on a state or national scale. Additionally, data which are recorded and stored parcel by parcel render chronological comparisons difficult because of changing tract boundaries which may affect both size and shape.

The U. S. Forest Service attempts to overcome these problems in its National Forest inventory which is based fundamentally on land use data acquired from aerial photography by using a dot grid to sample land use.[17] This approach, in addition to being faster and cheaper, thus permitting coverage of large areas, alleviates many data handling problems.

When properly designed, point sampling is a reliable data collection technique. Brian Berry tested the reliability of several sampling techniques for treating areally-distributed data[18] and decided that a systematic unaligned point sample is the most efficient. According to him, "the real advantages of systematic unaligned point sampling lie not so much in the collection of data, whether by field work or aerial photography, but (a) in providing quick methods of estimating percent cover, with variance estimates known; (b) in facilitating studies of relationships between distributions in space through time; and (c) in facilitating storage of data and mapping by machine."[19]

[16] Clawson and Stewart, p. 116.

[17] G. E. Doverspike, F. M. Flynn, and R. C. Heller, "Microdensitometer Applied to Land Use Classification," *Photogrammetric Engineering*, Vol. 31, No. 2 (March, 1965), p. 294.

[18] Brian Berry, "Sampling, Coding, and Storing Flood Plain Data," *U.S.D.A. Handbook 237*, Washington, 1962.

STEP TWO: ESTABLISHING A CLASSIFICATION SYSTEM

The second phase of the system is the grouping of individual uses into hierarchial categories to form a classification system. Once the use data have been gathered they can be used in any detail desirable.

When using the traditional deductive (or logical division) approach to land use classification discussed earlier one must be exhaustive in setting up categories. It is necessary to know beforehand the types of land use one will be dealing with and to develop a classification which can accommodate all of them. The ever-present *miscellaneous* category, regardless of what it is called, is testimony to the difficulty of this approach.

The inductive approach which we are advocating is based on the grouping of detailed use data and avoids many of the problems ordinarily encountered. The investigator need have no exhaustive list of uses before beginning interpretation, and the classification, since it will include only those uses actually interpreted, may be much simpler and easier to devise.

A classification system can be established which is especially applicable to a particular problem. Or, if the user wishes to compare these data with those collected by investigators in other locations or at other times, the data may be grouped to facilitate comparison.

AN EXAMPLE

An interpretation experiment using stereo photography of rural and urban areas in Wyoming, Massachusetts and Tennessee was devised to test the reliability of the proposed system. Although complete results are not yet available, it is possible to draw some obvious conclusions from the bulk data and to provide some examples to illustrate our main points.

Twenty individuals who were serving as land-use consultants to the Association of American Geographers Commission on Remote Sensing were used as interpreters. These individuals were randomly assigned to a control group and an experimental group. The

[19] *Ibid.*, p. 14.

control group was instructed simply to interpret the land use on the four stereo-pairs. They were allowed to use whatever system they deemed appropriate. The experimental group was supplied with detailed instructions about the techniques discussed in this paper and told to use that approach, interpreting land use parcel by parcel in as great detail as they could.

At the time this report was written 16 consultants had returned their interpretations. Table 2 summarizes the average number of types of uses identified by each interpreter on all photos, the number of double-use categories and the number of sample points from a total of 282 selected at random which each interpreter failed to interpret.

The following observations are based on a preliminary analysis of the 16 initial returns (7 control, 9 experimental):

- The experimental group produced the most detailed interpretations. Its members identified an average of 55 types of uses compared to 39 for the control group (column 1).
- With a few exceptions the types of uses identified by the experimental group were more specific and had fewer ambiguous categories. The control group, for example, had three times as many double classes (column 2).

TABLE 2

	Total Number of Classes Used	*Number of Double Classes**	*No. of Sample Points for which No Interpretation Reported*
Control			
1	31	6	31
2	43	13	7
3	30	3	0
4	28	1	18
5	39	1	45
6	78	13	9
7	26	14	1
Average	39.3	7.3	15.8
Experimental			
1	35	3	5
2	66	4	1
3	58	3	0
4	52	0	4
5	68	0	1
6	48	2	2
7	92	2	0
8	51	5	2
9	26	1	1
Average	55.1	2.2	1.8

* These are not multiple use categories, but double classes indicating either/or classification situations such as industrial or business-commercial.

- The control group had many more classes based on criteria other than use (for example: marginal farmland; irrigated; heavy ground cover; unsuitable for agriculture and bare ground).
- The interpretations by the experimental group were generally more reliable, due not so much to the ability of the interpreters, but to a *grouping* error in the mapping techniques used by the control group. The experimental group, inasmuch as they mapped parcel by parcel tended to identify correctly isolated uses surrounded by areas of uniform use, such as churches in residential areas, whereas the control group tended to identify the whole area as one of uniform use. This reliability is also evident in the experimental group's lower average number of sample points for which no interpretation was reported (column 3).
- It is exceedingly difficult to break away from traditional approaches to land-use mapping. One member of the experimental group virtually ignored all instructions and mapped the land uses by broad categories rather than interpreting detailed uses. Even the ones who followed instructions occasionally lapsed into more traditional techniques.
- In general, the better the interpreter, the more detailed the interpretation, regardless of which group he was in.

CONCLUSIONS

As stated above, these six generalized conclusions are observations based on a preliminary analysis of the land uses reported and scored for all sample points for each interpreter. An overall evaluation of each interpreter's map, land-use categories, and explanations of land use classes also contributed to these conclusions. Further statistical and cartographic analysis of the data generated in this interpretation experiment hopefully will provide more definitive measures of the accuracy and compatibility of the proposed interpretation and classification system.

SUMMARY

We have attempted to air some of the most common problems associated with land use classifications and to propose a system enabling each person working with sensor imagery to collect data which would be useful to himself as well as compatible with other land use systems and classifications. The system proposed for collection of land use data has two basic parts—the interpretation of use in as great detail as possible, and the development from the interpreted data of a classification system which is specifically suited for the problem at hand. We believe this approach will yield not only more useful data, but more reliable data as well. Preliminary analysis of experimental results tentatively supports these beliefs.