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Land-Use Interpretation with Radar Imagery

Borders of small-scale land-use regions were consistently identified when land-use change corresponded to topographic change.

Introduction

The necessity of mapping, inventorying, and monitoring land use is increasingly evident with regard to the conservation and wise management of the world's resources. Whereas this conclusion is especially apparent in the developing nations where the imbalances among population pressure, food supply, and economic development are most pronounced a similar, if less urgent, situation exists in the developed nations as well. In addressing these problems various remote sensing systems and technologies are being explored with regard to specific areas of applied research.

Abstract: *The potential of radar imagery as a data base for small-scale thematic land-use mapping is explored. Nine interpreters were provided with a simple qualitative interpretation key and asked to create land-use regions over a 1500 mile area of the United States. Most interpretation discrepancies occurred in semi-arid portions of the study area but several borders were agreed upon, particularly where land-use change corresponded to topographic change. In written descriptions of the regions, respondents agreed upon composition of land uses but not on location of changes. An inability to maintain similar hierarchical land-use levels within and between maps was also evident. Although a surprising amount of border agreement did occur, the results point to the necessity of more stringent classification keys and/or the abandonment of land-use regionalization by synoptic survey alone.*

Among other works, the recent Active Microwave Workshop Report (Matthews, 1975) concludes that, "Experiments are needed to define the abilities of radar imagery for detection, identification, and mapping of land areas . . ." (p. 47). To date, several investigations have reported on the radar detectability of various specific land uses (e.g., vegetation, crops), but few have attempted to assess the potential of using radar imagery to examine the mix, composition, and changes of synoptic land-use patterns. In the latter case the results of Nunnally (1969) and Henderson (1975) attend the topic most directly in that land-use regions are bounded, described, and named. Moreover, Henderson attempted to create an interpretation key identifying land-use elements contributory to map revision and consistency.

Obviously, to be a truly useful document any land-use mapping procedure must be considered in terms of its reproducibility. Regardless of the methodology and data base employed, results are less valuable if the information cannot be updated and revised in a compatible format. Given the paucity of work devoted to thematic land-use mapping with radar *per se*, it is not surprising that virtually no one has evaluated the consistency of categories and/or regions with reference to radar land-use regions. Although Lewis, *et*

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al. (1969) conducted interpretation consistency tests for cultural features *vis-à-vis* radar imagery and Bryan (1974, 1975) studied the detectability consistency for urban features in a similar manner, work devoted to the broader, synoptic view of entire landscapes appears to be absent from the literature.

Specifically, this study is an attempt to ameliorate that void. The purpose is to determine if a simple, qualitative key can be used to create consistent small-scale general land-use maps (*c.* 1:250,000) with similar regions and boundaries.

Methodology

A strip of K-band APQ-97 radar imagery traversing an area approximately 12 miles wide and 1,500 miles long was employed as the study base. Stretching from eastern Minnesota to northern Utah, the area contained several diverse topographic and land-use regions, thus providing a range of environments for interpretation. Nine interpreters were enlisted to participate in the experiment. Each observer was a graduate student or professor of geography with training and familiarity in land-use patterns and aerial photo interpretation.

A brief description of radar imagery and its properties relevant to general land-use mapping was given to each participant. They were then shown land-use maps of the United States as compiled by Marschner (1959), Anderson (1970), and Austin (1965) and informed that the purpose of the experiment was to use radar imagery as a data base to create a land-use map of similar generalization and content. Samples of radar imagery exclusive of the study area were shown to the personnel in order to illustrate how variations in topography, vegetation, urban area, water, field patterns, and transportation networks appear on K-band radar imagery. Instructions were then given to create land-use regions based on the appearance and variation in five key elements: topography, natural vegetation, field pattern and size, settlement pattern, and transportation network.

The decision to utilize a simple qualitative key was made for the following reason. First, the necessity of generalizing information is implicit in creating small-scale land-use regions. Although particular elements must be examined in the decision-making process each factor must be integrated and weighted to form an overall picture. Small-scale thematic mapping is a highly subjective technique and each decision must be made almost on a region-by-region basis. Given this fact it was decided to provide only the five general characteristics as guidelines.

It could be argued equally well that one should create a key incorporating as many restrictions and parameters as possible to reduce the number of variables. Each end of the spectrum (i.e., simple key-complex key) is of merit. However, based on the inherent qualitative nature of small-scale thematic land-use maps and the decision-making complexity of designing a comprehensive key, the basic key approach was selected for initial analysis into the problem. In short, it was believed there was little need to employ an extremely convoluted technique if an elementary method had not been tested that might provide viable results.

Land-use regions were to be delineated on the imagery by each interpreter and a brief written description for their decisions provided. As problems with the gain control on the HV polarization had reduced its usefulness only the HH polarization was used for interpretation. However, it was felt a single polarization would provide adequate data for land-use mapping at this level of detail. Each person was then shown the radar imagery comprising the study area and mapping was initiated. No person saw the results or regions of any other observer in order to minimize suggestion and bias.

Analysis and Results

One of the enigmas pertaining to land-use analysis at this scale (regardless of system or method employed) is the inability to assess the accuracy of the regions created. As stated earlier, regionalization is a subjective process and one cannot simply state a regional border in any other spot than "X" is incorrect (Nunnally and Witmer, 1970). Still, to be a useful technique producing viable data there must be a measure of compatibility among results (Anderson, 1971). Since there were no right or wrong answers by the nine interpreters the discussion will focus on the consistency of decisions and regionalizations and, by implication, the utility of the key/guidelines employed.

A total of 38 different land-use divisions[1] was recorded by the interpreters. The

[1] A division is a sub-area of a region. It may imply that an area of similar land use was separated by one or more different regions, or that the interpreter recorded observed differences insufficient to be designated as a regional change but worthy of note.

number of regions created by each person varied from 20 to six, with the 20-region map having 26 divisions and the six-region map having no divisions. The variability among interpreters in creating land-use regions is illustrated in Table 1. Note that only five of the respondants created divisions within their regions and only four discerned repetitive land-use regions separated by at least one region. This observation is perhaps more striking when one considers that "I" repeated a region only once in divising 13 regions and 21 divisions.

As might be expected given the general nature of the guidelines, considerable disagreement occurred in identifying and placing land-use borders. However, the variation was not uniformly dispersed across the study area. As can be seen in Figure 1, the number of divisions and variability among interpreters was most pronounced in the semi-arid mountainous region of South Dakota and Wyoming. From the eastern end of the study area in Minnesota west to Pierre, South Dakota, only nine separate divisions of land use were recorded with no reoccurrence of regions. While some variability is evident in that portion of the study area containing the South Dakota Badlands and Black Hills (areas west of Pierre) one finds 21 different divisions in Wyoming and northeastern Utah. Apparently, interpreters were influenced by changes in topography and physical elements of the landscape to a greater extent than by fluctuation in cultural attributes (e.g., field pattern, settlement) in the eastern half of the study area where physical alterations were more subtle.

As land use becomes less intense more disagreement on region/division identifiability was evident. Only in instances of sharp breaks in topography and physical elements was there a measure of concurrence on borders. Note that all nine interpreters placed land-use borders near Pierre, South Dakota where the Oahu Reservoir separates an area devoted to grain production from one of semi-arid grazing. Unanimity also occurred at the beginning of the Badlands and the mountain ridge west of Caspar, Wyoming. Eight interpreters agreed on the borders of the Black Hills and at the point where a mountain ridge abutted a basin in western Wyoming. Seven identified a border where a sharp break in topography coincided with a land-use change in eastern Wyoming (Figure 1). Although changes in field pattern, vegetation, and/or settlement was evident in each case the change in physical landscape undoubtedly enhanced the shift as seen on the imagery.

In contrast to these points of congruity, note that only 11 of the 38 division boundarys were identified by at least six interpreters. Twenty division borders were held in common by only three or less respondents, and eight borders were delineated by a single notation. The absence of marked topographic variation in areas of extensive land use (i.e., semi-arid, uncropped land) markedly increased the heterogeneity among interpreters' decisions. Cultivated lands in the eastern part of the study area produced fewer numerical discrepancies in opinion. With this in mind it is perhaps insightful to briefly examine the attributes and characteristics accorded the regions by the interpreters.

As mentioned above, each interpreter was shown examples of radar imagery illustrating the appearance of assorted physical and cultural features. In creating land-use regions they were asked to employ five general physical and cultural attributes and describe their appearance and change for each region/division they defined. The nine written descriptions of each region/division were incredibly homogeneous in content. Although the borders were placed in diverse locations the words used to characterize the

TABLE 1. VARIABILITY IN LAND USE REGIONALIZATION AMONG INTERPRETERS

Interpreter	Number of Regions	Number of Divisions	Repetition/Reoccurrence of Divisions or Regions
A	16	20	yes
B	6	None	no
C	20	26	no
D	8	15	yes
E	14	19	yes
F	13	None	no
G	11	None	no
H	12	None	no
I	13	21	yes

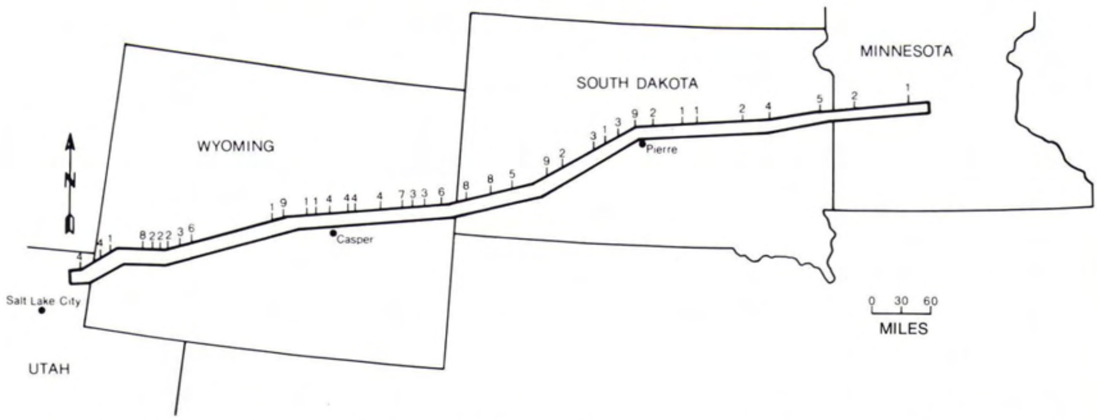

FIG. 1. The placement of each land-use border and the number of interpreters indicating a border at that point.

regions and to denote changes were almost identical among eight of the nine interpreters. To illustrate, central and eastern South Dakota contained many border locations (Figure 1), but the characteristics identifying the areas repeatedly mentioned the same changes in field pattern, water bodies, and settlement as reasons for delineation. Apparently there was agreement on what was changing but not on where. In the eastern, more humid portions of the study area concurrence on cultural factors dominated descriptions, but reference to topographic and drainage features were prominent in the western, semi-arid half of the study area. While one could expect disagreement in border placement, use of virtually identical parameters and words for identification of dissimilar areal regions was, to say the least, unanticipated. One interpreter, C, was markedly atypical in his regional descriptions. Although he employed cultural and physical attributes to define borders in the eastern half of the study area, the western segments were based almost entirely upon one aspect—topography. In fact 16 of his 26 divisions were delimited solely by observed changes in relief. In later conversation he stated that the shift in topography was sufficiently striking to swamp or override other physical/cultural considerations.

Reasons for the discrepancy among interpreters can be attributed to two related factors: the nature of the qualitative key and the hierarchical nature of land use. Although use of the key did produce valid maps based on rational decisions, its relatively unstructured nature, perhaps not unsurprisingly, resulted in much inconsistency. Respondents were seeing similar features and changes in land use, but transition and thus the location of borders was at times incompatible. In short, a flexible key produced flexible regions. This fact can then be linked to the hierarchical nature of land-use classification. In creating land-use regions the problem of maintaining a consistent level of generalization or detail is of paramount importance. The conundrum exists for any data base but is particularly relevant to remote sensing analysis as attested to by Nunnally and Witmer (1970) and Anderson (1971). With specific regard to radar imagery, Nunnally (1969), in a small area in North Carolina, found that land-use regions could be created but were not of the same level of detail. This study tended in part to build on Nunnally's work by developing three areas: an interpretation key was devised; a more extensive study area was employed; and numerous interpreters were tested to discover what consistency occurred in region/border identification regardless of hierarchy.

Patently, the results of this study point to the necessity of more stringent classification keys and/or the abandonment of land-use regionalization by synoptic survey alone. Interpreters not only were inconsistent in border placement but also in the hierarchical level of land use assigned to each region.

CONCLUSIONS

The purpose of this study was to explore the consistency of radar imagery for small-scale thematic land-use mapping (1:250,000 and smaller). Nine interpreters analyzed the study area and created land-use divisions and regions. Several borders were agreed upon, particularly where land-use change coincided with changes in topography.

Much more variation in delimitation occurred in the semi-arid portions of the study area where cultural features (e.g., settlement pattern, field size) were less pronounced than in the eastern sections. However, the discrepancy among borders was not so severe as first might be perceived. An examination of the description of each region provided by the interpreters indicated that, for the most part, the interpreters were in fact agreeing on what they observed but not on the location of borders separating the land-use regions. The problem was in essence twofold: one of identifying land use and land-use borders in transition areas and one of maintaining consistency of generalization (i.e., the same hierarchical level) within an interpreter's map and among all nine different maps.

Although a relatively small number of interpreters was employed it is believed that the results point to the necessary development of more restrictive interpretative keys and guidelines. In spite of the nonspecific nature of small-scale land-use maps and the synoptic view desired, consistent regionalization is unlikely when using only general parameters. Anderson (1971), among others, has pointed to the need for standardized or quasi-standardized categories. A related question, posed by results of this study, is that of standardized regions and borders of land-use maps. If, in fact, consistent borders as well as categories are desired, a stepped format is requisite. Thematic land use is general in nature but requires specific detailed guidelines to produce the desired overview. This might be possible if cells or polygons of a pre-determined size are used to first classify the land use into specified categories. Subsequently, the units could be bounded into regions. Although this step introduces a level of imprecision in the data it could improve the consistency and agreement of regionalization. It should be remembered, in any case, that the implementation of efficacious land-use regions should be predicated on the needs of the user.

Regionalized land-use maps are a product in demand. The question is whether consistent regionalization can be performed, and whether it can be accomplished by utilizing remotely sensed imagery as a data base. Radar imagery may provide much if not the only source of consistent repetitive coverage for much of the world (Matthews, 1975). Work devoted to land-use mapping with this sensor should and is continuing.

References

Anderson, J. R. (1970), "Major Land Uses," *National Atlas of the United States of America*, Arch C. Gerlack, ed., U. S. Department of the Interior, Geological Survey, Washington, D.C., pp. 157-159.

_________ (1971), "Land Use Classification Schemes," *Photogrammetric Engineering*, 37 (4), pp. 379-389.

Austin, M. E. (1965), *Land Resource Regions and Major Land Resource Areas of the United States*, Agricultural Handbook No. 296, U. S. Department of Agriculture, Washington, D.C.

Bryan, M. L. (1974), "Extraction of Urban Land Cover Data from Multiplexed Synthetic Aperture Radar Imagery," *Proceedings of the Ninth Symposium on Remote Sensing of the Environment*, University of Michigan, Ann Arbor, pp. 271-289.

_________ (1975), "Interpretation of an Urban Scene Using Multi-Channel Radar Imagery," *Remote Sensing of Environment*, 4 (1), pp. 49-66.

Henderson, F. M. (1975), "Radar for Small-Scale Land Use Mapping," *Photogrammetric Engineering and Remote Sensing*, 41 (3), pp. 307-319.

Lewis, A. J., H. C. MacDonald, and D. S. Simonett (1969), "Detection of Linear Cultural Features with Multipolarized Radar Imagery," *Proceedings of the Sixth Symposium on Remote Sensing of Environment*, University of Michigan, Ann Arbor, pp. 879-895.

Marschner, F. M. (1959), *Land Use and Its Patterns in the United States*, Agricultural Handbook No. 153, U. S. Department of Agriculture, Washington, D.C., 277 pp.

Matthews, R. E. (ed.) (1975), *Microwave Workshop Report*, Scientific and Technical Information Office, National Aeronautics and Space Administration, Washington, D.C., NASA SP-376, 502 pp.

Nunnally, N. R. (1969), "Integrated Landscape Analysis with Radar Imagery," *Remote Sensing of Environment*, 1 (1), pp. 1-6.

_________ and R. E. Witmer, (1970), "Remote Sensing for Land-Use Studies," *Photogrammetric Engineering*, 36 (5), pp. 449-453.