UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Interagency Report
NASA-67
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Mr. J. Robert Porter, Jr.
Acting Program Chief,
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INTERAGENCY REPORT NASA-67

RADAR AS A TOOL FOR REGIONAL INVESTIGATIONS*

by

Nelson R. Nunnally**

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Sincerely yours,

William A. Fischer
Research Coordinator
EROS Program

*Work performed under NASA Contract No. R-09-020-024
Task No. 160-75-01-32-10
**Department of Geography, University of Illinois, Urbana, Illinois

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RADAR AS A TOOL FOR REGIONAL INVESTIGATIONS*

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University of Illinois

Remote sensor system capabilities are being studied by investigators from numerous disciplines to determine how the various systems may be most effectively and economically used in future studies of Earth phenomena. One system which appears to have the capacity for a wide range of applications is radar. Several published reports have demonstrated the feasibility of identifying such diverse phenomena as geologic structures, physiographic units, vegetative communities, and types of polar pack ice from radar imagery.[1]

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1. Herbert O. Rydstrom, "Interpreting Local Geology from Radar Imagery," Proceedings of the Fourth Symposium on Remote Sensing of Environment, Infrared Physics Laboratory, Willow Run Laboratories, Institute of Science and Technology, University of Michigan, Ann Arbor: 1966, pp. 193-201.

R. D. Leighty, "Terrain Information from High Altitude Side-Looking Radar Imagery of an Arctic Area," Proceedings of the Fourth Symposium on Remote Sensing of Environment, Infrared Physics Laboratory, Willow Run Laboratories, Institute of Science and Technology, University of Michigan, Ann Arbor: 1966, pp. 575-585.

S. A. Morain and David S. Simonett, "Vegetation Analysis with Radar Imagery," Proceedings of the Fourth Symposium on Remote Sensing of Environment, Infrared Physics Laboratory, Willow Run Laboratories, Institute of Science and Technology, University of Michigan, Ann Arbor: 1966, pp. 605-622.

V. H. Anderson, "High Altitude, Side-Looking Radar Images of Sea Ice in the Arctic," Proceedings of the Fourth Symposium on Remote Sensing of Environment, Infrared Physics Laboratory, Willow Run Laboratory, Willow Run Laboratories, Institute of Science and Technology, University of Michigan, Ann Arbor: 1966, pp. 845-857.

*This report is based on research conducted under Geological Survey contract ONR for continuation of studies in the Asheville Basin.

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While geographers are interested in specific Earth phenomena, their prime concern is oriented toward the total landscape--the associations of phenomena as they exist on the Earth's surface and how these associations vary with location. Since radar sensors are capable of distinguishing a wide variety of phenomena, the question of whether they can detect varying associations of phenomena should be investigated.

The imagery which was used for the study covers a portion of the Asheville Basin in North Carolina, extending from Hot Springs to an area southeast of Hendersonville. The area is approximately 50 miles long and 12 miles wide. The imagery is K-band multiple polarization radar imagery (HH and HV) which was flown in September, 1965. Scale of the original contact print varies from approximately 1:170,000 to 1:205,000. These scale figures are based on measurements between recognizable points on the radar print.

Techniques Used In the Analysis

The hypothesis of this paper is that radar provides a means for delimiting varying associations of physical and cultural phenomena through outlining image variation in tone, texture, pattern and shape. The term "integrated landscape" has been chosen as a name for the types of units delimited.

If it can be shown that the image patterns delimited on the radar are correlated with known, observable variations of physical and economic phenomena, then the empirical data can be said to support the hypothesis. There are, however, varying degrees of support. Admittedly, statistically valid sampling techniques and statistical analysis are more meaningful than visual means of correlation. While statistical

approaches will be used eventually, they are beyond the scope of this preliminary report. Instead, supporting evidence in the form of farm type and crop distribution maps, aerial photos, and findings of other investigators were used.

As will be demonstrated in this report, enough information can be interpreted from the radar image to characterize each of the regions. The very thing which permits the rapid identification of regions (the small scale and limited resolution) prohibits interpretation of detailed regional variations. Even so, the techniques have value. Other techniques of regional analysis demand vast amounts of data collected on a large scale, plus time consuming analysis of the data to establish regional categories and permit generalizations of the findings. With radar regions one needs to sample only when detailed data about regional characteristics are required. And, in these cases, the sample size need be only a fraction of that required by other approaches.

If it can be established that general regions can be delimited on radar quickly and accurately, the technique will represent a considerable improvement over other approaches from the standpoint of time, cost, comparability, and accuracy.

Delimitation and Description of Landscape Types

On the HH polarization imagery, it is possible to identify areas which exhibit a more or less homogeneous pattern throughout and which are distinctly different in appearance from other areas. The difference in appearance is a result of the patterns produced on the image by the tone, size, shape and arrangement of the objects which were imaged.

Examples of objects imaged include both cultural and physical items such as field patterns, vegetation, roads, water bodies, and landforms. The identifications are based entirely on qualitative assessments of the imagery. It is possible to offer tentative explanations of some patterns with only limited prior knowledge of the area if a person has photo interpretation experience and some general knowledge of radar systems.

Eleven distinct aerial patterns were delimited on the imagery, and some of them could be subdivided on the basis of variations within the main pattern (Figure 1). In the following section, examples taken from several of the eleven areas, hereafter referred to as regions,[2] are described, analyzed, and shown to agree with empirical variations. The six selected for detailed analysis were chosen because they met the following criteria. They were among the more readily differentiated regions, and, therefore, perhaps more reliable. They were well represented in the "mid-range" portion of the image. Along the top and bottom edges where the look angle is either near vertical or near horizontal grazing incidence, the image quality is poor. Finally, horizontal density traces were available for some portion of the region and could be used to illustrate the image texture. The image patterns of the remaining five regions are interpreted but are not compared to observed data for the reasons just stated.

Region 1.--The most noticeable pattern, and the easiest to delimit,

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2. Region is used in both text and illustrations in lieu of the bulkier expression "integrated landscape type," although geographers do not usually consider widely separated areas to belong to the same region even if the areas exhibit similar characteristics.

Figure 1

Integrated landscape types distinguished on K-band radar imagery. The numbers on the HH polarization refer to the regions discussed in this paper. The HV image with the names of features is intended for orientation.

occurs in the mountainous areas of the imagery. The distinctive pattern in these areas is the result of two conditions: (1) gross tone changes, from very light to very dark, which cover large areas and occur with regularity; and (2) the lack of any noticeable secondary patterns within the lighter-toned areas. The enlargement and the density trace in Figure 2 illustrate the nature of the patterns which result from the rugged terrain in the first case, and a nearly continuous forest cover in the latter situation. Some non-forest areas are visible, but most appear to support a grass cover. The topographic effect is related to the active nature of the radar system which results in a high return from the illuminated slope, and little or none from the shadowed slope.

It can be inferred, then, that there is sparse settlement and little cultivated land in Region 1. In fact, some of the areas are largely within National Forests and contain few farms. In most of the region there are two farm types; mountain commercial and mountain marginal (Figures 3 and 4). Spatially, both are composed largely of woodlands, with the bulk of the remaining acreage used for pasture and hay due to the emphasis on grazing. The amount of cropland is small, usually limited to three acres or less.[3]

Region 2.--Adjacent to the mountains in the northwestern portion of the Basin a second pattern may be identified. The density trace and the enlargement in Figure 5 show the pattern--many regularly spaced, linear light and dark areas and other irregularly shaped, but uniformly distributed, tonal patterns.

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3. Robert W. Peplies, "Occupance Formation Theory: A Case Study of the Asheville Basin." Unpublished Ph.D dissertation, University of Georgia, 1968.

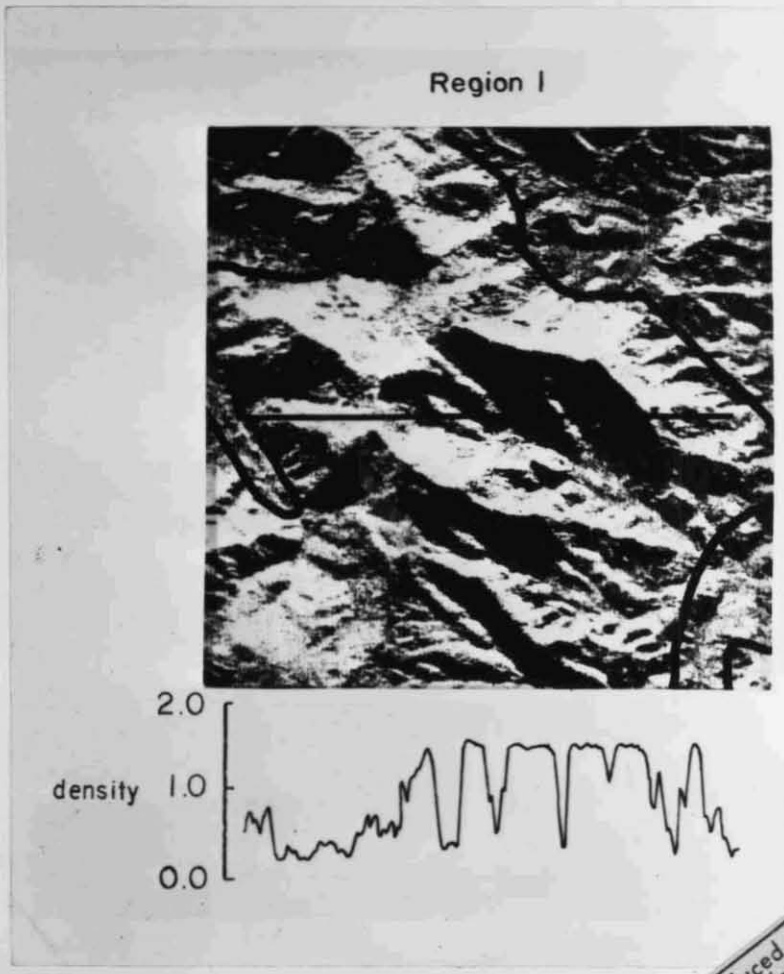

Figure 2

An enlarged portion of radar region 1 with microdensitometer trace. The trace was made along the horizontal black line in the center of the photograph. Note the size and density of the illuminated and shadowed slopes of the ridges.

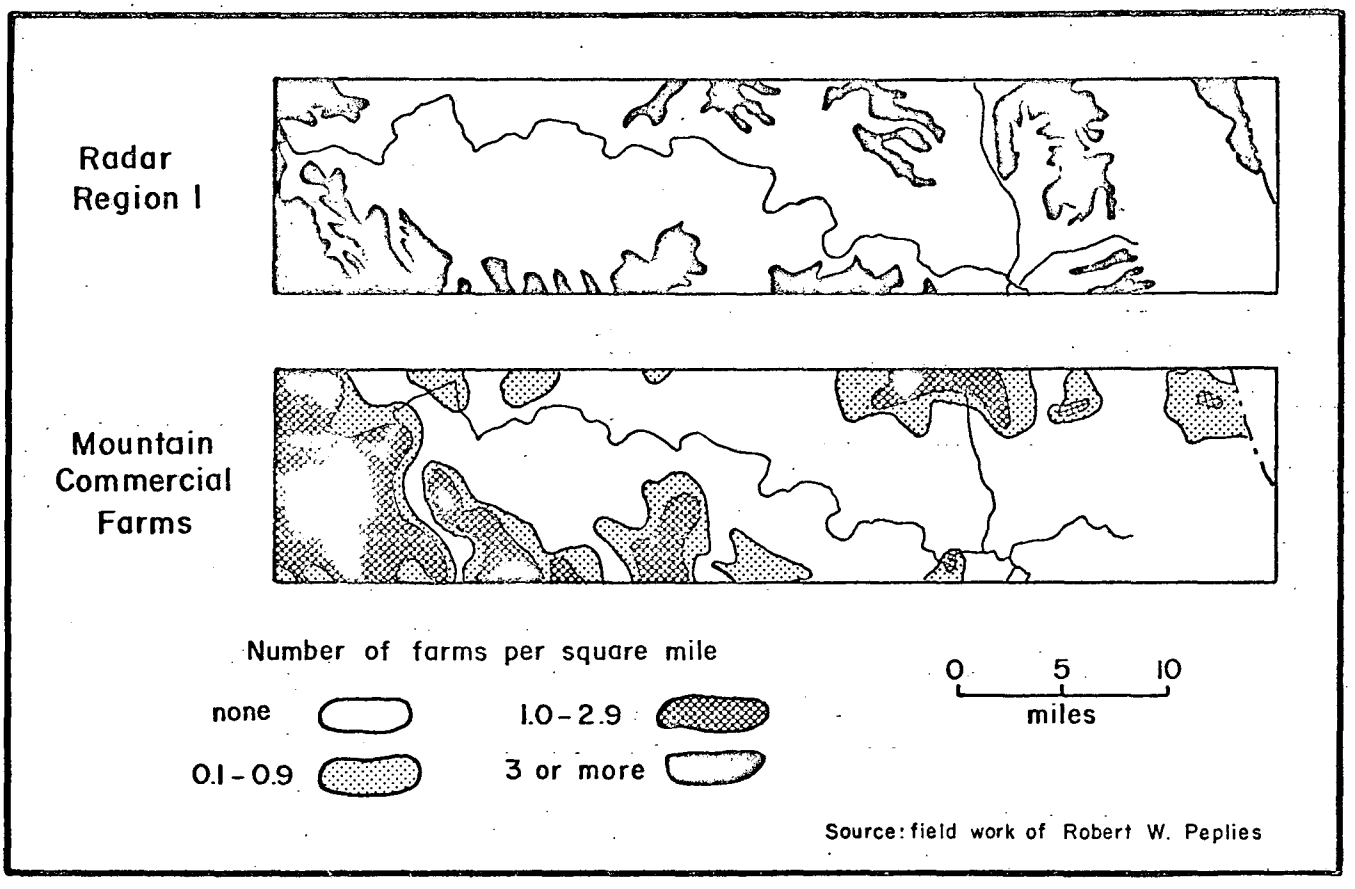

Figure 3

Radar-delimited region 1 compared to the density of mountain commercial farms. The main concentrations of mountain commercial farms are in the same general locations as the segments of region 1. The boundaries do not coincide, partly because of the sizes of the farms and the generalizing effect of isopleth mapping.

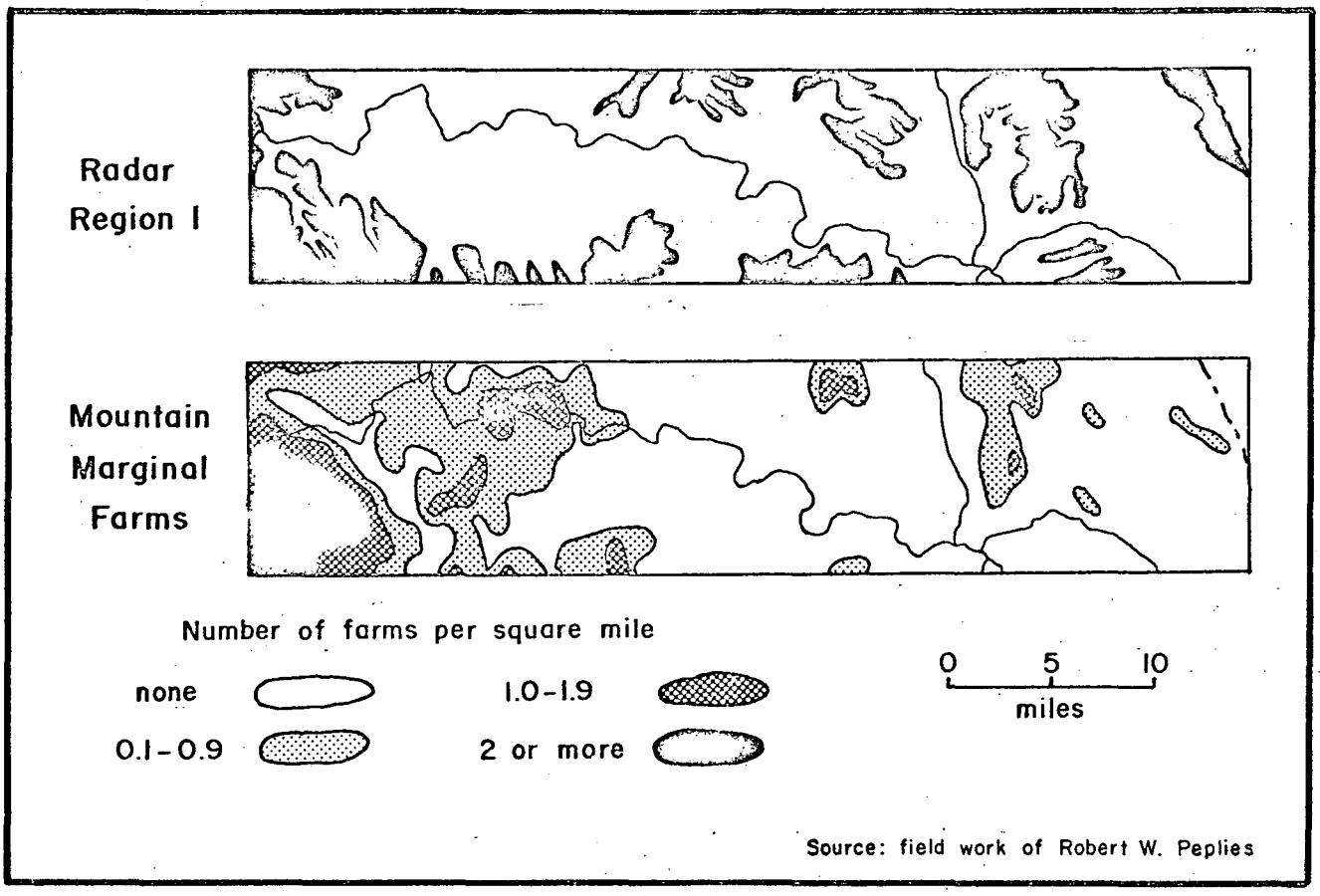

Figure 4

Radar-delimited region 1 compared to the density of mountain marginal farms. See legend to Figure 3.

There is little difficulty in interpreting the major pattern. The linear effect is caused by the tone change associated with stream valleys, with one side giving a bright return and the other being in a shadow. Since the high and low returns are narrow and linear, the relief can be interpreted as moderate.

The non-topographic tonal changes are associated largely with vegetation and crop patterns. The lighter tones on the interfluves--continuous on some, fragmented on others--are due to the higher returns which wooded areas give.

The appearance of the Region 2 landscape suggests that a significant portion of the area is cleared (60 to 80 percent) and perhaps cultivated. Cleared land seems to occupy most of the stream valleys, much of the sloping land and some of the interfluves. The lack of tonal variation in the non-wooded areas probably means that most of the cleared land is put to one use (such as pasture or abandoned land) or that field sizes are so small that individual fields are not resolved, yielding an integrated signal.

The dominant farm type in Region 2 is a family operation which has been given the name "strath farm" (Figure 6).[4] Land use descriptions of both Regions 2 and 3 apparently relate to strath farm characteristics. Woodland, pasture and cropland portions are located in relation to slope. Forests are located on interfluves and in some cases along streams, while crops are largely on uplands, and pastures are on slopes. Crops include tobacco, hay, corn and vegetables, with hay occupying the most area. The main non-cropland use is pasture, and woodland is generally limited to less than 25 percent of the farm area.

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4. Ibid.

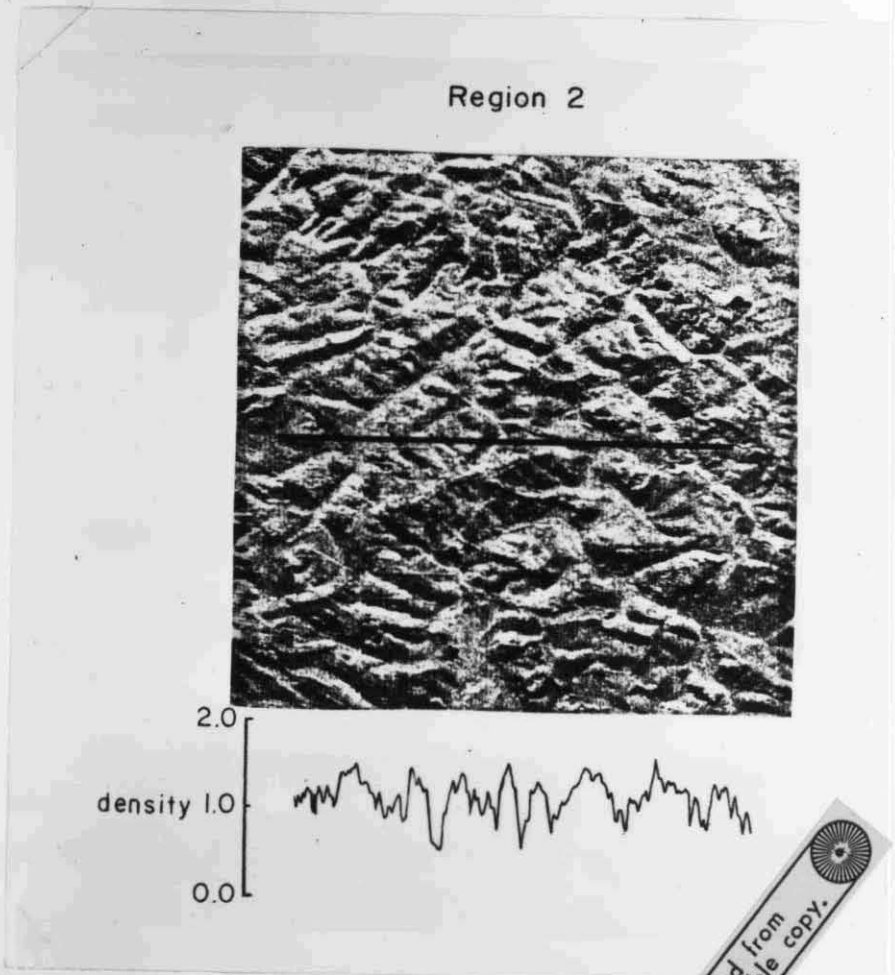

Figure 5

Enlarged portion of radar region 2 with microdensitometer trace. The stream valleys orthogonal to the radar scan show up well. The moderate topographic texture can be inferred from the frequency and magnitude of change in the density trace.

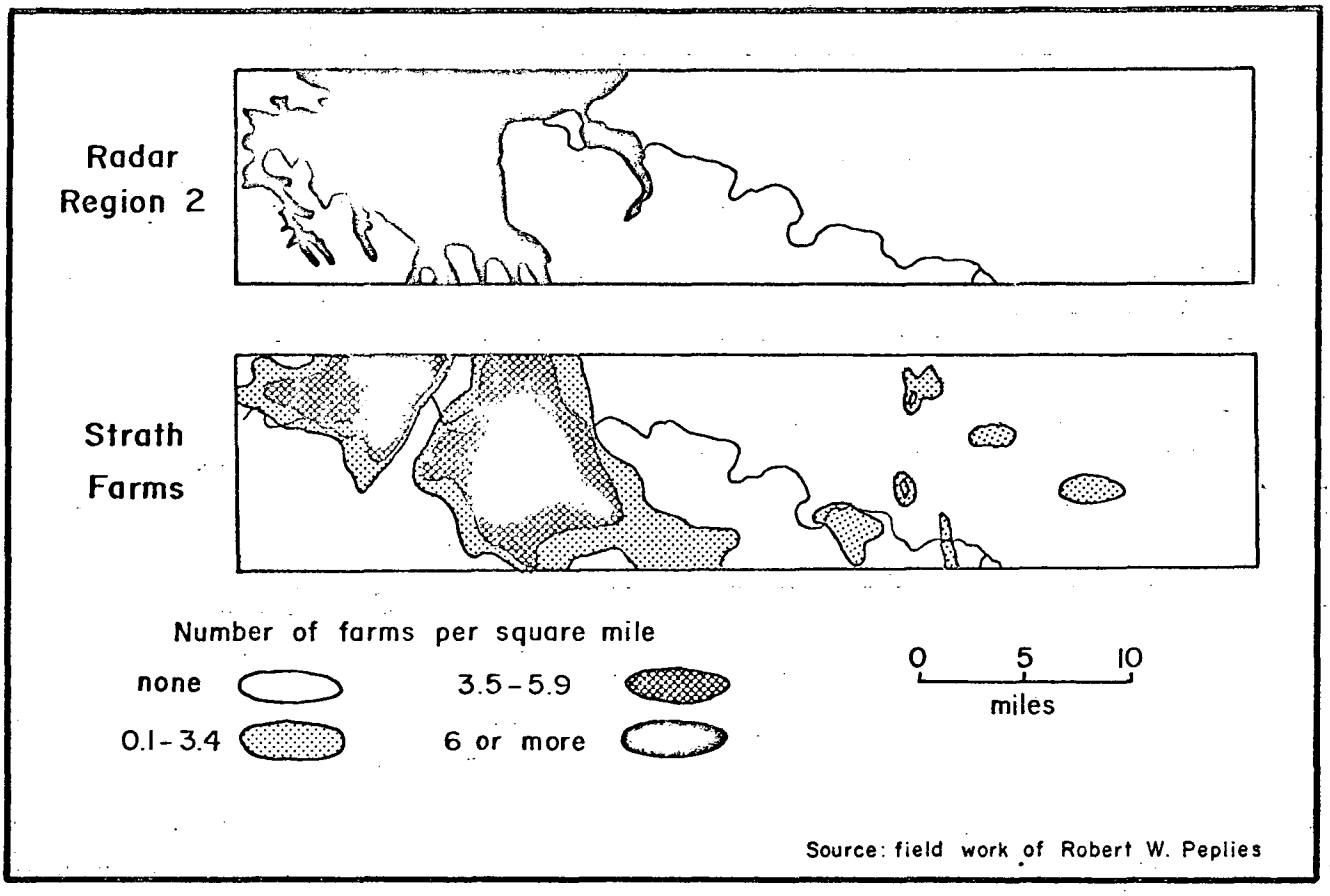

Figure 6

Radar-delimited region 2 compared to the density of strath farms. Although the boundaries do not coincide the correlation of region 2 with areas containing strath farms is evident.

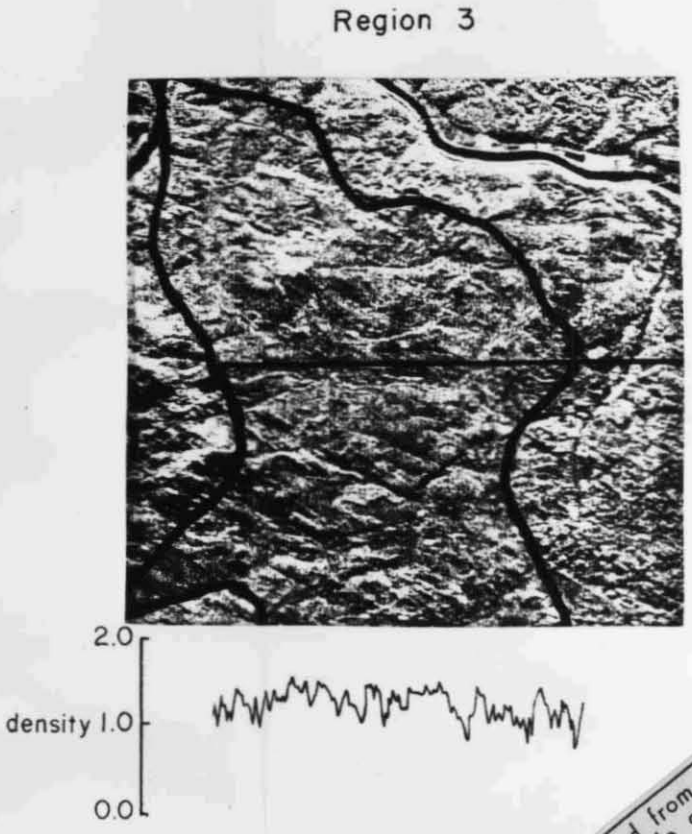

Figure 7

Enlarged portion of radar region 3 with microdensitometer trace. The density range of this trace is less than that of previous regions, reflecting more uniform topography. The photographic texture and the form of the density trace in this region are largely the product of cultural practices and phenomena rather than land forms or other physical phenomena.

Region 3.--The tonal pattern in the third landscape type varies more in size, shape, and variety of tones and, overall, is of a finer texture than Regions 1 and 2 (Figure 7). All of this indicates subdued topographic expression and a more intense occupance with more agriculture, less forest, and a greater variety of phenomena. The lack of any large areas of uniform tone indicates generally small field patterns and woodland area (but large enough to be resolved).

The differences between Regions 2 and 3 are, in part, related to topography and level of agricultural intensity, but there are additional and different elements in Region 3. Like Region 2, it contains a large number of family farms, but in addition, it contains a large concentration of non-farm residences (Figure 8).

Region 4.--The most intricate and finest textured pattern is found in Region 4. In addition to its fine texture and wide tonal variation there are numerous lineaments arranged into rectangular and other regular geometrical patterns. Also, some of the highest returns present on the imagery are found in the Region 4 areas. This is particularly evident in the HV polarization.

The Region 4 areas represent the urbanized areas of the Asheville Basin, with Asheville, Enka, and Hendersonville being particularly noticeable. On the basis of the dense, light tones it is possible to subdivide these urban areas into "core" areas (not necessarily limited to the CBD) and less developed "fringe" areas.

The fine texture, lineaments, and regular geometric patterns evident in Type 4 areas are the result of the urban street patterns and block developments (Figure 9). A definite change in texture can be observed as the eye scans outward from the urban centers; the texture

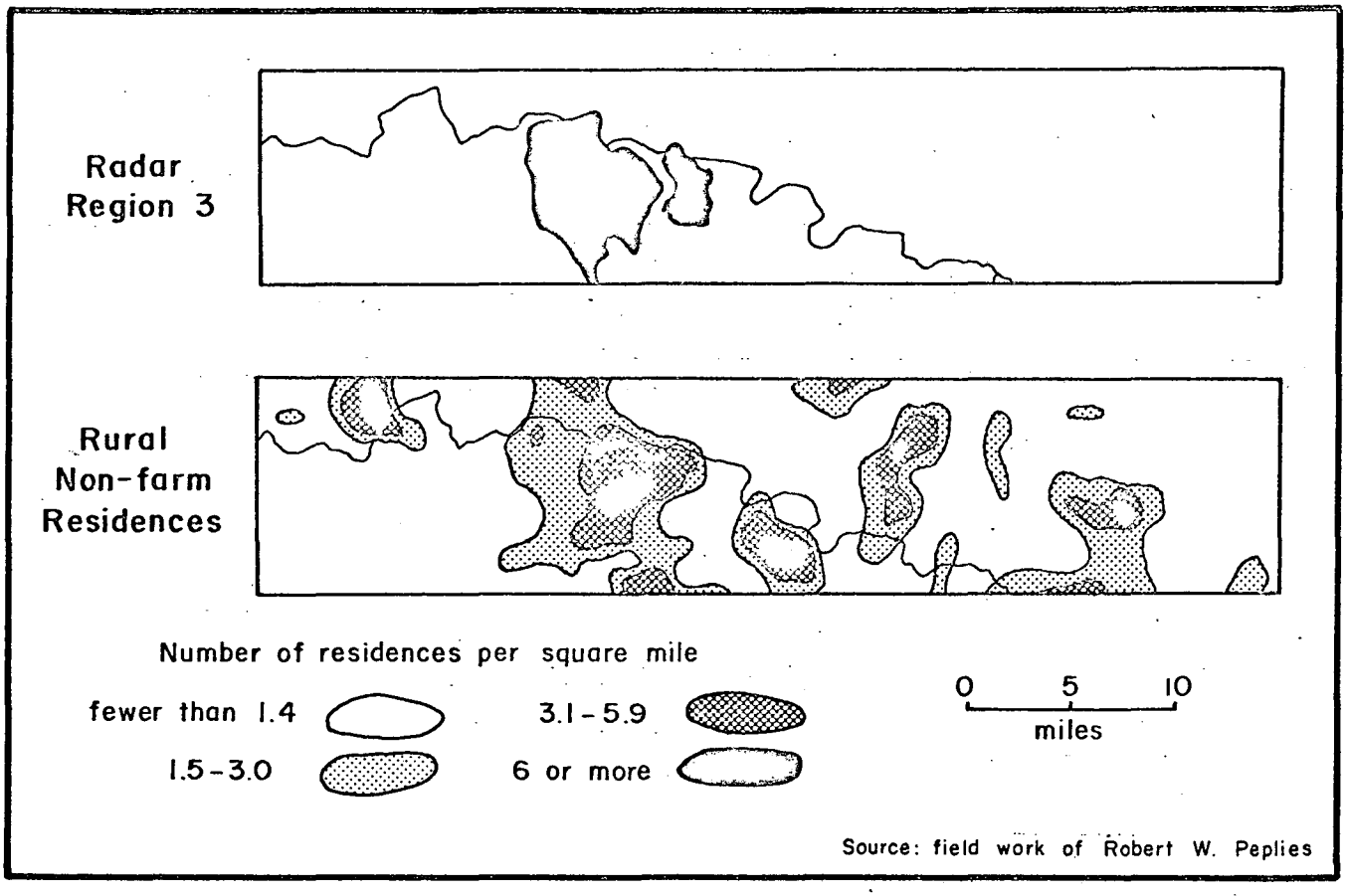

Figure 8

Radar-delimited region 3 compared to the density of rural non-farm residences. While there are rural non-farm residences elsewhere in the radar area the concentration in region 3 is the largest and most dense. This emphasizes the significance of rural non-farm elements to the landscapes of region 3.

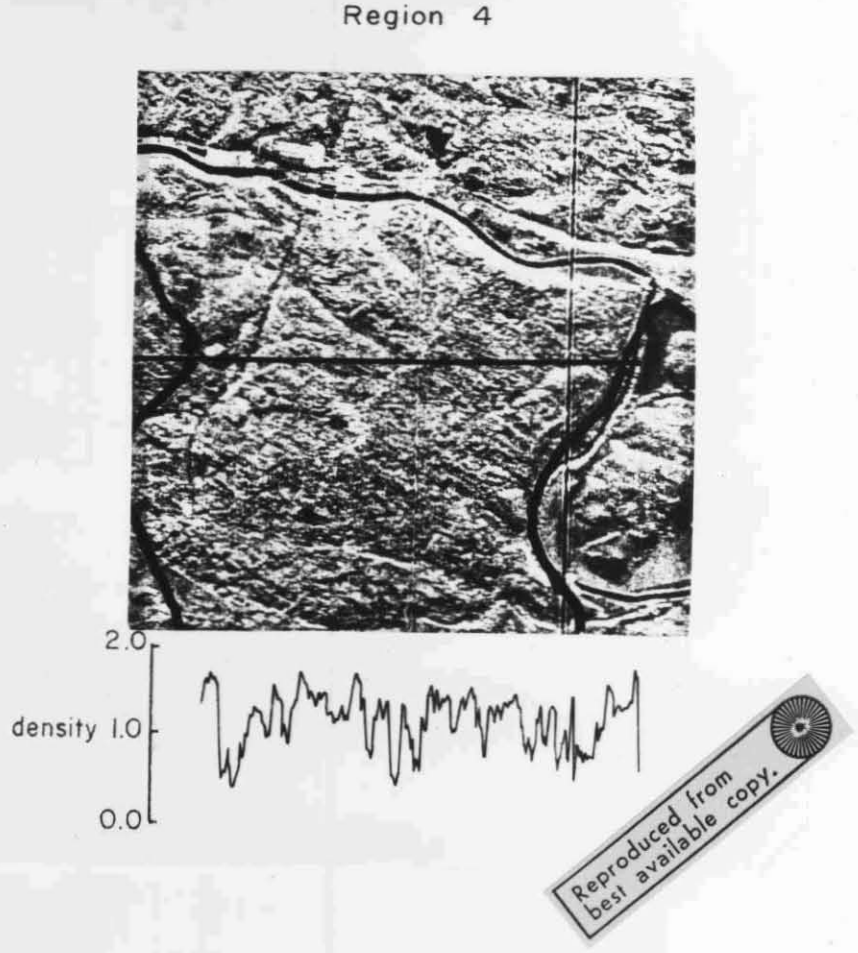

Figure 9

Enlarged portion of radar region 4 with microdensitometer trace. The unique texture and the corresponding density trace are the consequence of the urban pattern, with its streets and buildings. The most intense tones are reflected from large buildings in the central business district and apartment complexes.

becomes coarser and the rectangular patterns become less noticeable.

The intense reflections of the "core" areas (subtype b) which are not confined to one central location probably result from the high density of large buildings and transportation facilities which provide numerous corner and antenna reflectors for the radar waves.

There was a striking correlation in Region 4 with the urbanized areas identified by Robert W. Peplies (Figure 10).[5] Field checks have shown that the light toned areas, called "core" areas earlier, are commercial centers (the CBD, shopping centers, and the larger neighborhood centers and strip commercial developments), with a high concentration of industrial and warehousing functions and railroad switchyards.

Region 7.--Immediately southeast of the Asheville urban complex is an area which yields one of the least complex returns other than the mountain regions (Figure 11). Tonal contrast within the area is limited, and tones occur in large tracts which display little internal variation. This suggests that field sizes are much larger than average and that there is little variety in land use. The dark tones imply that there are no crops which have heavy, broadleaf foliage such as corn and beans, but rather that the fields are used largely for hay and pastures, or were planted to crops such as grain which would have been harvested before September. This leads one to believe that some form of operation involving livestock dominates the agriculture here.

Investigation revealed that Region 7 consists almost entirely of one large landholding--the Biltmore Estate. The estate is functional as a tourist attraction as well as an agricultural operation.

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5. Ibid.

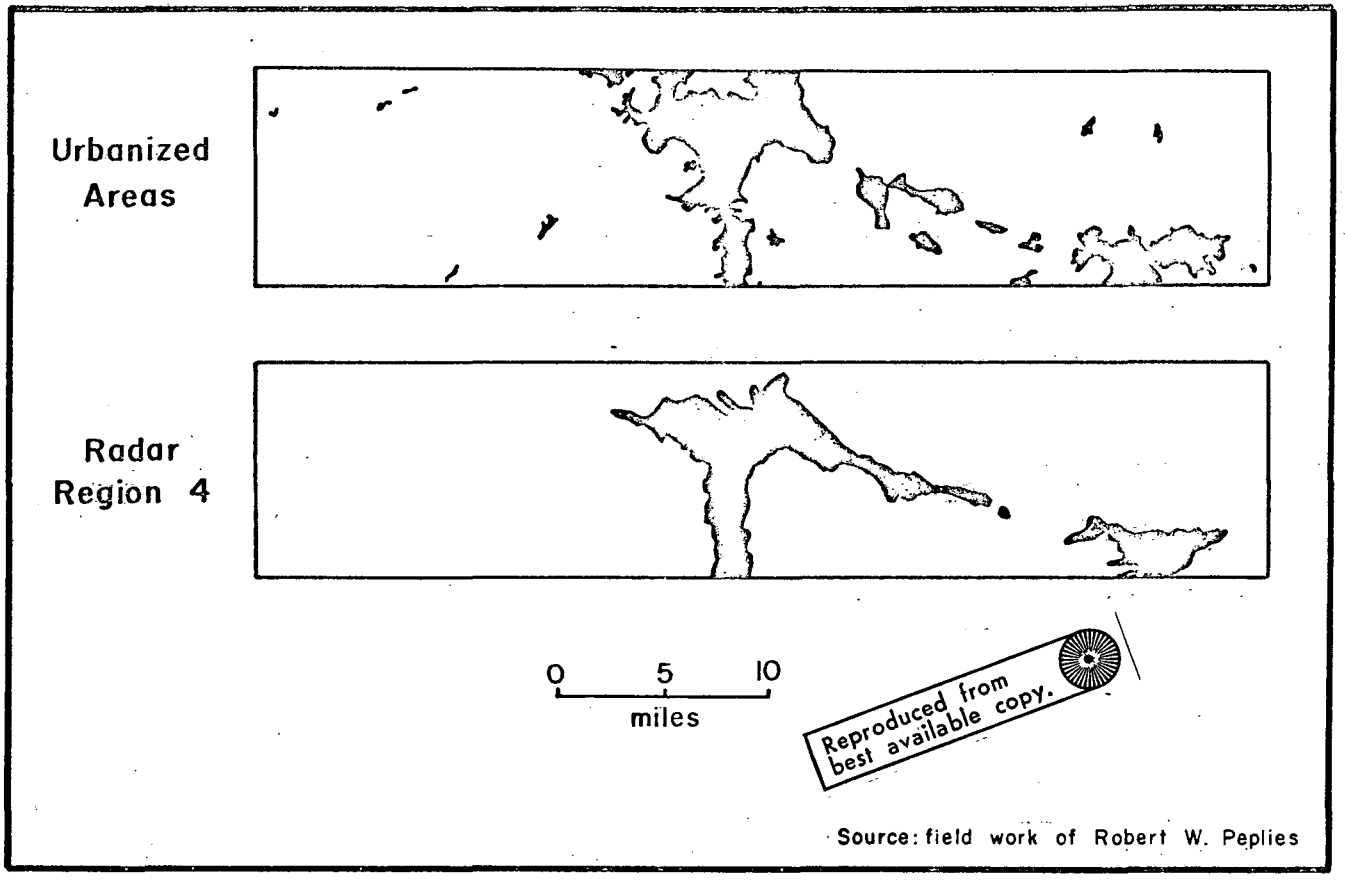

Figure 10

Radar-delimited region 4 compared to the distribution of urbanized areas. The good correlation between radar region 4 and the urbanized areas of the Asheville Basin is evident from this figure.

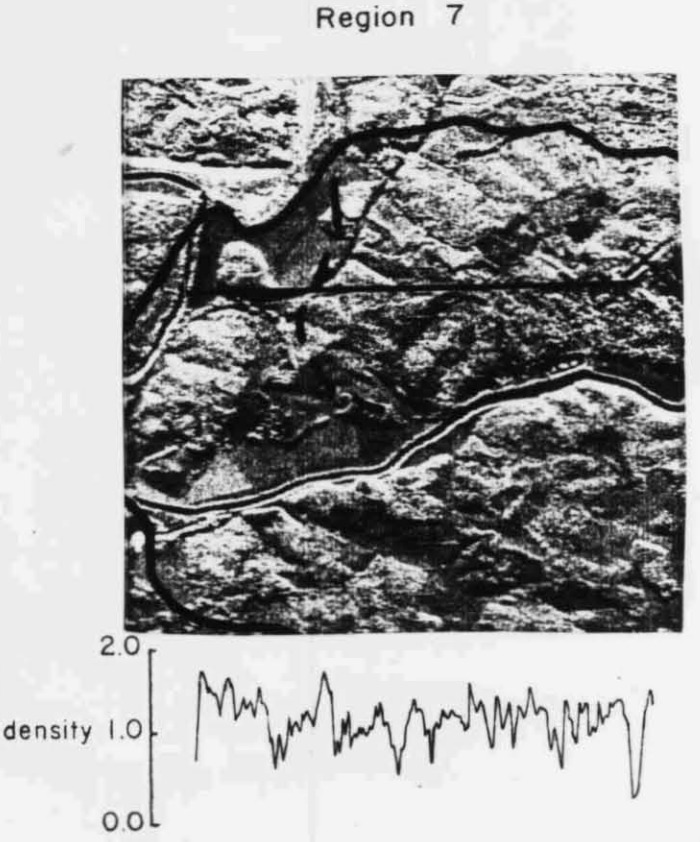

Figure 11

Enlarged portion of radar region 7 with microdensitometer trace. The main features of the region are the large fields of uniform tone and the large areas of continuous forest cover. The dashed line separates the area occupied by the fields from the predominantly forested portion.

Dairying is the primary agricultural enterprise but horticultural and forestry activities also are important. Dairying is centered in the sub-region 7b, while 7a contains the bulk of the horticulture and forestry operations.

Region 10.--The area designated as Region 10 contains several recognizable elements (Figure 12): (1) wide tonal variety is evident; (2) definite, rectangular shapes occupy part of the area; (3) tones are relatively uniform within the rectangles and within other large, but more irregularly shaped areas; and, (4) there is no tonal evidence of relief. All of these factors indicate that the area is one of intensive agriculture which is conducive to large fields and a crop variety suggestive of "corn-belt" type farming.

Region 10 is unique in terms of its description as well as its appearance. The large rectangular fields are associated with cash corn and corn-livestock operations, and with large dairying operations (Figures 13 and 14). In neither case are the entire operations included within the limits of Region 10. Crops, which cover an average 27 percent of the area of dairy farms, are limited to the alluvial floodplains while pastures, woodlands, and farmsteads are located on the sloping land outside the region. The cash corn and the corn-livestock operations are located mostly on the alluvial floodplains. They are rectangular or square in shape, 25 to 200 acres in size and have about 80 percent of the total area devoted to crops. Farmsteads and woodlands which account for less than 20 percent of the farm area may be located outside the alluvial valleys.[7]

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7. Ibid.

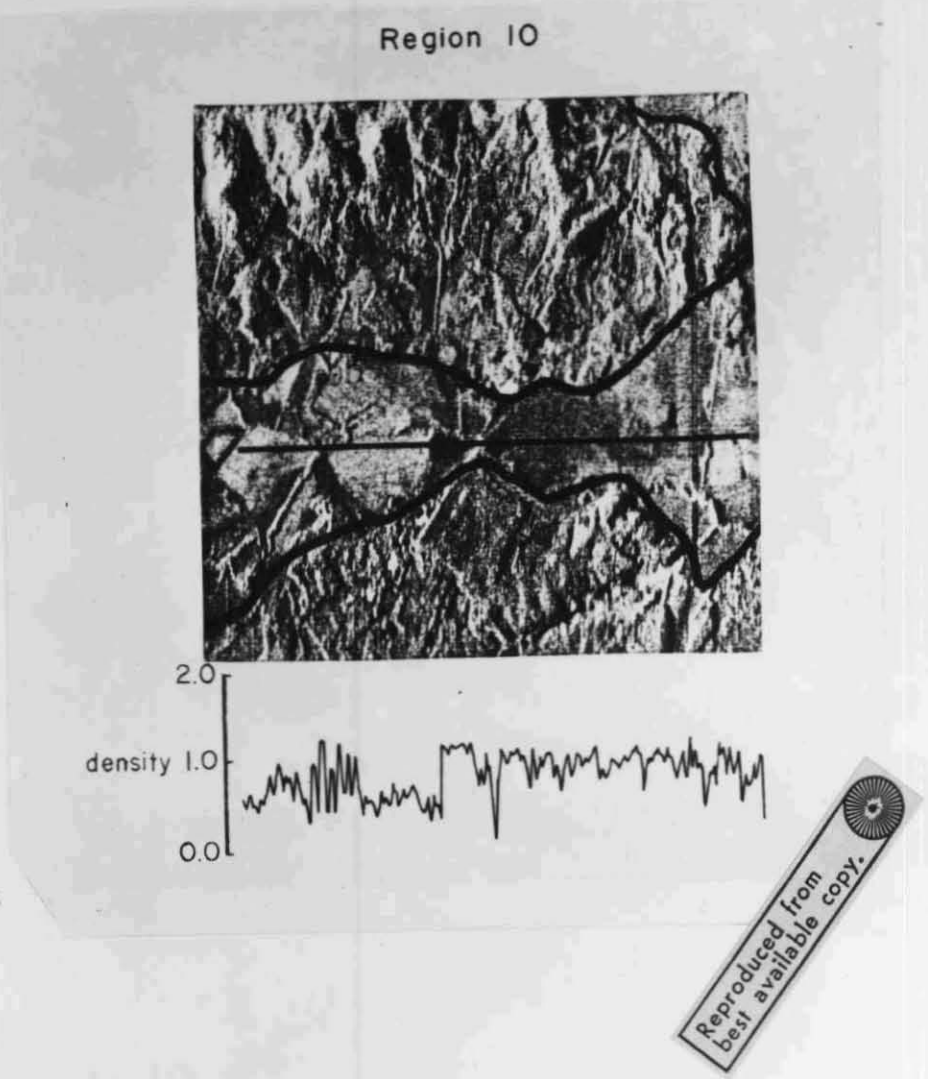

Figure 12

Enlarged portion of radar region 10 with microdensitometer trace. The areas of uniform texture and density are large fields of standing corn, harvested fields, and pasture.

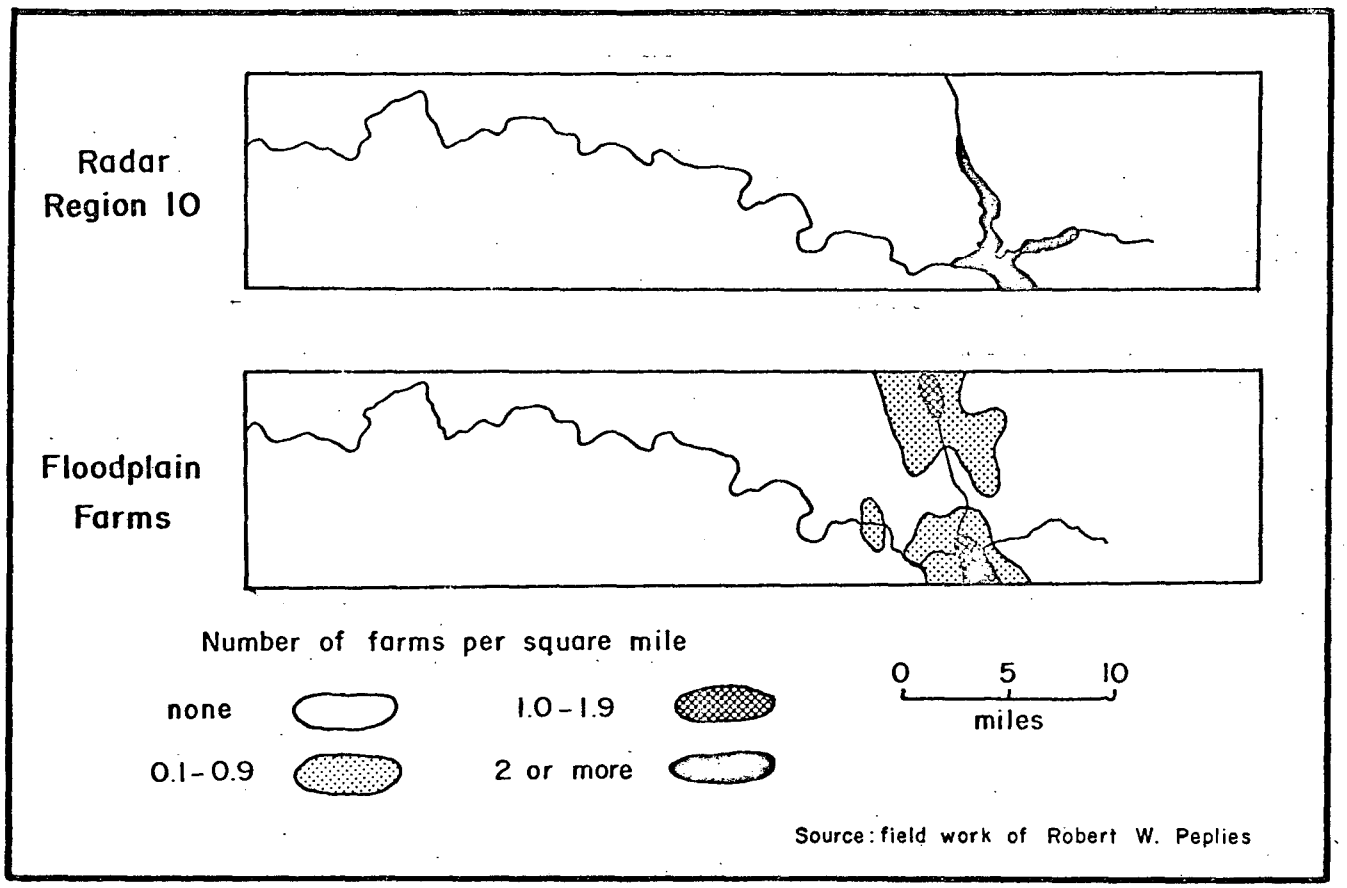

Figure 13

Radar-derived region 10 compared to the distribution and density of floodplain farms. While some floodplain farms are found along upper Cane Creek the largest concentration is at the confluence of Cane Creek and the French Broad River where region 10 is centered.

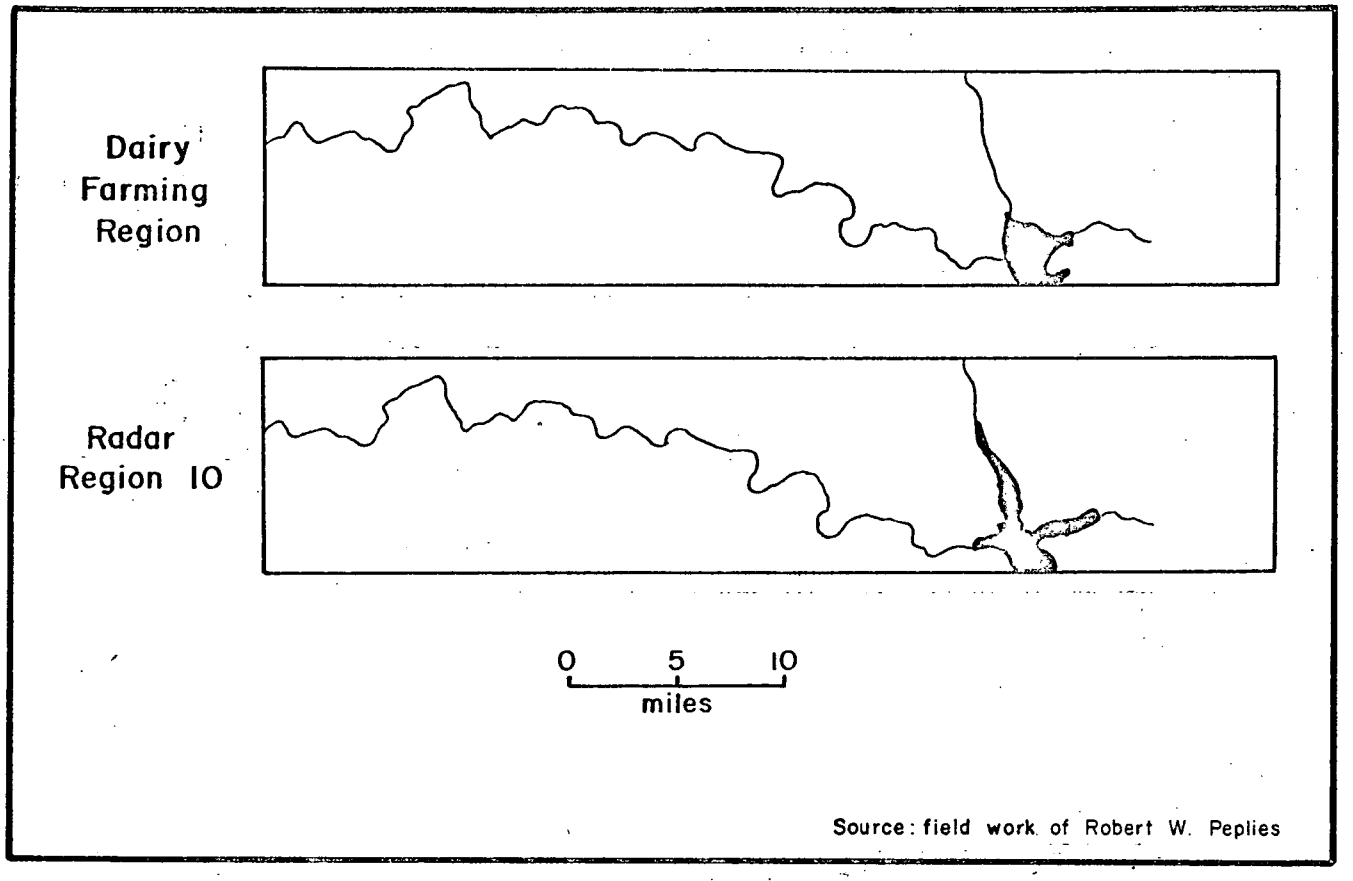

Figure 14

Radar-derived region 10 compared to the dairy farming region. A good correlation exists between radar region 10 and the dairy farming region identified by Robert Peplies (see text).

Brief descriptions of the other regions.--Three separate areas displayed enough similarities that they were designated Region 5. These areas, while distinctly different from surrounding types, are difficult to characterize. Shapes and tones appear to be rather blurred, but small distinct lineations are evident. Overall, the tone is light and there are few distinct field patterns or woodland tracts. Some of the formerly cleared land in these areas has been abandoned and is slowly reverting to forest. The landscape is somewhat similar to urban fringe areas but can be separated easily from the adjoining urban areas. The overall appearance suggests that the area is either not primarily agricultural or that agriculture is neither intense nor commercially oriented.

A variety of phenomena are present in Region 6--one of the obvious ones being the Asheville Airport. Like Region 5, however, many of the forms are blurred, and there are few, if any, definite field patterns. They differ in that large woodland and open tracts do exist in the Region 6, although there is no large tonal contrast between the two. The more noticeable of the open areas are located on or near the floodplain of the French Broad River. The lack of tonal variation in these open places suggests that either they were used for pasture or hay or that they were idle at the time the radar was flown. At any rate, the area is not one of intensive crop agriculture.

Region 8 is more extensive than any except types 1 and 2. It is limited to locations between mountainous extensions in the southeastern portion of the study area and is subdivided by these extensions into three separate units. The landscape is characterized by low relief; wide variation in tonal contrast; a large amount of open land with

irregular sizes and shapes, random distribution, and tonal differences; and, forested stream courses. Trees cover from 5 to 30 percent of the area, depending upon location, and are not restricted to any particular topographic situation. All of this evidence indicates a variety of crops grown in medium to small fields, and fairly intensive agricultural pursuits including some form of livestock operations.

One small area in Region 8 differs from the rest in that it yields a pattern of finer texture. There is little evidence to explain the reason for the finer texture. The area has been designated as subtype b, however.

West of Region 8 in the southern end of the study area is a region which is similar in some respects. There is definite similarity of topography and in amounts of forested and open land. The main difference is that the Type 9 landscape has the appearance of being much more orderly with many rectangular fields and wooded areas and does not seem to have as much variety of tone. Tonal contrast appears to be less than that observed in Type 8, but this probably is inherent to the radar system.

While Region 9 supports a crop variety similar to that of Region 8, the relative emphasis is different. The greater abundance of darker tones suggests more acreage in crops such as hay, pasture and/or small grains, and less emphasis on lighter toned crops such as corn and beans. This could be due to increased importance of livestock in the economy of Area 9.

Although Region 11 east of Asheville is not uniformly forested like the mountainous sections, it still lacks any definite tonal patterns. The cleared land which is evident shows little variation in

tone. This may be due to its location near the margin of the imagery where tonal contrast is poor. If much farming is carried out in the area, there is little evidence to indicate the fact.

Summary

The conclusions reached regarding the character of the regions discussed in this paper appear to be sound.

The maps and farm type descriptions of Robert Peplies provide evidence of regional differences among some of the regions analyzed. In at least two cases, the urban complex (Region 4) and the Biltmore Estate (Region 7), Peplies has delimited regions of similar aerial extent through analysis of field data. Further field work confirmed these findings as well as the interpretations of the remaining regions.

Several observations may be pertinent to the evaluation of the approach described in this report: (1) regions outlined may not all belong to the same hierarchial category; (2) in some cases it is difficult to say whether an area is different enough to represent another region or whether it is a separate part of a region already identified; and (3) the technique is basically subjective. However, the fact that these questions cannot be resolved does not invalidate the method of study or the usefulness of the results. For example, even if quantifiable data which describe the characteristics of different phenomena are obtainable from radar, there is no agreement among geographers as to the best analytical techniques for using such masses of data to delimit regions. Furthermore, there is an infinite number of such characteristics, and someone must make a subjective evaluation regarding the best ones for analysis.

Certainly there is a very real possibility that radar, and perhaps small scale, very high altitude photography, can be used for rapid, reliable regional delimitation. Also, some interpretation is possible at the same scale. Not only can broad land use categories be identified, but it may be possible to identify specific uses (including crop types, vegetative communities, and urban land uses) where the size of the pattern is large enough to be resolved. Assuming that regional delimitation and even limited interpretation are possible, then field interpretation and field checking of data could be held to a minimum--thus lowering costs associated with data collection while covering larger areas with better reliability than is presently possible over a major portion of the earth.