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LAND USE RESPONSE TO KARST TOPOGRAPHY IN THE TELLICO TEST SITE

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Abstract

Certain aspects of the relationships existing between an environmental variable, karst landforms on calcareous rocks and a cultural variable, the land use patterns associated with such karst topography, were examined. A sample of the land uses throughout the test site yielded class percentages which were compared with the test site in general and with two stratifications within the test site: (1) the area underlain by the Knox Group rocks; and (2) the dominant agricultural areas of the test site. Significant statistical differences were demonstrated through the use of the chi-square test.

A sample of the land uses occurring *only* on the karst depressions was compared successively with the land use sample of the entire test site and the two stratifications. These tests showed the most significant difference to exist between the land use on karst depressions and the land uses in the agricultural areas, and the least significant between the depressions and the area of the Knox Group rocks, the most important karst lithologic unit. A test of the extent of karst influence on land use in an agricultural area showed that only those fields containing karst depressions seemed to be influenced. The combinations of land uses on contiguous fields showed insignificant differences and tended to approach the typical class percentages of the agricultural areas in general.

Several type-situations of karst occurrence were investigated in order to ascertain the particular land use patterns and controls existing in the various sections of the test site. These included karst appearing in strike valleys, in the "Knobs," the Copper Ridge overthrust sheet, a floodplain example, and in an area structurally controlled by faulting.

Introduction

Man's perception of his physical environment and his behavioral adjustment to it have long been topics for discussion among geographers (Freeman, 1961). Only recently, however, has attention been given to the more rigorous methods of quantitative analysis in ascertaining such perceptions and adjustments (Saarinen, 1969). One such adjustment, man's response to the physical landscape as measured by his preference for certain spatial patterns and combinations of land use, was examined using the well developed karst topography of the Tellico Test Site as a test location. Several basic questions were posed for research attention: (1) Is there a significant difference between land use assemblages on karst terrain and other land use assemblages within the test site; and (2) if a significant difference exists, how is it expressed in terms of land use response to this particular environmental variable?

The Tellico Test Site is part of Test Site 177 (the Tennessee Valley Test Site) administered by the National Aeronautics and Space Administration. The portion of the test site investigated extends from the Notchy Creek Knobs in the southern part of the Tellico Test Site to the Tennessee River and its impoundments in the northern part. Parts of the Lenoir City, Concord, Madisonville, and Vonore USGS-TVA 7½-minute quadrangles, and the entire Loudon and Meadow quadrangles were included (see Figure 1). The area of the

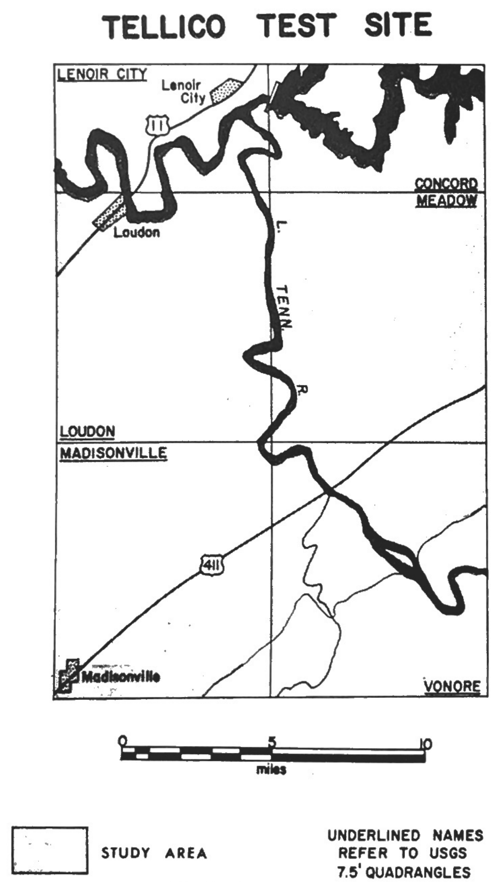

FIG. 1. *Location map*

Notchy Creek Knobs is not included, even though it is usually considered in the sedimentary sequence of the Valley of East Tennessee, since topographically it forms a foothill zone to the local expression of the Great Smoky Mountains and contains no karst occurrences. The remainder of the rock units considered contain some solutional topography.

The Tellico Test Site contains a cross-section of two major physiographic provinces—the Great Smoky Mountains and the Ridge and Valley province, locally represented by the Valley of East Tennessee. The Great Smoky Mountains are primarily pre-Cambrian and early Cambrian slates and quartzites in this vicinity. They are characterized by rugged mountains with steep, V-shaped valleys and sharp ridge crests. The Valley of East Tennessee is a broad lowland belt containing alternating ridges and valleys. These features trend northeast-southwest and generally parallel the Great Smoky Mountains. The relief in this lowland belt ranges from nearly level land along stream bottoms to quite steep and hilly terrain along the ridges and "knobs."

The underlying rocks in this area of the Ridge and Valley porvince are predominantly limestones, sandstones, dolomites, and shales. These rocks are mainly Cambrian, Mississippian, and Ordovician strata which have suffered intense folding and faulting, resulting in high dip angles and overturned beds.

The topographic expression of the sequence of ridges and valleys in the Valley of East Tennessee is, of course, the result of differential erosional resistance of the various limestones, sandstones, dolomites, and shales. Most of the ridges are supported by dolomites and sandstones, while the valleys are underlain by limestones having sinkholes and other prevalent solution features.

The Tellico Test Site is drained primarily by the Little Tennessee River and its principal tributary, the Tellico River. These major streams and several of their smaller tributaries, such as Toqua Creek, cut across the grain of the ridges and valleys and appear to be antecedent in character. Most other lowland tributaries occupy strike valley positions and are thus subsequent to folding and erosion. Many of the small streams are intermittent and many others are apparently subterranean. resulting in a poorly-defined drainage pattern on the limestone units. Streams flowing over other strata, however, have a well-defined pattern.

The Valley of East Tennessee has been listed by several authors (Thornbury, 1965, p. 120, for example) as one of the major areas of karst development in the United State (see Figure 2). Approximately 725 individual depressions resulting from solution of calcareous rocks are present in the area considered. The majority of the depressions lie within the boundaries of surface expression of the Knox Group limestines and dolomites, even though all other strata contain facies exhibiting some solutional activity, as stated above. The depressions, disappearing streams, and subterranean drainage ares were interpdeted from TVA panchromatic aerial photography. The regional geologic information was generalized from the state geologic map. (Hardeman, *et al*, 1966).

FIG. 2 *Karst landforms map*

The Knox Group limestones and dolomites occur in three strike valley locations within the test site. The northernmost location lies just north of the Bat Creek Knobs and their extension to the east of the Little Tennessee River, the Red Knobs. North of the Bat Creek Knobs this limestone valley has considerable subterranean drainage in the vicinity of New Macedonia, but the remainder is drained by Clear Prong and Fork Creeks. Hickory Valley is the local name given to the section north of the Red Knobs, which also has subterranean drainage and, in addition, few surface streams. The middle location of the Knox Group rocks is south of the Bat Creek Knobs/Red Knobs ridge. Few surface streams, some even disappearing, and subterranean drainage, also characterize this area. The southern occurrence of the Knox Group rocks lies in one of the small valleys between Negro Ridge and the Notchy Creek Knobs. This occurrence does not exhibit the degree of subterranean drainage and lack of stream density exemplified by the previous two, and as might be expected, does not have the same high development of karst terrain. It is drained west of the Little Tennessee River by a strike-controlled reach of the Tellico River and its tributary, Corntassel Branch, and by the headwaters of Notchy Creek itself. East of the

Little Tennessee River it is drained principally by Ninemile Creek.

Not only are the majority of the solution depressions found on the Knox Group rocks, but also the largest depressions and the best developed uvalas (Thornbury, 1969). The presence of a karst landscape characterized mainly by sinkholes with only occasional uvalas signifies an early stage of development of this particular form of weathering and erosion.

The Bat Creek Knobs/Red Knobs area does not have a large number of solutional features, but the several that are present resemble the type known as the "karst valley," originally described by Mallott (1939). This type of valley differs from the blind valley or normal uvala in that it is surrounded by clastic (or non-calcareous) rocks. This particular classification does not apply in this case, since the two units underlying this ridge, the Ottosee Shale and the Holston Formation, both contain calcareous facies. In the case of the Holston Formation, a gradation from crystalline limestone to marble is present.

Most of the area between the northern occurrence of Knox Group rocks and the Tennessee River is underlain by the Copper Ridge Dolomite, indicative of one of the many overthrust sheets in the Valley of East Tennessee (Thornbury, 1965, pp. 124-125). This area is not characterized by large numbers of solutional features, and those present appear to be specific locations of preferred weathering. One small area of this overthrust sheet, however, north of Glendale, appears to have depressions similar to the karst valleys described above as existing in the Bat Creek and Red Knobs.

Only one small area of karst on a floodplain seems to be worthy of note. Approximately one mile south of Fort Loudon there is a large depression which may have been the swallow-hole of the Tellico River at an earlier time. The Tellico's lower course seems to have been "captured" by the headwaters of Fourmile Creek and diverted to the west, leaving the long valley between Mile 2 on the Tellico River and the Little Tennessee River dry. This depression, however, is on ancestral, not contemporary, floodplain.

One other factor seems to be of significance in the placement of karst features in the test site, namely, the presence of faults. Several depressions in the western section of the central occurrence of the Knox rocks lie directly on traces of known faults, suggesting that their alignment is fault-controlled and that their presence is at least partly influenced by preferred weathering along crush zones associated with the faulting.

Sampling and Testing

The land use map of the Tellico Test Site (Witmer, 1970) was used as the data source for the land use sample of the area being considered. The twenty-two land uses originally categorized on the land use map were classified into four groups for the purposes of this study. They include woodlands, hay/pasture lands, croplands, and lands having cultural structural forms such as residences, roads, stores, churches, farm ponds, etc. This classification was employed in order to minimize any possible errors which might have resulted from the original categorization (Nunnally and Witmer, 1970b).

The sampling system employed in this study is the stratified systematic unaligned sample. As Berry (1962 p. 24) has pointed out, "The most efficient point sample for analysis of areal distribution, for making estimates of areal coverage of phenomena, and for comparative analysis, appears to be a stratified systematic unaligned sample." This sampling system has also been employed in other land use studies (Nunnally and Witmer, 1970a).

Determination of the sample size was necessary prior to construction of the sampling network. A sample of the various sections of the test site indicated that the 246 square miles under consideration contained an estimated 17,220 individual land use parcels. As Griffin (1962) illustrates, if the maximum error E is desired in conjunction with a particular level of confidence Z, and the standard deviation *is known*,

$$n = \frac{\sigma^2 z^2}{E^2}$$

If the standard deviation of the population is not known, then an estimate from the sample is used instead. In that case, the confidence level must be specified in terms of the particular probability level expressed by the t-test for the appropriate number of degrees of freedom. Since the appropriate value of t depends on the sample size, an iterative solution, that is, one which requires repetitive trial to reach a limiting value, must be used. The modified formula becomes:

$$n = \frac{s^2 t^2}{E^2}$$

where s is the standard deviation computed from the sample, and t is the appropriate t-value for the confidence level required.

The iterative procedure may be circumvented somewhat when determining the sample size needed for estimating proportions, such as the relative percentages of land use being sought in the sample of the Tellico Test Site, Griffin (1962) shows "that the standard deviation of a proportion reaches its maximum value when $p = 0.5$. Therefore, the $p = 0.5$ assures that the estimated sample size n is large enough." The modified formula is given as:

$$n = \frac{p(1-p)t^2}{E^2}$$

In order to be 95 percent confident that the error in estimating the proportions of land use will not exceed 2 percent, the required sample size n must be:

$$n = \frac{(\tfrac{1}{2})\ (\tfrac{1}{2})\ (1.645)^2}{(0.02)^2} = 1690$$

where 1.645 is the appropriate t-value for all degrees of freedom for 2000 and above for the 95 percent confidence level. As can be readily seen, 1690 samples provide a sample approximately equal to 10 percent of all the land use parcels in the test site. Measurement indicated that a one-inch-square grid superimposed on the land use map would provide 1715 sample points in the system being used, and this grid size was adopted. The sample yielded the percentages of land use given in Table 1 for the portion of the test site under consideration.

TABLE 1. *Tellico Test Site land uses.*

	Percentages
Woodland	36.0%
Hay/Pasture	33.3%
Cropland	22.3%
Structures	8.4%
	Total 100.0%

There were several potential ways of viewing the testing of the relationships between karst topography, the land uses occurring on that topography, and other land use combinations in the Tellico Test Site. The first and most obvious way was to compare the land uses occurring on the karst terrain alone with the composite land use sample of the *entire* area under consideration. A second method was to compare the karst terrain land uses with the land uses occurring on the principal karst lithologic units of the Knox Group, since presumably the greatest variation would be found on these units which have the greatest development of solutional forms. A third alternative is to investigate the probability that there is an interrelationship between predominantly agricultural areas and karst occurence. An indication of the difference between these two stratifications of the test site is the comparison in Table 2 of the relative acreages in the land use classes being employed.

TABLE 2. *Comparison of land use sample percentages.*

	Woodland	Hay & Pasture	Cropland	Structures	Area (Acres)
Test Site	36.0	33.3	22.3	8.4	168,500
Knox Group Rocks	27.9	30.7	33.2	8.2	75,500
Agricultural Areas	17.0	37.6	37.0	8.4	95,600

As Table 2 indicates, the Knox Group rocks have greater proportions of hay/pasture and cropland, indicating they are more agriculturally-oriented areas than would characteristically be found in the test site at random. The dominant agricultural areas derived from the land use map have nearly the same proportions of cropland and hay/pasture land, but less than half the woodland proportion of the entire test site. Those woodland land uses found in the agricultural areas are usually related to the farm enterprise, such as woodlots and small pulpwood plantings.

A more rigorous inspection of the land use proportions of these three samples required quantitative assessment of their relative difference. The traditional and more powerful tools of statistical inference have been developed for sampling from populations that can be assumed to have some specified form of distribution such as the normal or binomial. Since no assumption can be made about the land use data evolving from the sample of the test site, one of the non-parametric tests must be used. These tests do not asume anything explicit about the nature of distribution. Perhaps the most common of the tests used in assessing the difference between non-parametric distributions is the chi-square (x^2) test. It is commonly used to test the "goodness of fit" of observed frequencies to expected frequencies in order to determine whether the difference between the two distributions is greater than might be expected to occur by chance (Berry, 1962, p. 20). In general, few such tests are available (Harvey, 1970), and they are not as powerful as the classical parametric statistical procedures (King, 1969). Because of this latter fact, the chi-square results obtained are viewed in a *relative* manner only.

Applying the chi-square test to the null hypothesis that: there is no significant difference between the land use proportions in the entire test site and those occurring on the Knox Group rocks, first requires the construction of the contingency table of sampling frequencies presented in Table 3.

The observed frequencies in Table 3 are those derived by tabulating the sample points occurring on Knox Group rocks. These accounted for 44.8% of the area of the test site. The expected frequencies are computed using the percentages given in Table 1. Computation using the chi-square formula then gives:

$$x^2 = \sum_{i=1}^{k} \frac{(\text{Observed} - \text{expected})^2}{\text{expected}}$$

$$= \frac{(214 - 276)^2}{276} + \frac{(235 - 256)^2}{256} + \frac{(255 - 171)^2}{171} + \frac{(63 - 64)^2}{64}$$

$$= 56.6$$

Since the number of categories, k, equals 4, the number of degrees of freedom is 3. The critical x^2 value at the 0.01 significance level for 3 degrees of freedom is 11.3. Since $56.6 > 11.3$, the hypothesis that there is no significant difference between the samples can be rejected and it may be concluded that there probably is a significant difference.

TABLE 3. *Frequencies for test site Knox Group Comparison*

	Woodland	Hay/Pasture	Cropland	Structures	Total
Observed	214	235	255	63	767
Expected	276	256	171	64	767

The same procedure may be used to test the null hypothesis that there is *no* significant difference between the land use proportions in the entire test site and those occurring in the agricultural areas as interpreted. (See Table 4).

$$x^2 = \frac{(165 - 351)^2}{351} + \frac{(366 - 324)^2}{324} + \frac{(361 - 217)^2}{217} + \frac{(82 - 82)^2}{82}$$

Since the x^2 critical value remains the same, i.e., 11.3, this latter hypothesis can also be rejected. A more radical departure of land uses in the agricultural areas from the test site is indicated by the greater x^2 statistic.

TABLE 4. *Frequencies for test site/agricultural areas comparison*

	Woodland	Hay/Pasture	Cropland	Structures	Total
Observed	165	366	361	82	974
Expected	351	324	217	82	974

Each of the three testing possibilities involving stratifications of the test site necessitates the measurement of the area actually included in the karst depressions. After the interpretation of the actual extent of each depression from the aerial photography, they were plotted on the land use map and the areas in each land use class measured using a sampling grid similar to that employed for the test site land use sample. Table 5 lists the percentages of sample points occurring in each class.

TABLE 5. *Land use percentages—Karst depressions*

Woodland	28.0
Hay/Pasture	36.0
Cropland	31.0
Structures	4.9
Total	100.0 (930 sample points)

Use of the chi-square statistic to test null hypothesis analogous to those presented above yielded the following results:

1) Comparison of test site sample and karst depression sample $x^2 = 63.7$ (significant at 0.01 level)
2) Comparison of Knox Group sample and karst depression sample $x^2 = 21.2$ (significant at 0.01 level)
3) Comparison of agricultural areas sample and karst depression sample $x^2 = 89.8$ (significant at 0.01 level)

Even though all three of these tests provided significant results, their relative values provide additional information. The most significant difference exists between the land uses in karst depressions and land uses occurring in adjacent agricultural areas. This is especially significant since the great majority of karst occurs in these agricultural areas. Several situations characterize the land use differences in these areas: more karst appears on woodland in agricultural areas (28.0% versus 17.0%); less cropland has karst (31.0% versus 37.0%); and most significant statistically, 51% fewer cultural structural forms are found on karst (4.9% versus 8.4%). As would be expected, the least variation was found between the Knox Group land uses and their associated karst land uses.

The foregoing analysis provides general results concerning the entire test site and the two stratifications chosen for inspection, but yields no information concerning specific land use patterns. Before discussing these specific patterns, one general pattern item deserves consideration (i.e., an inquiry into the problem: "How far from the actual depression does the influence of karst extend in a land use-decision making context?") The largest single area of karst occurrence, that north and east of New Macedonia Church in the south-central portion of the Loudon quadrangle, was used to investigate this question.

Land use decisions in this sample area were considered in the following manner. Each land use parcel was considered to represent a discrete decision, and those parcels having depressions (core set) were grouped for comparison with each set of *successively* contiguous parcels. This, in effect, forms a core of parcels having karst occurrences with roughly concentric zones of parcels being progressively further away from the depressions.

TABLE 6. *Land use parcel frequencies—New Macedonia test example*

	Woodland	Hay/Pasture	Cropland	Structures	Total
Core set frequencies	15	28	13	5	61
Core set percentages	24.6	46.0	21.2	8.2	100.0
1st Contiguous Zone frequencies	17	25	23	14	79
1st Contiguous Zone percentages	21.5	31.6	28.1	17.8	100.0

Since the best developed karst area was being considered, it was assumed that it would have the analogous significant difference between itself and the surrounding agricultural area as found for the test site in general, if not the exact computed chi-square statistic. Therefore, assessing the spatial influence of the core area of karst topography becomes a question of ascertaining which surrounding zone of land use parcels represents the threshold level of decisions. In a general case, this could be accomplished by computing the chi-square statistic for each successive zone of parcels until the kth zone demonstrated a significant result. In the particular case under consideration, a significant difference was found between the core set and the first surrounding set of contiguous parcels. Tables 6 and 7 summarize the frequencies from which chi-square was computed.

Chi-square computed for the observed and expected parcel

TABLE 7. *Area sample point frequencies—New Macedonia test example*

	Woodland	Hay/Pasture	Cropland	Structures	Total
Core set frequencies	211	184	117	21	533
Core set percentages	39.6	34.5	22.0	3.9	100.0
1st Contiguous Zone frequencies	156	145	198	33	532
1st Contiguous Zone percentages	29.4	27.2	37.2	6.2	100.0

frequencies yielded 12.7, significant at the 0.01 level for three degrees of freedom. The same test applied to the area sample points yielded 84.2, similarly significant. It may be concluded, *in this individual test case,* that the influence of karst terrain extends only through the set of land use parcels actually containing the depressions. This may or may not be true in areas having other areal densities of karst depressions. The technique illustrated in this test, however, provides a means for quickly assessing each individual situation.

Discussion of Karst-Land Use Relationships

There are several land use combinations of particular interest in the various sections of the Tellico Test Site. In those areas of karst, for example, which are characterized by a *high* density of relatively small depressions, cropland land uses predominate almost to the entire exclusion of other types. Several locations within the test site exemplify this situation, among them the agricultural area east of the Meadow community near the eastern margin of the Meadow quadrangle, and the strike valley in the vicinity of the Lakeside settlement in the northwest corner of the Madisonville quadrangle. This common situation may be a reflection of the

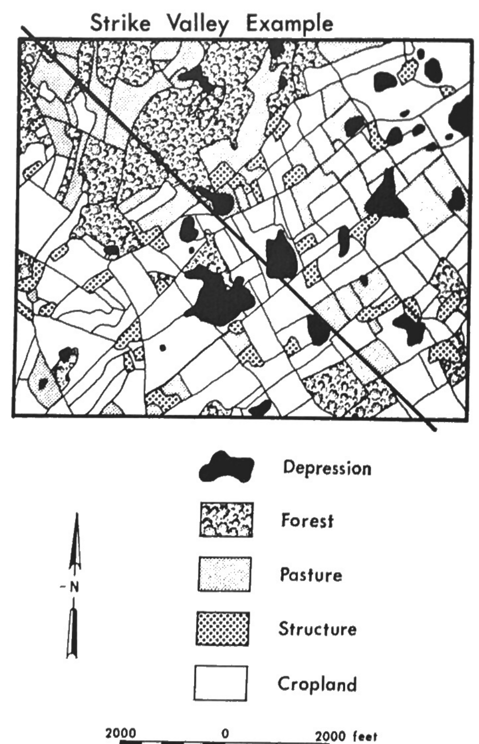

FIG. 3 *Map of land use/karst relationships in a typical strike valley situation*

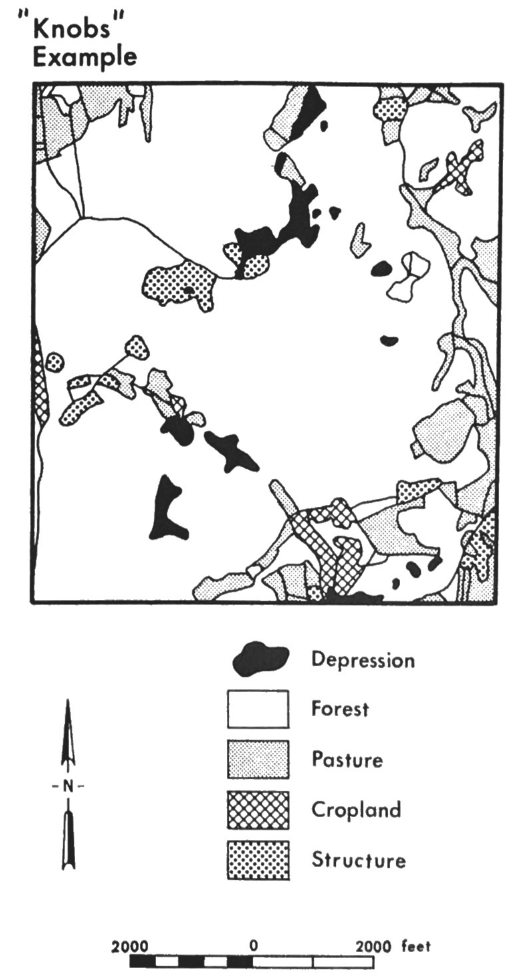

FIG. 4 *Map of land use/karst relationships in "Knobs" example*

greater development of residual soils in the more easily dissolved facies. Hay and pasture land uses are characteristically peripheral to these cropland areas. As might be expected, few isolated areas reflect the tendency for this land use to be grouped. Isolated occurrences of cropland are usually related to small, preferred locations in stream valleys and creek bottoms traversing predominantly forested areas.

Other land uses on karst do not resemble the particular clustering of cropland. In most other areas, woodland and hay/pasture land are relatively intermixed where occurring in close proximity. More commonly, though, singular depressions in areas of low depression density have these latter uses interspersed in no particular pattern. The northern half of the Loudon quadrangle, mostly covered by the Copper Ridge overthrust, is a good example of this tendency.

With these gross patterns in mind, it is appropriate at this stage to consider individual cases of land relationships to karst topography. These will be structured in the context (i.e. strike valleys, knobs, overthrust

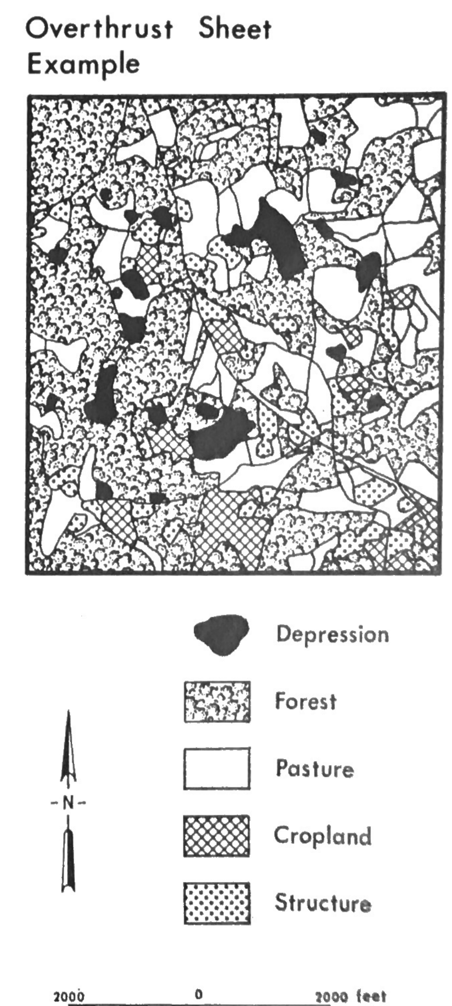

FIG. 5 *Map of land use/karst relationships in a typical area of the Copper Ridge overthrust sheet*

sheets, floodplain, and fault zones) in which the occurrence of karst was described above.

As previously noted, the occurrences of Knox Group rocks in the strike valleys have the greatest density of karst depressions. A section of the eastern part of the Meadow quandrangle has been chosen as an example of this type (see figure 3). The dominance of cropland is evident in the solution areas, with woodlands occupying upper slopes, and hay and pasture lands characterizing the lower slopes adjoining the cropland. Roads and residences carefully avoid solution areas, but six farm ponds occupy portions of depressions. It is interesting to note that these ponds almost always occur at or very near field boundaries, which generally are unaffected by the presence of karst. The boundaries which unerringly cross the larger depressions testify to this fact. The cross-section line in Figure 3 trends across the strike valley.

The choice of a sample area to illustrate karst occurrence among the "Knobs" is severely limited because of the few depressions existing in these areas. The area selected lies in the northeast section of Meadow quadrangle between Cloyd and Floyd Creeks (see Figure 4). The area is predominantly forested, with other land

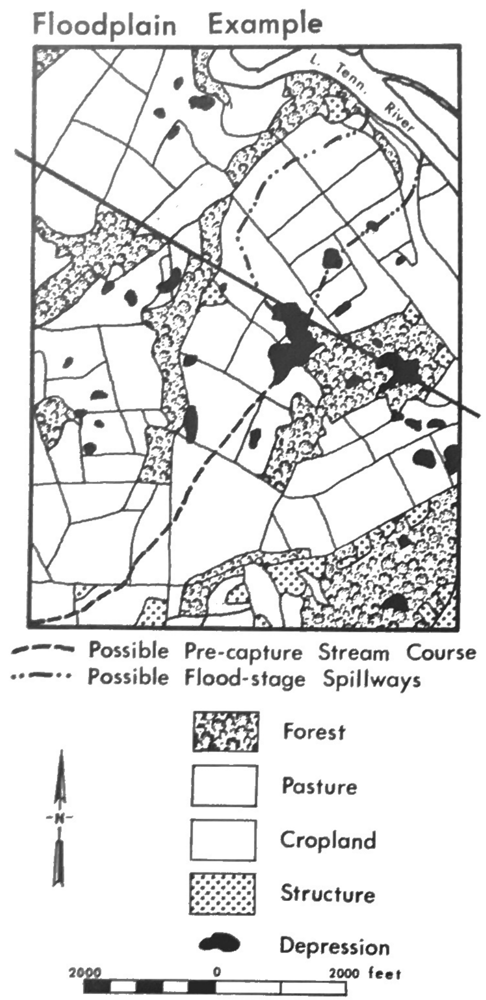

FIG. 6 *Map of land use/karst relationships on ancestral floodplain*

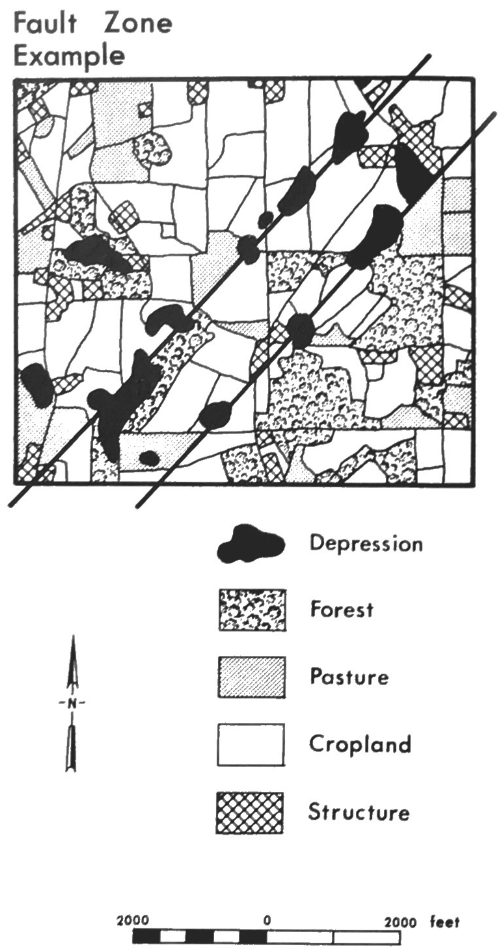

FIG. 7 *Map showing land use/karst relationships in fault zone example. Cross-sectional lines show inferred location of faults*

uses occurring in narrow valley locations in the case of pasture and small cropped areas, and a quarry typical of the Holston Formation also appears in the upper part of the example.

The largest area of solution on the Copper Ridge overthrust sheet straddles the boundary between the Concord and Meadow quadrangles. State Highway 95 bisects the area (see Figure 5). Although the land use pattern is seemingly complex, it is because of the large number of residences along this major feeder route to nearby Lenoir City, three miles north across Fort Loudon Dam. In this area, karst areas are characteristically hay lands included within pasture surrounded by woodland. Possibly because of their status as relatively preferable agriculture lands within this dominantly non-agricultural locale, field boundaries commonly follow depression limits, at least in the case of the large depressions.

The only significant karst depression on floodplain is on the ancestral floodplain of the Tellico River south of the historical site of Fort Loudon (see Figure 6). This entire floodplain is in cropland and a lake was in evidence at the time of photography within the limits of the large depression interpreted as a swallow hole. Woodlands occupy the low bluffs on either side of the floodplain, and cropland again appears on the benches approximately 100 feet above the floodplain, along with some hay and pasture land. Field boundaries in this example are severely influenced by the breaks in slope at the edges of the floodplain and the benches. The cross-sction line trends across the floodplain and lateral benches.

A section of the central extent of Knox Group rocks was chosen for closer inspection of the effects of faulting on land use/Karst relationships. It lies in the north-central part of the Madisonville quandrangle (see Figure 7). Although certain land use combinations pertain to this example, it is the alignment along the fault zone that best characterizes this type, with a stairstep effect in decreasing elevation toward the northeast imparted along this trace. Although mostly cropland appears along the cross-section lines in Figure 7, other depressions in the area show pasture along wetter stream bottoms, and woodlands are found occupying the steeper-walled depressions. Field boundary decisions appear to be completely unaffected by solutional activity.

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LITERATURE CITED

Berry, B. J. L. 1962. *Sampling, Coding, and Storing Flood Plain Data*. Agricultural Handbook No. 237, USDA. 24 p.
Freeman, T. W. 1961. *A Hundred Years of Geography*. Aldine Publishing Co., Chicago. 74 p.
Griffin, John I. 1962. *Statistics, Methods, and Applications*. Holt, Rhinehart and Winston, New York. p. 188-189.
Hardeman, W. D. 1966. *Geologic Map of Tennessee (East Central Sheet)*. State of Tennessee, Division of Geology, Nashville.
Harvey, D. 1970. *Explanation in Geography*. St. Martin's Press, New York. 313 p.
King, L. J. 1969. *Statistical Analysis in Geography*. Prentice-Hall, Inc., Englewood Cliffs, N.J. 81 p.
Malott, C. A. 1939. "Karst Valleys," *Bulletin of the Geological Society of America*, 50: 1984 p.
Nunnally, N. R. and R. E. Witmer, 1970a. *A Land Use Interpretation Experiment*. Technical Report 69-5, USGS.
__________. 1970b. "Remote Sensing for Land Use Studies," *Photogrammetric Engineering*. 36: 449-453.
Saarinen, T. F., 1969. *Perception of Environment*. Commission on College Geography Resource Paper No. 5, Association of American Geographers, Washington, D.C. p. 3-4.
Thornbury, W. D. 1969. *Principles of Geomorphology*, 2nd. ed. John Wiley and Sons, Inc., New York. 311 p.
__________. 1965. *Regional Geomorphology of the United States*. John Wiley and Sons, Inc., New York. 609 p.
Witmer, Richard E. 1970. *Tellico Test Site Land Use Map*. Technical Report 69-4, USGS GEOGAP Program, Contract 14-08-0001-12009.

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A SURVEY OF THE MICROTINE AND ZAPODID RODENTS OF WEST TENNESSEE

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ABSTRACT

A total of 235 specimens of the subfamily Microtinae and the family Zapodidae were examined and collected from West Tennessee. *Microtus pinetorum* was collected readily throughout the study area. *M. ochrogaster* was absent from the southern tier of counties. *Ondatra zibethicus* was found throughout the study area. *Zapus hudsonius* was infrequently collected and found only in the northern half.

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INTRODUCTION

In western Tennessee, the mammals of the rodent groups Microtinae and Zapodidae are poorly known. Therefore, a study was initiated to learn more about