# EXTRAPOLATION OF FOREST COMMUNITY TYPES WITH A GEOGRAPHIC INFORMATION SYSTEM

Wayne K. Clatterbuck and John Gregory[1]

Abstract: A geographic information system (GIS) was used to project eight forest community types from a 1,190-acre (482-ha) intensively sampled area to an unsampled 19,887-acre (8,054-ha) adjacent area with similar environments on the Western Highland Rim of Tennessee. Both physiographic and vegetative parameters were used to distinguish, extrapolate, and map communities. Accuracy of the GIS-generated community map was tested by sampling community types from 211 plots and assessing whether the predicted communities actually occurred. Probability statements were formulated to assess map accuracy within a specified confidence level for each community type. The extrapolated composite community map was 85 percent correct at the 90 percent confidence level. Maps of six community types - American beech, northern red oak, black oak-hickory, yellow-poplar, post oak, and scarlet oak - were also 85 percent correct at the 90 percent confidence level. The map was accurate less often, 70 percent and 80 percent correct at the 90 percent confidence level, for American sycamore-sweetgum and chestnut oak communities respectively. These results indicate that when forest communities across a landscape are similar in species composition, structure, and physiography, sampling and inventories of these communities can be reduced or eliminated.

## INTRODUCTION

The use of Geographic Information Systems (GIS) by natural resource organizations has expanded greatly beyond just map making capabilities in the last 5 years. Lipscomb and Williams (1989) described some of the more specific uses of a GIS for forest management activities such as fire weather danger simulations and logging transportation costs. The Tennessee Wildlife Resources Agency (TWRA) is using its system as a tool to model wildlife habitat parameters for improved management of wildlife species (Davis 1982). The objective of this paper was to determine if GIS technology could be used to model and predict with an acceptable degree of confidence, forest attributes or community types across the landscape. Can a vegetational and physiographic database obtained from intensively sampled portions of the landscape be used to accurately describe forest communities with similar biotic and physiographic environments? Such a process would conserve substantial sampling and

[1]Staff Forester, Forest Resource Planning, Tennessee Department of Conservation, Division of Forestry, Nashville, TN 37243-0444; and Forester, Tennessee Wildlife Resources Agency, Nashville, TN 37204.

inventory costs while generating forest community databases for wildlife habitat management much more quickly than could be obtained through 100 percent inventories.

## STUDY AREA

The study was conducted on the 19,887-acre (8,054-ha) Cheatham Wildlife Management Area (CWMA), situated in the Western Highland Rim physiographic region of Tennessee (Fenneman 1938), and managed by the TWRA. The CWMA is located approximately 25 miles (40 km) west of Nashville, TN (36012'N, 8705'W). Braun (1950) described the vegetation of the Western Highland Rim as part of the Western Mesophytic Forest, a transition area between the Mixed Mesophytic Forest Region of the mountains to the east and the Oak-Hickory Region to the west. The CWMA consists of narrow to broad ridges, steep dissected side slopes, and V-shaped upland stream valleys. Elevations range from 480 ft (146 m) in the valleys to 820 ft (250 m) on the ridges. Site index for upland oaks ranges from 55 ft (17 m) at 50 years on the exposed dry south slopes to 85 ft (26 m) on the well-drained footslopes and cooler moist north slopes (Schnur 1937).

According to Smalley's (1980) hierarchical classification of forest sites, the CWMA is within the Highland Rim and Pennyroyal physiographic province, Western Highland Rim region, Highland Rim plateau subregion, and two landtype associations: strongly dissected plateau and moderately dissected plateau. Six landtypes from the two landtype associations are present on the CWMA: narrow ridges and convex upper slopes; broad ridges - north aspect; broad ridges - south aspect; cherty north slopes; cherty south slopes; and footslopes, terraces, streambottoms, and upland depressions with good drainage (Smalley 1980). Agronomical, climatological, and geological characteristics of the region are described by Smalley (1980). Prevalent tree species on the study area include white oak (*Quercus alba* L.), northern red oak (*Q. rubra* L.), black oak (*Q. velutina* Lam.), scarlet oak (*Q. coccinea* Muenchh.), post oak (*Q. stellata* Wangenh.), chestnut oak (*Q. prinus* L.), hickories (*Carya* spp.), yellow- poplar (*Liriodendron tulipifera* L.), American beech (*Fagus grandifolia* Ehrh.), sweetgum (*Liquidambar styraciflua* L.), white ash (*Fraxinus americana* L.), American sycamore (*Platanus occidentalis* L.), dogwood (*Cornus florida* L.), blackgum (*Nyssa sylvatica* Marsh.), sourwood (*Oxydendrum arboreum* L.), and sassafras (*Sassafras albidum* (Nutt.) Nees).

## PROCEDURES

In a previous study, eight statistically discrete community types (yellow-poplar, northern red oak, post oak, American beech, chestnut oak, scarlet oak, black oak-hickory, and sycamore-sweetgum) were defined and mapped on an intensively sampled 1,190-acre (482-ha) compartment within the CWMA.[2] The community classification was expanded to cover the entire 19,887-acre (8,054-ha) CWMA. The process of projecting these community types to unsampled areas will be referred to as extrapolation in this paper. The variation and landscape heterogeneity associated with the community classification system were recognized and accepted as a source of the variation encountered during the extrapolation process.

## GIS Extrapolation

The extrapolation procedure involves two steps. We first describe or define each community according to physiographic features, i.e., landtype, topographic slope, aspect, and then integrated these features to produce maps of forest community types. The second step involves evaluating the accuracy of the community map. Thus, the extrapolation procedure is not only a test of differentiating and defining communities by physiographic parameters, but also a test of projecting those parameters or community entities on the landscape.

The projection of the community classification system on the landscape was accomplished with a Geographic Information System (GIS) that assembles, stores, retrieves, and manipulates data in formats to allow information to be mapped and spatially analyzed. The GIS uses different coverages, i.e., layers, of information such as topography, vegetation, soil, hydrology, etc. in a point, line, or polygon form that are referenced to a coordinate system. Roads, easement right-of-ways, waterways, and specific units of the landscape such as fields or ponds can be digitized and geographically referenced. These coverages are superimposed on each other to yield a geographically connected information system which can be used in planning and decision-making analyses.

The GIS database for the CWMA was compiled during previous TWRA inventories. Earth Resource Data Analysis System (ERDAS) software (ERDAS, Inc. 1987) was used to organize data geographically. Grid cell size was 0.67 acre (0.27 ha), and each cell contained information on landtype, topographic slope, and aspect of locations within CWMA. Communities were defined according to these geographic parameters; ERDAS was used to integrate and manipulate these coverages to produce maps of community types. The GIS output was a gray map of eight computer symbols, with each symbol representing one grid cell and its corresponding community type.

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[2]Clatterbuck, W.K. 1988. Classification and analysis of forest plant communities on Cheatham Wildlife Management Area in north-central Tennessee. Unpublished USDA Forest Service Report, RWU-4102, Study No. 1.45. Southern Forest Experiment Station, New Orleans, LA.

Accuracy testing involved selecting sample points from each community type on the map, "ground-truthing" those points, and assessing whether the predicted communities actually occurred. Departures were recorded and evaluated for future refinements in the extrapolation process as well as in the community classification system. A probability statement concerning the accuracy of the projected community types was formulated and used to determine the degree of accuracy within some level of confidence (e.g., a community type on the map is 85 percent accurate at the 95 percent confidence level). The equations and reasoning used in these methodologies are in accordance with those reported by Ginevan (1979) and modified by Aronoff (1982) who used hypothesis testing to determine consumer and producer risks. Consumer's risk, i.e., probability of accepting an inaccurate map is as follows:

$$A \geq \frac{\sum_{X=0}^{X'} N!}{[X!(N-X)!]QL^{(N-X)}(1-QL)^{X}} \tag{1}$$

To use this equation, a minimum acceptable map accuracy (QL), a sample size (N), and a consumer's risk (A) are selected. The maximum number of allowable misclassifications (X') is found such that the cumulative probability of having X' or fewer misclassifications is less than or equal to A.

Producer's risk (B) is the probability of incorrectly rejecting an acceptable map of some high accuracy (QH) by having more than X' misclassifications. The equation for producer's risk is:

$$B = \frac{\sum_{X=X'+1}^{N} N!}{[X!(N-X)!]QH^{(N-X)}(1-QH)^{X}} \tag{2}$$

The primary consideration in evaluating extrapolation success is determining the number of samples to take and the maximum number of misclassified samples to allow to attain a prescribed map accuracy.

Approximately 30 samples per community type were adequate to achieve an accuracy of 85 percent with a 90 percent level of precision. Samples for each community type were selected at random from the map where the same community type covered five contiguous grids. Each sample represented at least 3 acres (1.2 ha) of the predicted community type. Map accuracy and confidence levels were altered when community misclassifications were more frequent than desired or if 30 samples for a community type were not represented on the map. A total of 211 sample plots was used for a sampling density of one plot per 94 acres (38 ha).

## RESULTS AND DISCUSSION

### Community Matrix

To predict community occurrence on CWMA, a matrix of aspect and percent slope that described the eight communities was constructed (Table 1). Six of the community types were adequately defined by aspect and percent slope: northern red oak, black oak-hickory, yellow-poplar, scarlet oak, American beech, and post oak; chestnut oak and sycamore-sweetgum were not. However, both chestnut oak and sycamore-sweetgum communities were delineated by landtype: chestnut oak on broad undulating ridges greater than 250 ft (76 m) wide, and sycamore-sweetgum in the stream valleys. The two landtypes depicting chestnut oak and sycamore-sweetgum communities were superimposed onto the coverage created by the aspect and percent slope matrix to generate a composite map for all eight communities. The overlay of the landtype map effectively replaced communities defined by the matrix (Table 1) in the 0 to 8 percent slope range that occurred on the broad ridge crests and in stream valleys with chestnut oak and sycamore-sweetgum communities respectively. Thus the only communities defined by the matrix at 0 to 8 percent slope were on narrower ridge crests less than 250 ft (76 m) wide. The percentage of land area within CWMA in each community type, as predicted by the aspect-slope percent matrix superimposed with landtype maps, is shown in Table 2.

Table 1.--Community types by aspect and percent slope, as used in the extrapolation analysis.[1]

| Aspect | Percent slope | | |
|---|---|---|---|
| | 0-23 | 24-35 | >35 |
| North | Yellow-poplar | Northern red oak | Northern red oak |
| Northeast | Yellow-poplar | Northern red oak | Northern red oak |
| East | Black oak-hickory | Black oak-hickory | American beech |
| Southeast | Black oak-hickory | Black oak-hickory | American beech |
| South | Scarlet oak | Scarlet oak | Post oak |
| Southwest | Scarlet oak | Scarlet oak | Post oak |
| West | Scarlet oak | Scarlet oak | Post oak |
| Northwest | Yellow-poplar | Northern red oak | American Beech |

[1]The map created by this matrix was overlayed with landtype maps to define the two communities (chestnut oak and sycamore-sweetgum) that could not be defined by aspect and/or percent slope.

Table 2.--Extrapolation analysis: predicted area by community type and mapping accuracy.

| Community type | Predicted land area | Sample plots | Correctly identified plots | Map accuracy | Confidence level of map | Allowable plot misclassifications |
|---|---|---|---|---|---|---|
| | --Percent-- | ------------Number------------ | | ------------Percent------------ | | -Maximum number- |
| Yellow-poplar | 1.4 | 12 | 10 | 85 | 90 | 3 |
| Northern red oak | 17.8 | 31 | 26 | 85 | 90 | 7 |
| Black oak-hickory | 17.4 | 31 | 28 | 85 | 90 | 7 |
| Chestnut oak | 16.3 | 25 | 18 | 80 | 90 | 8 |
| American beech | 20.9 | 30 | 24 | 85 | 90 | 6 |
| Scarlet oak | 8.8 | 22 | 17 | 85 | 90 | 5 |
| Post oak | 14.0 | 32 | 29 | 85 | 90 | 7 |
| Sycamore-sweetgum | 3.4 | 28 | 19 | 70 | 90 | 10 |
| Total | 100.0 | 211 | 171 | 85 | 90 | 44 |

## Map Accuracy

Six of the GIS generated communities were within map accuracies of 85 percent at the 90 percent confidence level: yellow-poplar, scarlet oak, post oak, northern red oak, black oak-hickory, and American beech (Table 2). Communities that were misclassified usually appeared as communities that occur adjacent to the predicted communities. The scarlet oak and yellow-poplar communities only contained 22 and 12 samples, respectively, as contiguous map grids for these communities were scarce. Although 30 samples for each community type were initially sought, the scarlet oak and yellow-poplar communities at the smaller sample size were within the prescribed map accuracies.

The map was accurate less often for sycamore-sweetgum and chestnut oak communities. Both these communities were defined by landtype rather than the aspect-percent slope matrix in the extrapolation. Communities were often classified as American beech and northern red oak rather than sycamore-sweetgum, and black oak-hickory rather than chestnut oak (Table 3). The landtype representing sycamore-sweetgum communities extended into narrow, V-shaped, second-order streams on the GIS map, locations where this community does not occur. Generally, sycamore-sweetgum communities appeared more often as stream width increased and as valleys became more U- shaped. Adjustments in the data base could be made so that the stream bottom landtype would not extend into V-shaped, second-order streams.

Chestnut oak communities were defined on ridge crests greater than 250 ft (76 m) wide. Ridge crests in the compartment where the community type classification was developed rarely exceeded 400 ft (122 m) in width and occupied a very small portion of the compartment. Several ridges on the CWMA were wider than 400 ft (122 m), but less than 1,000 ft (305 m), and constituted a much larger percentage of the total land base within CWMA (Table 2) than represented in the sampled compartment. Several oak species (white oak, scarlet oak, black oak, post oak, and chestnut oak) were present on these ridges. Accordingly, many of these wider ridges (>400 but <1,000 ft or >122 but <305 m) contained black oak-hickory communities rather than the predicted chestnut oak community. Alterations in the community classification system will be necessary to accommodate extrapolation of these different communities on these wider ridges.

Approximately 4.3 percent or 867 acres (350 ha) of the GIS generated map contained blocks of 20 or more continuous grids that were composed of three or more communities. Within these blocks, no one community was continuous or connected. Refinements in the database and modeling procedures should allow each unit of the landscape to be mapped and interpreted more clearly. One refinement currently being implemented by TWRA is changing their GIS modeling procedure from a grid to a polygon format so that areas of varying shape and size can be mapped.

Table 3.--Extrapolation: accuracy of community type projections.

| Predicted community | Actual community | | | | | | | | Sample |
|---|---|---|---|---|---|---|---|---|---|
| | Sycamore-sweetgum | Scarlet oak | Post oak | Yellow-poplar | American beech | Black oak-hickory | Chestnut oak | Northern red oak | size |
| | Number of plots[1] | | | | | | | | --n-- |
| Sycamore-sweetgum | 19 | | | | 5 | | | 4 | 28 |
| Scarlet oak | | 17 | 3 | | | 2 | | | 22 |
| Post oak | | | 29 | | 1 | 2 | | | 32 |
| Yellow-poplar | | | | 10 | | | | 2 | 12 |
| American beech | | | | | 24 | | | 6 | 30 |
| Black oak-hickory | | | | | | 28 | 3 | | 31 |
| Chestnut oak | | | | | | 7 | 18 | | 25 |
| Northern red oak | | | | | 1 | 4 | | 26 | 31 |
| Total | | | | | | | | | 211 |

[1]Of the 211 extrapolated classifications, 40 were misclassified.

## SUMMARY

The use of the GIS was instrumental in generating a landscape model of forest community types. The composite CWMA community map was 85 percent correct at the 90 percent confidence level. All but two community type projections were within the prescribed limits. The slightly lower map accuracies and confidence levels for the chestnut oak and sycamore-sweetgum communities would not alter forest management or habitat modeling for these communities. Although some variation is present in both the community classification system and the extrapolation, the level of map accuracy achieved was more than adequate to serve as a database in modeling vegetation for wildlife and forest management.

Perhaps the greatest usefulness of GIS generated community classification modeling is the characterization and estimation of vegetational properties across the landscape. Great advances in forest management and habitat planning can be made if a treatment successfully applied to a community at one location can be expected to be successful on the same community type at another location. Currently, the community classification is being used to assess habitat potential. Community classification is also playing a role in the planning and decision-making processes used to appraise the effect of forest management on wildlife habitat. This study provides a broad qualitative extrapolation of communities. Further research should quantify the variation and consistency of forest communities and community properties or values across even broader landscapes of the Western Highland Rim.

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