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Forest Area Estimates from Landsat MSS and Forest Inventory Plot Data

Richard A. Birdsey, W. Frank Miller, Jon Clark, and Robert H. Smith

SUMMARY

Forest area estimates for Puerto Rico from Landsat multispectral scanner data were compared with area estimates derived from black and white aerial photographs. Area estimates were adjusted according to a field check at 141 sample plot locations. Adjusted Landsat area estimates differed from adjusted photo area estimates by 1.7 percent. The sampling error for Landsat data was nearly twice the sampling error for photo-interpreted data.

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INTRODUCTION

Forest area estimates are used worldwide for resource evaluation, monitoring, and planning. Recent concern about deforestation in the tropics has revealed the lack of current, reliable forest area estimates in many developing countries (UNESCO 1978). Many countries do not have the financial and technical resources at hand to conduct large scale forest inventories.

Landsat multispectral scanner (mss) data has, in recent years, been considered for its potential contribution to forest resource evaluation. Computer-processed satellite data can be substituted for data previously obtained from time-consuming photo interpretation. A recent study has documented the feasibility of applying Landsat technology to forest inventory (Nelson and Hoffer 1979). Landsat imagery has been used in the tropics to monitor forest cover alteration (Williams and Miller 1979), and in Costa Rica, Landsat data was incorporated into a geographic data base to develop cover type estimates for resource analysis (Sader 1980). In the most recent World Forest Inventory, visually-interpreted Landsat images were the only sources of information for some remote regions in Latin America (Lanly et al. 1982).

In general, the most successful projects have combined Landsat with ground truth or other geographic information. Some studies have explored the possibility of merging Landsat data with forest survey field data gathered by the U.S. Forest Service (Langley et al. 1980; Mroczynski et al. 1980). These pilot studies have established the feasibility of incorporating Landsat data into a sampling framework and demonstrated the usefulness of a geographic information system for accurately registering forest survey plot data with the Landsat data.

This study was initiated after a recent inventory of Puerto Rico highlighted the limitations of existing aerial photography (Birdsey and Weaver 1982). The inventory data was used to assess the potential benefits from combining Landsat data with forest survey data in Puerto Rico.

OBJECTIVES

The project goal was to develop rapid, efficient survey techniques for mountainous tropical regions. Specific objectives were:

1. Develop an area stratification based on terrain and Holdridge's ecological life zones (Holdridge 1969).
2. Compare forest area estimates from Landsat data with estimates from black and white aerial photography.
3. Evaluate potential benefits from combining Landsat data with forest survey data.
4. Explore usefulness of a geographical data base for combining the various data sources.

STUDY AREA

A search for Landsat data covering Puerto Rico found only one usable scene with cloud-free coverage of the northwestern third of Puerto Rico (fig. 1). Two ecological life zones account for most of the area: the subtropical moist forest zone receives between 1,000 and 2,000 mm of annual rainfall, and the subtropical wet forest zone receives between 2,000 and 4,000 mm of annual rainfall (fig. 2). Mean annual biotemperature ranges from 18° to 24° C.

The moist forest zone includes the coastal plain, interior valleys, and a wide band of limestone hills. Crops, pasture, and urban land uses are common in the plains, valleys, and lower slopes. Secondary forests are developing on the less productive, steeper slopes which are no longer farmed. Portions of the limestone hills are virtually inaccessible due to extremely rugged topography. The hills support a complex forest vegetation on varied slope positions. Tall forests in the sinkholes, bottoms, and lower slopes grade into scrub vegetation or bare soil on the xeric upper slopes, ridges, and cliff faces. Steep, forested slopes, sensitive to disturbance, have little commercial forest management potential.

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The wet forest zone includes most of the higher, wetter sites in the central mountains. Active and abandoned coffee plantations are common, interspersed with pasture, cropland, and secondary forest. The steep slopes and high rainfall quickly cause soil erosion and reduced soil productivity when the land is cultivated. Coffee grown under shade trees reduces the exposure of bare soil to intense storms. A portion of this life zone receives high rainfall (more than 2,500 mm/year) on slopes greater than 60 percent. Some forested areas are critical water catchments and should remain under protective forest cover.

METHODS

Forest Survey

An initial estimate of forest area was made from a dot-count on black and white 1:20,000 aerial photographs taken in 1977. Forest area estimates obtained from the dot-count were adjusted according to a ground check of land use at each sample location. Data on species composition and timber volume were obtained by establishing permanent sample plots at all forested sample locations. A detailed site description was made for each forested location. Fieldwork was done in 1980 and included land cover checks at 437 locations.

Landsat Image Processing

The Landsat scene was processed at the Mississippi Remote Sensing Center (Miller et al. 1982). The digital Landsat data were classified using a technique which combined elements of both supervised and unsupervised classification procedures. This technique consisted of selecting several training fields from the study area, with each field including a dominant cover type and a variety of other cover conditions. Statistics (reflectance values) from each training field were pooled for clustering into spectrally similar classes (Lockheed Engineering Co. 1977). Clusters were then assigned cover classes based on ancillary information, including panchromatic 1:20,000 stereo aerial photographs, topographic quadrangle maps, half of the ground truth information from the 1980 forest survey, and some additional field observations. Once the clusters were assigned the appropriate cover classes, the entire scene was classified using the maximum likelihood approach.

Prior to image processing, the survey area was stratified into two regions using the life zone classification. The two life zones have different land use patterns and produce different spectral responses in similar vegetation. In order to improve classification accuracy, each life zone had to be classified separately. To accomplish this, the entire scene was classified twice using unique sets of training statistics from each life zone. Only data which fell inside the life zone from which the statistics were taken was valid.

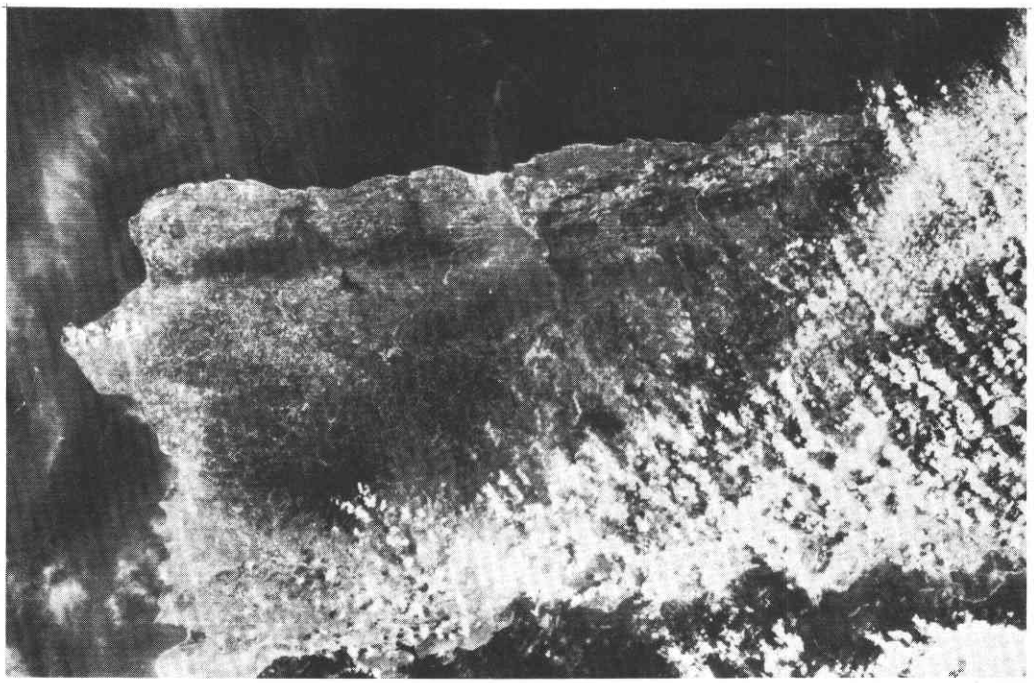

Figure 1.—*Landsat MSS coverage and atmospheric conditions, Western Puerto Rico, March 30, 1978.*

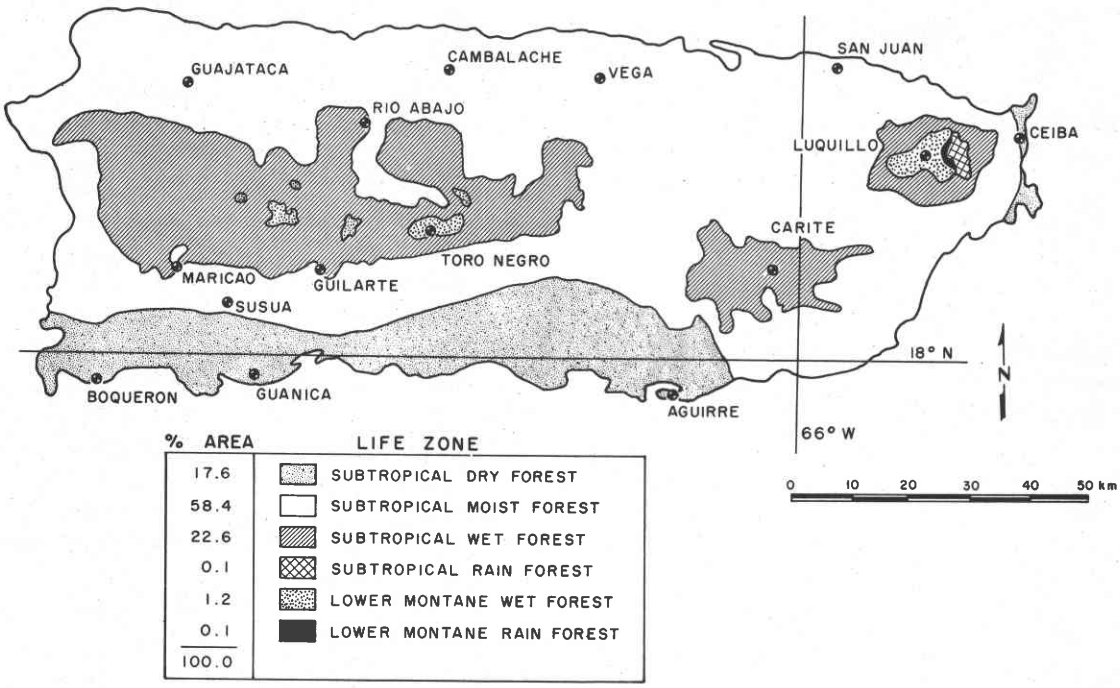

Figure 2.—*Ecological life zones of Puerto Rico.*

In order to stratify the Landsat data, classify each stratum separately, recombine the strata into a single product, and make use of ancillary data, a geographic data base was constructed. The data base employed a grid or cell-based system and an arbitrary set of coordinates. The data base allowed access of all data types or classes from one cell, or a group of cells, simultaneously.

A visual interpretation of a black and white print of the Landsat data revealed the presence of variable atmospheric haze over the study area. Reflectance values were elevated in the haze regions to an extent that varied with the density of the haze. In order to eliminate classification errors due to haze, only the haze-free portion of the Landsat scene was used in this analysis. The haze region was delineated on a 1: 250,000 scale print of the data, then digitized and added to the data base.

Merging the Data

The two classified Landsat data sets, digitized life zone boundaries, and the digitized haze boundaries were input to the data base for merging. By using the life zone map as a mask, the valid portion of each classification was extracted and the two portions were merged to produce one valid land cover map.

Each forest survey plot location was digitized within a particular 4-ha cover type cell (fig. 3). The 4-ha resolution ensured that most plots were correctly registered within the identified cover type cell. The Landsat classification results were treated as an initial estimate of forest area, just as the aerial photos provided an initial estimate of area for the forest survey. The Landsat estimate was then adjusted according to actual ground cover at the forest survey plot locations. The adjusted estimate explains misclassified data cells and changes in land use between the date of image acquisition and the collection of ground truth. Sampling errors were estimated using random sampling formulae, as in the forest survey.

RESULTS

To allow fair comparison of the three area estimation procedures, the region covered by atmospheric haze in the cloud-free portion of the Landsat scene was eliminated from the study area, leaving 205,000 ha or 23 percent of the land area of Puerto Rico. This area included 141 field plot locations from the forest survey for ground truth.

Forest Survey

Area estimates based on 1980 forest survey data were computed for the haze-free portion of the study area for each of the two life zones (table 1). A total of 5160 photographic classifications were made, and 141 sample locations were visited in the field. The

adjusted proportion of forest area for the moist forest zone was 31 percent, and for the wet forest zone, 52 percent.

These area estimates can be further subdivided by land use categories based on photo and field observations (table 2). Results are similar to area estimates for the whole island since the study area represents the range of conditions found in Puerto Rico, excluding the dry southern coast. Forest cover is more prevalent in the wet forest zone, especially active and abandoned coffee shade. Nonforest land uses occupy more than two-thirds of the moist forest zone, with pasture and cropland together occupying 57 percent of all land.

Table 1.—*Forest cover estimates for the haze-free study area from 1980 survey data*

Forest life zone	Total area	Proportion of forest land		Sampling error[1]
		Unadjusted	Adjusted	
	hectares	*percent*		
Moist	122,484	51.9	30.5	3.1
Wet	82,888	71.9	52.1	3.7
Total	205,372	60.4	39.2	

[1]By random-sampling formula, 67 percent probability level.

The proportion of photo misclassification exceeded 25 percent for each life zone (table 3). In the moist forest zone nearly all misclassifications were due to difficulty in distinguishing forest from pasture in transition areas where trees and shrubs begin encroachment. Because of shadows and poor photography, pasture often appeared as non-stocked or young secondary forest.

In the wet forest zone, misclassification occurred when bananas, bamboo, fruit trees, and other vegetation common to rural residences appeared as forest in the photographs. Some plots were misclassified due to the presence of a new "shadeless" coffee variety. Land clearing between the photography date and the fieldwork also contributed to misclassifications. A land classification scheme which could yield better results with black and white photography has been developed (table 4).

Landsat Classification

Uncorrected Landsat forest area estimates for the haze-free region were similar to unadjusted forest survey estimates in both life zones (table 5). Active and abandoned coffee shade could not be distinguished from secondary forests; however, several

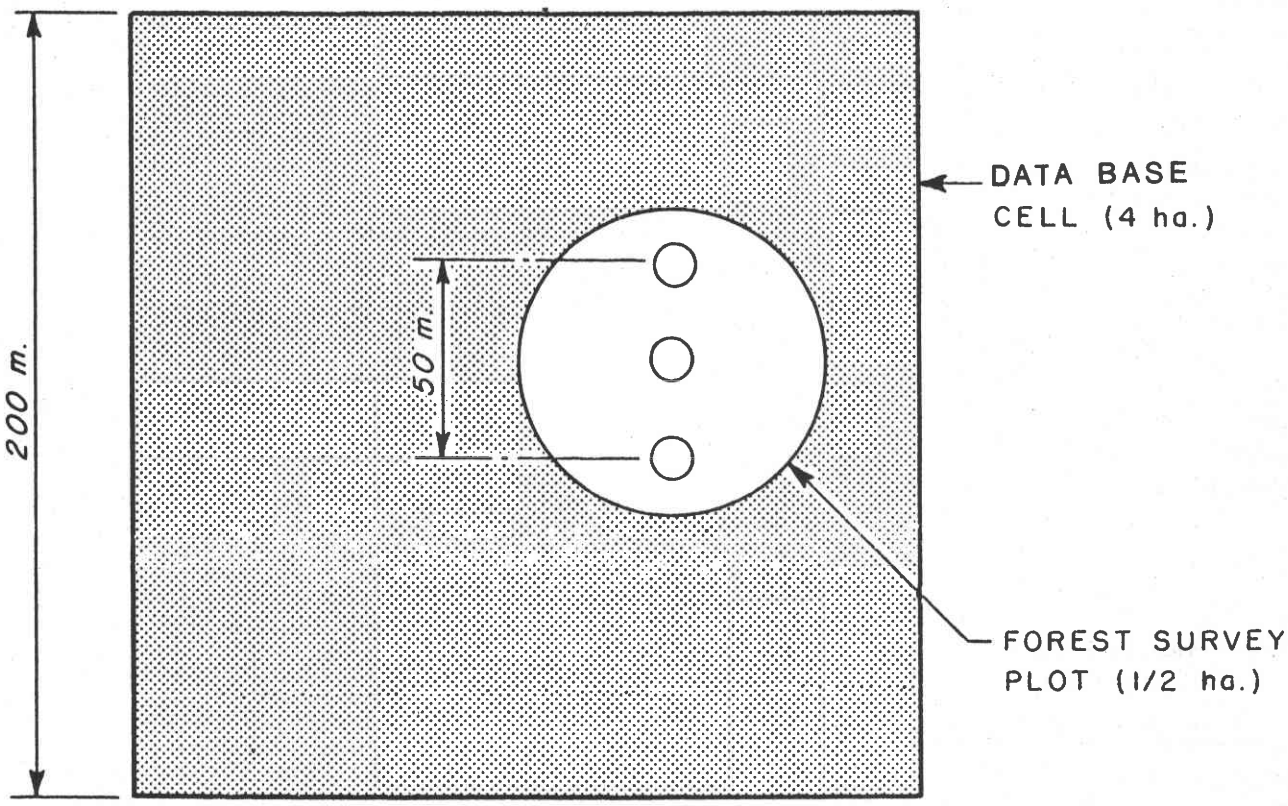

Figure 3.—*Relative sizes of a Landsat data base cell and a forest survey plot area.*

subdivisions of secondary forest and distinct agriculture/forest transition classes were found for each life zone (table 6). The classification scheme and the reflectance values for identical cover types were different for each life zone, indicating that treating each separately improved the overall results.

During processing an evaluation area was selected in each of the life zones, and land cover mapped by photo interpretation. Evaluation areas were selected with good photographic coverage to minimize photo-interpretation errors. The Landsat results were then compared to this "known" cover classification. This preliminary test indicated a fairly accurate forest/nonforest detection capability, with more variable results among specific cover classes (table 7). Detailed cover classes could not be distinguished due to the high proportion of "edge effect" between cover types. Many small farms are used for a variety of purposes, including fruit production, shade, vegetable gardens, etc. These mixed land uses were confused with non-stocked forest land in the moist forest evaluation area, and agriculture/forest transition in the wet forest evaluation area.

Table 2.—*Area by land use for the haze-free area from 1980 survey data*

Land use	Forest life zone: Moist	Forest life zone: Wet
	percent	
Forest:		
Nonstocked	5.2	0.0
Secondary	17.4	21.7
Abandoned coffee shade	6.7	17.8
Active coffee shade	1.2	12.6
Total forest	30.5	52.1
Nonforest:		
Inert[1]	12.4	14.8
Cropland[2]	27.8	18.6
Pasture[3]	29.3	14.5
Total nonforest	69.5	47.9
All land	100.0	100.0

[1]Urban and industrial areas, roads, rights-of-way, residential, water, other.
[2]Includes shadeless coffee and idle farmland.
[3]Includes unimproved pasture.

Table 3.—*Photo classification results for 141 field plots*

Land cover	Photo classification: Moist forest	Photo classification: Wet forest	Plots mis-classified: Moist forest	Plots mis-classified: Wet forest
	number of plots			
Forest	40	56	18	18
Nonforest	34	11	1	0
Total	74	67	19	18

Table 4.—*Land classification capabilities of black and white aerial photography for secondary forest cover in Puerto Rico*

Cover class	Class description
Inert	Includes urban, residential, and industrial areas; rights-of-way; water; roads; other nonforest and non-agriculture uses.
Cropland	All cropland and orchards, shadeless coffee, and idle farmland.
Pasture[1]	Grassland with less than 10 percent tree and shrub crown closure.
Transition	Grassland with 10 – 50 percent tree and shrub crown closure.
Young secondary	Fine-textured appearance, occasional scattered large crowns, with crown closure more than 50 percent.
Secondary	Uniform intermediate crown texture, with occasional gaps or emergent trees.
Abandoned coffee shade	Coarse texture of large-crowned trees, with occasional gaps or emergent trees.
Active coffee shade	Large-crowned trees form an incomplete upper canopy layer; small trees and other vegetation visible between crowns.

[1] Will include some nonstocked forest land.

Several image processing problems were investigated during the classification procedure. Atmospheric haze partially covered the study area, raising the reflectance values of all land cover types. A test area in the haze region was successfully classified when treated separately. However, since haze conditions were not uniform, numerous classifications would have been necessary to apply this to the entire study area.

Shadowing and variable reflectance in the mountainous terrain also caused problems. Adding digital terrain data to identify additional strata was considered but rejected due to resolution incompatibility. Aspect and elevation change so rapidly in the complex terrain that National Cartographic Information Center digital data resolution excludes microtopographic relief, and an individual data cell would likely show only an average terrain reading.

Merged Cover Estimate

Adjusted Landsat area estimates were nearly identical to adjusted aerial photo dot-count area estimates (tables 1, 8). When ground truth was used to correct Landsat area estimates, similar results were

Table 5.—*Area by land use for the haze-free area from Landsat data*[1]

Land use	Forest life zone: Moist	Forest life zone: Wet
	percent	
Forest:		
Nonstocked	8.6	0.0
Young secondary	8.5	25.7
Intermediate secondary	19.0	16.8
Older secondary	10.3	27.6
Total forest	46.4	70.1
Nonforest:		
Inert[2]	21.4	0.2
Agricultural[3]	32.2	29.7
Total nonforest	53.6	29.9
All land	100.0	100.0

[1]Shadowed areas were distributed proportionally among other categories.
[2]Urban and industrial areas, roads, residential areas, water, other.
[3]Pasture, cropland, and agriculture/forest transition (idle farmland and unimporved pasture).

obtained despite a high percentage of misclassified data cells. The sampling error was higher than from photography due to a higher percentage of cell misclassifications, especially in nonforest cover types (table 9). The most common misclassifications occurred in distinguishing small agricultural plots and rural homesteads from forest land, much of which is in transition from the nonforest to forest category.

DISCUSSION

During project execution, some problems surfaced regarding merged forest survey and Landsat data. For example, the field plots were too small, and photo interpretation too unreliable to extend the point sample cover class to a larger area which could be used for training. Also, the field plots were widely dispersed over the study area, and usable plots near identifiable features did not represent the full range of cover diversity. Several additional training sites were visited to complete the Landsat classification.

Certain processing techniques showed promise and will be tested in future projects. Preliminary data stratification, including haze level and detailed terrain classification, would effectively partition the data into relatively uniform subsets within each life zone. Each strata would then be classified separately using internal training statistics. Disadvantages to this approach are the additional time needed to perform the classification and extra ground truth requirements.

Some problems could be avoided if a better selection of aerial photographs or Landsat data were available. Persistent cloud cover, common in mountainous tropical areas, makes complete, cloud-free photographic coverage difficult to obtain. This also reduces the likelihood of the Landsat satellite passing overhead on a clear day. Puerto Rico's location outside a Landsat data receiving station compounds the problem; only a single year of data was available.

In sum, the study has identified some opportunities and problems associated with using remote sensing for forest area estimation in Puerto Rico. Both Landsat data and aerial photography gave roughly

Table 6.—*Cover classes discriminated from Landsat data*

Forest life zone	Cover class	Class description
Moist	Inert	Includes all highly reflective areas; construction, urban, residential, bare soil, clouds.
Moist, wet	Agriculture (crop and pasture)	Land primarily used for cropland or pasture with less than 10% brush cover or stocking; scattered trees are common.
Wet	Agriculture/ forest transition	Low density brush/pasture, and forest/pasture edge.
Moist	Non-stocked forest (early transition)	Degraded and fallow cropland or pasture; small brush and ferns may predominate with scattered large trees common.
Moist, wet	Young secondary forest	Pasture or cropland with moderate to dense brush cover, reverting to forest, although occasional grazing may occur. Young growth is generally less than 5 m tall with or without larger old field trees scattered throughout or in clumps.
Moist, wet	Intermediate secondary forest	An intermediate stand structure where younger trees have reached the height of older trees; generally a relatively smooth canopy texture.
Moist, wet	Older secondary forest	Scattered larger dominant stems cause coarser canopy texture; considerable variation in individual crown tones.
Moist, wet	Shadow	Heavily shadowed areas, generally terrain shadowing; shadow/forest transition pixels; cloud shadows; and shadow/water transition.
Moist, wet	Water	All turbidity classes were grouped.

comparable area estimates. Each data source has unique classification problems originating with the difficult terrain and intermixed land uses found in many mountainous tropical regions. The study has demonstrated that Landsat MSS data is a viable alternative to panchromatic photographic data for area estimation in forest surveys. Where cloud- and haze-free Landsat data is available, photographic missions under difficult atmospheric conditions are unnecessary. Unfortunately, clear conditions are rare for many tropical mountain regions, and Landsat data availability is often sporadic. Complete digital cover classification under clouds or severe haze would require additional imagery, such as radar, which is not significantly affected by atmospheric conditions.

Table 7.—*Comparison of photo interpreted land cover and Landsat solution for two evaluation areas*

Forest life zone	Cover class	Photo results	Landsat results
		—*percent*—	
Moist	Forest:		
	Nonstocked	3	14
	Young secondary	1	9
	Intermediate secondary	78	55
	Older secondary	7	17
	Total forest	89	95
	Nonforest:		
	Agriculture and inert	11	5
		100	100
Wet	Forest:		
	Nonstocked	3	0
	Young secondary	6	18
	Intermediate secondary	80	18
	Older secondary	4	43
	Total forest	93	79
	Nonforest:		
	Agriculture and inert	7	1
	Agriculture/Forest transition	0	20
	Total nonforest	7	21
		100	100

Table 8.—*Forest cover estimates for the haze-free study area from merged forest survey and Landsat data*

Forest life zone	Total area	Proportion of forest land		Sampling error[1]
		Unadjusted	Adjusted	
	hectares	—*percent*—		
Moist	122,484	46.4	30.0	5.3
Wet	82,888	70.1	57.0	6.0
Total	205,372	55.9	40.9	

[1]By random-sampling formula, 67 percent probability level.

Table 9.—*Landsat classification results for 141 field plots*

Land cover	Photo classification		Plots mis-classified	
	Moist forest	Wet forest	Moist forest	Wet forest
	—*number of plots*—			
Forest	39	46	25	19
Nonforest	35	21	9	11
Total	74	67	34	30

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Ecological Assessment of the Roaring Branch Research Natural Area

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Ecological Assessment of the Roaring Branch Research Natural Area

Michael S. Fountain and James M. Sweeney

INTRODUCTION

The Roaring Branch Research Natural Area (RBRNA) was established in 1968 as a part of a nationwide effort to preserve examples of unique vegetative types. The area contains old-growth hardwood and shortleaf pine, probably components of the virgin stand. Showing no evidence of commercial harvest or recent fires, present vegetation probably represents a natural ecological succession relatively undisturbed by man (Ferguson 1968).

The RBRNA is located on the Caddo Ranger District of the Ouachita National Forest, about 51 km (32 miles) west of Glenwood, Arkansas. The area comprises the upper part of the Roaring Branch watershed and includes about 121 ha (300 acres) in Sections 26, 27, and 28, Township 4 South, Range 28 West, Fifth Principal Meridian, Polk County, Arkansas.

The area is accessible only by foot-trail from Forest Service Road 106 (Blaylock Rd.). Details concerning access and use can be obtained from the USFS Southern Forest Experiment Station.

PHYSIOGRAPHY—SOILS AND CLIMATE

The RBRNA lies in the Central Ouachita Mountains subdivision of the Ouachita Mountain physiographic province. These mountains are characterized by east-west parallel ridges, which are typical of much of the province. Rocks of this subdivision are a combination of igneous rock and sedimentary rock of novaculite, sandstone and shale. They represent several geologic ages. Ridges have sharp, rather narrow crests and tend to be very rugged with numerous large rock outcrops (Arkansas Dept. of Planning 1974).

The east-west orientation creates either north or south facing slopes with widely differing local climatic conditions. The overall climate of the RBRNA is one of hot summers and moderately cold winters. Precipitation is fairly heavy (annual average of 138.4 cm) and is normally well distributed throughout the year. Direct climatological data are not availabe for the area, but the Mt. Ida Station, located to the northeast at coordinate 34°32′N and 93°36′W (elevation of 212.4m), provides data that should be comparable (table 1). Additional precipitation data obtained from the Big Fork and Athens stations, due north and due south respectively of the area, follow the same general precipitation pattern as that of Mt. Ida.

The majority of the soils belong to either the Carnasaw or Clebit series.[1] The Carnasaw soils (clayey, mixed, thermic Typic Hapludults) are located on gently sloping to steep side slopes. They formed in material weathered from shale of Pennsylvanian age. Solum thickness ranges from 102 to 152 cm. This soil type is well-drained, low in natural fertility and strongly to very strongly acid. Estimated shortleaf pine[2] site index (base age = 50 years) is 18.3 - 21.5 m.

The Clebit soils (loamy-skeletal, siliceous, thermic Lithic Dystrochrepts) are shallow (solum thickness of 25.4 to 50.8 cm), well-drained gravelly fine sandy loam soils that formed in material weathered from sandstone. These soils

[1]Personal correspondence with Mr. Jeff Olson, Soil Conservation Service District office in Mena, AR. The soil survey report for Polk County is incomplete.

[2]Common names utilized throughout the paper are referenced in Appendix Table A, B, and C.

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Table 1.—*Climatological data from Mt. Ida Station (National Oceanic and Atmospheric Administration 1974, 1975, 1976, 1977, 1978)*

Year	Temperature (°C)			No. of frost-free days (°C)	Precipitation (cm)	
	Avg. Annual	Extremes			Total	Depart. from normal
		High	Low			
1974	15.2	41.1	- 9.4	181	186.8	48.2
1975	15.0	39.4	-12.8	173	139.5	0.8
1976	13.9	38.3	-15.0	182	116.4	-22.3
1977	15.3	37.8	-17.2	188	127.9	-10.8
1978	14.4	40.0	-17.2	169	121.2	-17.5
5-year Avg.	14.8	39.3	-14.3	178.9	138.4	- 0.3

are on ridgecrests and upper slopes of both ridges that form the northern and southern boundaries of the Research Natural Area (RNA). Estimated shortleaf pine site index (base age = 50 yrs.) is 12.1 m.

STUDY METHODS

Vegetative analysis used a systematic sampling scheme with nested quadrats as the basic sampling unit. The overstory component (trees > 4.0 cm at 1.3m) was sampled with rectangular quadrats (8 m × 12 m). The smaller tree classes (1.0 to 3.9 cm at 1.3 m) and the shrub component were sampled with 4 m × 6 m quadrats; the herbaceous vegetation was sampled utilizing 1 m × 2 m quadrats.

Sampling units were located by initially establishing a baseline on the northern boundary of the RNA. This baseline was then divided into 100 m units. Each unit thus represented a strip 100 m wide by the width of the entire RNA. These strips were subdivided into 100 m segments creating a series of 100 m × 100 m blocks encompassing the entire area. Location of the sampling unit within these blocks required the selection of 2 random numbers. The first number (from 1-100) defined the distance along the baseline for the beginning of the sample line (and was used for all plots on that line) and the second defined the distance along the sample line due south from the point selected by the first number. The point thus designated by this pair of random numbers located the northeast corner of the nested quadrats. Random numbers that would cause the quadrat location to overlap onto adjacent strips or to adjoining segments were not used. Accordingly, 100 plots were located and sampled. The northeast corner of each odd-numbered sampling unit was permanently marked with metal rods to facilitate future sampling to document successional trends.

Sampling of the overstory component consisted of recording all trees within the specified diameter range by species and diameter at breast height (to nearest mm at 1.3 m). The small tree classes were also tallied by species and diameter. Additionally the tree and shrub species occurring on the 4 m × 6 m quadrat were assigned an estimate of the percentage of the quadrat covered by each species according to the following classes:

Cover Class	*Estimated Cover (%)*
1	≤ 5
2	6-25
3	26-50
4	51-75
5	76-100

The percentage of ground cover was also estimated for each herbaceous species on the 1 m × 2 m quadrat utilizing these same classes.

In order to define the dominant vegetation of the RBRNA, importance values were calculated for all overstory tree species found on the area. These importance values are the sum of a species' relative frequency, relative density, and relative basal area where:

$$\text{frequency value} = \frac{(\text{no. of plots where species i occurs})\ 100}{\text{total no. of plots}}$$

$$\text{relative frequency} = \frac{(\text{frequency value for species i})\ \ 100}{\text{total frequency value for all species}}$$

$$\text{relative density} = \frac{(\text{no. of stems per ha for species i})\ \ 100}{\text{total no. of stems per ha for all species}}$$

$$\text{relative basal area} = \frac{(\text{basal area in m}^2 \text{ per hectare of species i})\ 100}{\text{total basal area in m}^2 \text{ per hectare for all species}}$$

Curtis and McIntosh (1951) proposed these concepts with the premise that species possessing the highest importance values can be used to characterize the dominant vegetation of an area.

As stated earlier, the area has a predominant east-west orientation that creates either north- or south-facing slopes. Empirical evidence quickly identifies different plant associations according to the degree of exposure of the site. Therefore, other approaches to the problem of defining quantitatively the vegetation of the RBRNA were to sort the plots according to their location on either north- or south-facing slopes and by their position on the slope. Six locations were defined (fig. 1). Data were not separated into slope classes (similar percent slope) because the effects of this variable were generally overridden by the potential insolation. Many steeper slopes located on the lower portion (1/3) of the north-facing slope or on midslope positions on the south-facing complicated classification. North-facing plots were relatively moist and often supported the highest species diversity while plots on the south-facing side in the same slope class were very dry.

Calculation of importance values, as developed for the tree component, was not applicable to the shrub or herbaceous component. The dominant species of these components was defined by computing the average percent cover and the relative frequency. The calculation of average percent cover utilized the midpoint of each cover class (2.5, 15.0, etc).

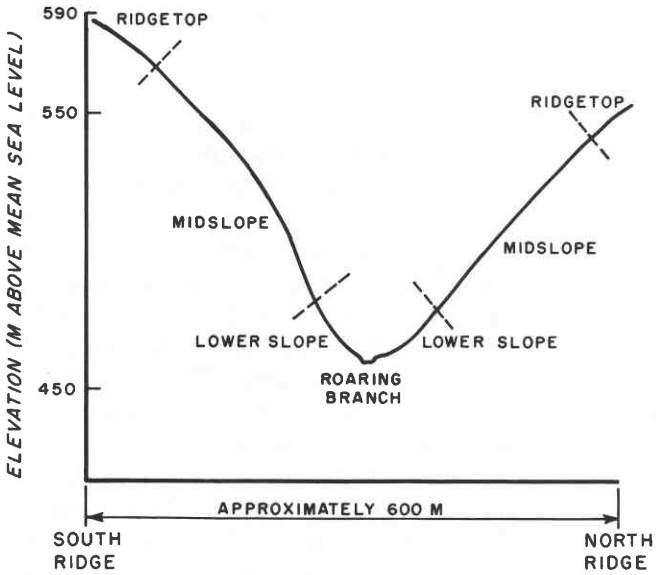

Figure 1—*Cross-section of the RBRNA illustrating the positions on the slope utilized to analyze the vegetative data (line 9, plots 46-50)*

RESULTS

Plant species found in the RBRNA are listed in Appendix Tables A, B, and C. Scientific nomenclature follows Steyermark (1975). All tests of significance throughout this paper are at the 5 percent probability level.

Overstory Component

Twenty-six species were found within the overstory quadrats (table 2). The overall dominant species were white oak, northern red oak, mockernut hickory, black oak, and shortleaf pine. White oak and northern red oak were the only 2 species to occur in more than 50 percent of the plots. In addition to the 5 above-mentioned species, only 4 more species (red maple, blackgum, American beech, and dogwood) occurred on more than 10 percent of the plots. Thirteen species occurred on 5 percent or fewer plots. They comprised only a minor component of the area as a whole but were more important on specific site conditions. White oak not only occurred on a large percentage of the plots but it also averaged over one-third of the basal area of each plot as many of the trees were fairly large (Appendix Table D).

Since all plots basically had either a due north or due south exposure, the data were examined to detect vegetational differences reflective of this difference in potential insolation. An analysis of variance between these 2 aspect classes for the major plot variables indicated a significant difference due to exposure (table 3). The average number of tree species occurring on the overstory quadrats differed significantly with the highest number occurring on the south-facing slope. The average basal area and number of trees per plot for all hickory species were significantly higher on the south-facing slope as were the average total basal area per plot and the average number of trees per plot. Pine basal area per plot and the average number of pine stems per plot were also significantly higher; shortleaf pine only occurred on south-facing plots. Total hardwood basal area per plot was not significantly different, but the average number of hardwood trees per plot differed signifi-

Table 6.—*Importance values for each species on each position on the slope within the Roaring Branch RNA*

South-facing slope					
Ridgetop		Midslope		Lowerslope	
Species	I.V.	Species	I.V.	Species	I.V.
no. red oak	100.31	shortleaf pine	73.18	no. red oak	49.44
white oak	43.14	white oak	70.03	mockernut	47.81
mockernut	37.30	mockernut	64.47	beech	41.26
shortleaf pine	27.21	no. red oak	38.79	black oak	27.53
black oak	25.15	black oak	21.00	white oak	25.47
black hickory	21.80	serviceberry	9.17	blackgum	23.74
blackjack oak	18.86	blackjack oak	5.67	sweetgum	21.54
red hickory	10.22	post oak	4.83	red maple	19.45
serviceberry	6.35	black locust	4.67	hophornbeam	17.80
sparkleberry	3.52	red hickory	2.32	dogwood	15.76
post oak	3.08	red maple	2.10	holly	5.17
black cherry	3.06	sparkleberry	2.00	winged elm	4.94
		blackgum	1.77		

North-facing					
Lowerslope		Midslope		Ridgetop	
Species	I.V.	Species	I.V.	Species	I.V.
white oak	58.54	white oak	151.92	no. red oak	94.28
mockernut	40.68	no.red oak	51.57	mockernut	38.92
beech	19.37	blackgum	27.99	white oak	34.06
black	30.90	red maple	27.45	post oak	24.50
no. red oak	30.66	black oak	10.45	hophornbeam	17.60
red maple	24.42	serviceberry	6.68	black cherry	13.72
blackgum	21.80	chinquapin	6.29	dwarf hackberry	13.71
hophornbeam	16.87	mockernut	5.34	black oak	11.94
dogwood	11.18	beech	4.99	gum bumelia	11.28
cucumbertree	9.20	dogwood	3.95	red maple	5.13
chinquapin	3.74	black locust	1.77	serviceberry	4.34
post oak	3.71	witch-hazel	1.58	winged elm	4.24
witch-hazel	2.59			blackjack oak	3.75
serviceberry	2.19				
sweetgum	2.12				
winged elm	2.09				

Shrub Component

The shrub component of the vegetation of the RBRNA included woody vines, shrubs, and stems of overstory trees that were less than 4.0 cm at 1.3 m. Fifty-one species were sampled in the shrub quadrats; 7 were vines, 13 were shrubs and the remainder were species also sampled in the overstory quadrats. In addition, 7 other shrub and vine species were found in the RNA but were not found in any of the plots (Appendix Table B).

Twenty-six of these species occurred on at least 5 percent of the plots (table 7): 19 of these were overstory component species. Mean percent cover for all species was low: none exceeded 11 percent although several were locally abundant (table 7—see highest percent cover). Lowbush blueberry, witch-hazel, white oak, mountain azalea, northern red oak, red maple, sparkleberry, and hophornbeam were the only species with mean percent cover greater than 2 percent. In frequency of occurrence, lowbush blueberry occurred on the largest number of plots (65) followed by white oak, witch-hazel, and northern red oak.

Examination of the shrub quadrat data by aspect classes (north-facing versus south-facing aspect) revealed that 10 species were significantly different regarding their presence on these two classes (chi-square 2 × 2 contingency table at 0.05 level). Seven of these species were overstory component species. Red maple, American beech, witch-hazel, white oak, mountain azalea,

Table 7.—*Shrub species that occurred on at least 5 percent of the quadrats on the RBRNA*

Species	Freq. (%)	Relative freq.	Average % cover	Highest % cover
lowbush blueberry	65	9.15	10.8	87.5
white oak	56	7.89	5.1	62.5
witch-hazel	51	7.14	9.2	87.5
n. red oak	49	6.90	3.8	37.5
sparkleberry	37	5.21	3.1	37.5
red maple	36	5.04	3.3	37.5
serviceberry	34	4.79	2.0	37.5
mountain azalea	28	3.94	4.7	62.5
mockernut hickory	28	3.94	1.6	15.0
black oak	28	3.94	1.2	15.0
blackgum	26	3.66	1.0	15.0
glaucous greenbriar	24	3.38	0.8	15.0
poison-ivy	21	2.95	2.0	37.5
sassafras	21	2.95	1.0	15.0
black locust	21	2.95	0.6	15.0
hophornbeam	19	2.53	2.3	37.5
Virginia creeper	19	2.53	1.2	37.5
American beech	18	2.52	1.3	37.5
black cherry	11	1.55	0.6	37.5
dogwood	10	1.41	1.3	37.5
muscadine	10	1.41	0.8	62.5
chinquapin	9	1.27	0.5	15.0
shortleaf pine	8	1.13	1.0	37.5
blackjack oak	7	0.98	1.0	37.5
common greenbriar	6	0.84	0.6	37.5
black hickory	6	0.84	0.5	15.0

glaucous greenbriar and sassafras were significantly associated with the north-facing slope. Shortleaf pine, mockernut hickory, and blackjack oak were the only species significantly associated with the southern aspect.

Sorting the data by position on the slope (fig. 1) revealed some interesting vegetative features of the area. Examination of this data, utilizing the chi-square test of independence, found sixteen species to be significantly different between the positions on the slope. Of the species that are only found as part of the understory, lowbush blueberry, witch-hazel, sparkleberry, mountain azalea, glaucous greenbriar, poison ivy, and Virginia creeper were significantly different. Tree species that were sampled by the shrub quadrat that were significantly different between location classes were: shortleaf pine, blackjack oak, white oak, red maple, blackgum, sassafras, hophornbeam, flowering dogwood, and American beech.

These data and table 8 which illustrates frequency of each species by location indicate that the dominant shrub species of each location would be:

Location	*Species*
South-facing ridgetop	lowbush blueberry, Virginia creeper, sparkleberry, shortleaf pine, blackjack oak
South-facing midslope	lowbush blueberry, white oak, sparkleberry, blackjack oak, shortleaf pine
South-facing lower slopes	poison ivy, witch-hazel, hophornbeam, blackgum, dogwood, Virginia creeper
North-facing lower slopes	witch-hazel, American beech, lowbush blueberry, white oak, hophornbeam, red maple
North-facing midslope	witch-hazel, lowbush blueberry, white oak, mountain azalea, red maple, sparkleberry
North-facing ridgetop	lowbush blueberry, Virginia Creeper, white oak, poison ivy, red maple, hophornbeam

Table 8.—*Frequency of occurrence of shrub species by position on slope (percent of plots sampled in each location)*

Species	Position on slope					
	South-facing slope			North-facing slope		
	Ridgetop	Mid	Lower	Ridgetop	Mid	Lower
lowbush blueberry	69.2	72.2	25.0	47.1	90.9	45.5
witch-hazel	7.7	0.0	62.5	82.4	93.9	9.1
mtn. azalea	0.0	0.0	12.5	29.4	63.6	9.1
glaucous greenbriar	15.4	0.0	25.0	29.4	39.4	9.1
poison-ivy	7.7	5.6	75.0	47.1	9.1	27.3
Virginia creeper	62.5	0.0	50.0	23.5	6.1	45.5
sparkleberry	38.5	38.9	12.5	11.8	54.5	18.2
white oak	15.4	55.6	37.5	47.1	87.9	45.5
red oak	7.7	11.1	37.5	47.1	57.6	27.3
blackgum	7.7	11.1	62.5	29.4	36.4	9.1
sassafras	15.4	0.0	0.0	29.4	36.4	18.2
hophornbeam	7.7	5.6	62.5	47.1	6.1	27.3
Amer. beech	0.0	5.6	25.0	70.6	15.2	0.0
flowering dogwood	0.0	0.0	50.0	17.6	9.1	0.0
blackjack oak	23.1	16.7	0.0	0.0	0.0	9.1
shortleaf pine	30.8	11.1	0.0	0.0	0.0	9.1
No. of plots	13	38	8	17	33	11

Several species were consistently found only on certain locations and were an important facet of that vegetative community. These include dwarf bumelia, fragrant sumac, hoptree, and Carolina buckthorn which were found only on the very tops of both the north and south ridge. Strawberry bush and deciduous holly were found only on lower slope plots.

Herbaceous Component

Forty-three herbaceous species were identified within the 1m × 2m quadrats (Appendix Table C). Area-wide, no single species exhibited a very high average percent cover or high frequency of occurrence (table 9). Narrow-leaf panicum, poverty grass, beggars-lice, bluestem goldenrod, and pussy's toes were the only species to exceed 1 percent average cover. Poverty grass, with the highest relative frequency, only occurred on 23 plots; it was followed by narrow-leaf panicum, bluestem goldenrod, beggars-lice, anomalus aster, pussy's toes and mountain mint. These were the only species to occur on at least 10 percent of the quadrants. Nine additional species occurred on 5 percent or greater of the plots. Fourteen species had only a single occurrence on the quadrats.

DISCUSSION

Ecological Status and Vegetative Description

The Roaring Branch RNA is a diverse area in both topography and vegetation. The area is comprised of several major plant communities which are created by the east-west parallel ridges that form the northern and southern boundary and by the influence of Roaring Branch itself.

As indicated, the topographic orientation results in either a north- or south-facing aspect for all sites on the area. The south-facing side is undergoing a progressive development toward a steady-state system. Its current status is, therefore, one typified by transition. Aerial photos of the area, as well as casual observation, indicate that this slope should be a shortleaf pine type (Ferguson 1968), but this was not borne out by the data. The dominant species (from 41 sample quadrats) classify this site as a northern red oak-white oak-mockernut hickory-shortleaf pine community. Examination of average basal area per plot shows shortleaf being rated as the second most important species with northern red oak being the principal dominant.

The pine stems on the area are generally large but scattered. Less than 50 percent of the overstory quadrats sampled on this slope (20 of 41) contained shortleaf pine. These individuals are of advanced age and are approaching their biological maturity (150+ years). As they age and mortality increases, the pine component will gradually be replaced, barring any major disturbance such as a wildfire. Sufficient pine reproduction does not exist to maintain this species' dominance in the stand. It ranks 23rd in frequency of occurrence on the shrub quadrats. In addition to this lack of pine reproduction, the

Table 9.—*Herbaceous species occurring on at least 5 percent of the quadrats on the RBRNA*

Species	Freq. (%)	Relative freq.	Average % cover	Highest % cover
poverty grass	23	10.31	1.7	62.5
narrow-leaf panicum	21	9.42	1.7	87.5
beggars-lice	17	7.62	1.5	37.5
bluestem goldenrod	17	7.62	1.3	87.5
anomalus aster	14	6.28	0.5	15.0
pussy's toes	12	5.38	1.0	37.5
mountain mint	10	4.48	0.8	15.0
prairie sunflower	9	4.03	0.6	37.5
common panic grass	8	3.59	0.4	15.0
panic grass	8	3.59	0.4	15.0
mountain hustonia	7	3.14	0.2	2.5
skullcap	7	3.14	0.2	2.5
bedstraw	6	2.69	0.4	15.0
broom sedge	6	2.69	0.3	15.0
wild yam	5	2.24	0.2	15.0
common lespedeza	5	2.24	0.2	15.0

area around the pine stems is largely occupied by hardwoods and woody shrubs that will prevent the re-establishment of pine on sites currently occupied by pines. The characteristic shrub component is a blueberry complex while the herbaceous component is typically a panic grass-beggars lice association.

The north-facing aspect, however, represents a fairly stable ecosystem. The principal overstory species, white oak, northern red oak, mockernut hickory, and blackgum, are also dominant in the shrub component. These species are therefore replacing themselves and will maintain their dominant positions through time, barring major disturbance. When all 3 vegetative components are considered, this side of the area is characterized as an oak-hickory complex with a blueberry-azalea-oak-chinquapin shrub component and panic grass-aster herbaceous component.

The ridgetop communities (northern and southern boundaries) are noticeably different from midslope positions on both aspects and somewhat different between ridges. The dominant overstory species on the north ridge are white oak, northern red oak, mockernut hickory, shortleaf pine and black oak. Black hickory and blackjack oak are also characteristic overstory species. Dominant shrub species are hoptree, fragrant sumac and hophornbeam while a prairie sunflower-panic grass-beggars-lice association dominates the herbaceous component. Also, frequently occurring on this position is purple cress, a species currently on the threatened species list for Arkansas (Arkansas Dept. of Planning 1974).

The southern ridge (mostly north-facing), with more exposed rock and shallower soils, is noticeably drier than the northern ridge. Dominant overstory species are northern red oak, mockernut hickory, white oak, and post oak. Common associates include hophornbeam, black cherry, dwarf hackberry and gum bumelia. Common shrub species are lowbush blueberry, bramble, and black locust. Typical herbaceous species were several panic grasses, poverty grass, prairie sunflower, bedstraw, and beggars-lice.

The south-facing midslope positions are characterized by a shortleaf pine-white oak-mockernut hickory complex with northern red oak and black oak as common associates. Increment core samples illustrated that 2 basic age classes exist within the main canopy layer: the shortleaf pines are 100+ years hile the hardwood component is considerably younger (50–75 years). These age differences further reflect the transition occurring. The shrub component is dominated by a blueberry complex plus transgressives of the principal overstory species. Frequently encountered herbaceous species are several panic grasses, poverty grass, and several species of beggars-lice.

Midslope positions on the north-facing aspect are dominated by widely scattered, large stems of white oak, northern red oak, and blackgum. These trees are essentially the same age as the shortleaf pines on the south-facing side (100+ years). Heart rot or hollow boles made exact age difficult to determine. Common overstory associates include red maple, blackgum, serviceberry, and chinquapin. It should be noted that all stems of chinquapin that were found were sprouts from stems that had died from the chestnut blight. Principal shrub species were lowbush blueberry, mountain azalea, witch-hazel, white oak, sparkleberry, red maple, and chinquapin. Common herbaceous species were pussy's toes, beggars-lice, several panic grasses, mountain mint, anomalus aster, and mountain hustonia. One species (rattlesnake plantain) was found that is currently on the threatened species list (Arkansas Dept. of Planning 1974).

The lower slope positions on both aspects were similar in species composition. The 5 most important species were the same, but the order of white oak and northern red oak was reversed. Perhaps the characteristic species for this portion of the area would be American beech, sweetgum, cucumbertree and dogwood rather than the dominant northern red oak-white oak-mockernut hickory complex. These lower slopes are adjacent to Roaring Branch which is spring fed and seldom, if ever, goes dry. It did maintain free-flowing surface water during the entire summer of 1980, which reputedly was among the

driest years in Arkansas on record. Species richness in all vegetative components is greatest on these lower slope positions. Several woody species are endemic to these slopes including cucumbertree, sweetgum, American holly, basswood, deciduous holly, and strawberry bush. Common herbaceous species were dwarf wild iris, beech drops, panic grasses, wild yam and several fern species (cinnamon fern, marginal shield fern, and Christmas fern). Two species, Indian cucumberoot and wake robin, are currently on the threatened plant species list for Arkansas (Arkansas Dept. of Planning 1974).

Wildlife Habitat Value

Although the Roaring Branch RNA is relatively small, its remote location and freedom from recent disturbance make it a prime wildlife area for species associated with old-growth, mixed hardwood-pine communities. The overstory is made up of a variety of both hard and soft mast-producing species. The 2 most important species (highest relative frequence and density) on the area are white oak and northern red oak, and the oaks as a group make up 65 percent of the overstory. Other hard mast producers, relatively abundant (occurring in 20 percent or more of the plots), include mockernut hickory, black oak, shortleaf pine, red maple and blackgum.

The primary producer of soft mast is lowbush blueberry, occuring on 65 percent of the sample lots at an average cover of 11 percent. Other important soft mast producers include sparkleberry, service berry, glaucous greenbriar, poison ivy, black cherry, dogwood, and muscadine, all of which occur in 10 percent or more of the sample plots. The species diversity in both soft and hard mast producers assures a relatively stable mast component which is an important wildlife habitat value.

A variety of species is also present in the Roaring Branch RNA herbaceous community, but sufficient quantity is lacking. Only 7 species occur on 10 percent or more of the study plots, and only 2 of these (narrow-leaf panicum and beggars-lice) are generally considered important wildlife plants. In addition to low frequency of occurrence, the average percent cover for all species is below 2 percent. Narrow-leaf panicum and beggars-lice, however, are important in some localized areas, reaching maximum cover rating of 88 and 38 percent respectively. The dominance of a closed overstory and the presence of a large shrub component reduce solar insolation below levels sufficient to support significant herbaceous growth. The absence of herbaceous ground cover must be considered a negative habitat value.

The composite wildlife habitat value of the Roaring Branch RNA is good. The remoteness of the area and its protected status enhance the current and future wildlife value. With the presence of an important, relatively stable mast component, this old-growth, mixed hardwood area is valuable habitat for many mid- to late-successional wildlife species. For early successional wildlife, the value and use are much more limited and would, to a large degree, depend on surrounding habitat conditions.

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Appendix

Appendix Table A.—*Tree species found on the Roaring Branch Research Natural Area (*indicates those species found outside sample quadrats)*

Family	Scientific Name	Common Name
Pinaceae	*Pinus echinata* Mill.	shortleaf pine
Cupressaceae	**Juniperus virginiana* L.	e. redcedar
Juglandaceae	*Carya ovalis* (Wang.) Sarg.	red hickory
	Carya texana Buckl.	black hickory
	Carya tomentosa Nutt.	mockernut hickory
Corylaceae	*Ostrya virginiana* (Mill.) K. Koch	hophornbeam
Fagaceae	*Fagus grandifolia* Ehrh.	American beech
	Castanea ozarkensis Ashe	Ozark chinquapin
	Quercus alba L.	white oak
	Quercus marilandica Muenchh.	blackjack oak
	**Quercus prinoides* Willd.	chinkapin oak
	Quercus rubra L.	n. red oak
	Quercus stellata Wang.	post oak
	Quercus velutina Lam.	black oak
Ulmaceae	*Celtis tenuifolia* Nutt.	dwarf hackberry
	Ulmus alata Michx.	winged elm
Magnoliaceae	*Magnolia acuminata* L. var *acuminata*	cucumbertree
Lauraceae	**Sassafras albidum* (Nutt.) Nees	sassafras
Hamamelidaceae	*Hamamelis virginiana* L.	witch-hazel
	Liquidambar styraciflua L.	sweetgum
Rosaceae	*Amelanchier arborea* (Michx.f.) Fern	serviceberry
	**Prunus mexicana* S. Wats	Mexican plum
	Prunus serotina Ehrh.	black cherry
Leguminosae	**Cercis canadensis* L.	e. redbud
	Robinia pseudoacacia L.	black locust
Aquifoliaceae	*Ilex opaca* Ait.f.	American holly
Aceraceae	*Acer* rubrum L.	*red maple*
	**Acer rubrum* var *Drummondii* (H.&A.) Sarg.	*Drummond red maple*
	**Acer saccharum* Marsh	*sugar maple*
Tiliaceae	**Tilia americana* L.	basswood
Cornaceae	*Cornus florida* L.	flowering dogwood
	Nyssa sylvatica Marsh.	blackgum
Ericaceae	*Vaccinium arboreum* Marsh.	*sparkleberry*
Sapotaceae	*Bumelia lanuginosa* (Michx.) Pers. var *albicans*	*gum bumelia*
Ebenaceae	**Diospyros virginiana* L. Sarg.	*persimmon*

Appendix Table B.—*Listing of shrub and vine species found on the Roaring Branch Research Natural Area (*indicates those species found outside sample quadrats)*

Family	Scientific Name	Common Name
Liliaceae	*Smilax glauca* Walt.	glaucous greenbriar
	Smilax rotundifolia L.	common greenbriar
Saxifragaceae	*Ribes missouriense* Nutt.	Missouri gooseberry
Rosaceae	**Crataegus marshallii* Egglest.	parsley hawthorn
	Rubus spp. L.	bramble
Rutaceae	*Ptelea trifoliata* L.	hoptree
Anacardiaceae	*Rhus aromatica* Ait.	fragrant sumac
	Rhus copallina L. var *latifolia* Engler	shining sumac
	**Rhus glabra* L. var *glabra*	smooth sumac
	Rhus radicans L.	poison ivy
Aquifoliaceae	*Ilex decidua* Walt.	deciduous holly
Celastraceae	*Euonymus americanus* L.	strawberry-bush
Hippocastanaceae	**Aesculus glabra* Willd.	yellow buckeye
Rhamnaceae	*Rhamnus caroliniana* Walt.	Carolina buckthorn
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper
	**Vitis aestivalis* Michx.	summer grape
	Vitis rotundifolia Michx.	muscadine
Hypericaceae	*Ascyrum hypericoides* L.	St. John's wort
Araliaceae	**Aralia spinosa* L.	devil's walkingstick
Ericaceae	*Lyonia mariana* (L.) DC.	staggerbush
	Rhododendron roseum f. *albidum* Steyer.	white mountain azalea
	Vaccinium stamineum L.	deerberry
	Vaccinium vacillans Torr.	lowbush blueberry
Verbenaceae	*Callicarpa americana* L.	French mulberry
Caprifoliaceae	**Lonicera flava* Sims.	yellow honeysuckle
	Lonicera sempervirens L.	trumpet honeysuckle
	**Symphoricarpus orbiculatus* Moench.	coral berry

Appendix Table C.—*Listing of all herbaceous species found in the Roaring Branch Research Natural Area (*indicates those species found outside sample quadrats)*

Family	Scientific Name	Common Name
Polypodiaceae	**Adiantum pedatum* L. var *pedatum*	maidenhair fern
	Asplenium platyneuron (L.) Oakes	ebony spleenwort
	**Athyrium felix-femina* (L.) Roth.	lady fern
	Dryopteris marginalis (L.) Gray	marginal shield fern
	Osmunda cinnamomea L.	cinnamon fern
	**Polystichum acrostichoides* (Michx.) Schott	Christmas fern
	**Pteridium aquilinum* (L.) Kuhn	bracken fern
	Thelypteris hexagonoptera (Michx.) Weath	broad beech fern
Gramineae	*Andropogon virginicus* L.	broom sedge
	**Bromus purgans* L.	brome grass
	Danthonia spicata (L.) Beauv.	poverty grass
	**Hystrix patula* Moench	bottlebrush
	Muhlenbergia tenuiflora (Willd.) B.S.P.	muhly grass
	Panicum commutatum Schultes var *communtatum*	common panic grass
	Panicum latifolium L.	wide-leaf panicum
	Panicum linearifolium Scribn. var *linearifolium*	narrow-leaf panicum
	**Panicum oligosanthes* Schultes	panicum grass
	Sporobolus spp. R.Br.	dropseed
Cyperaceae	**Carex* spp. L.	sedge
	Scleria spp. Bergius	nut rush
Araceae	**Arisaema atrorubens* (Ait.) Blume	jack-in-the-pulpit
Commelinaceae	**Tradescantia ohiensis* Raf.	spiderwort

Appendix Table C.—*Listing of all herbaceous species found in the Roaring Branch Research Natural Area (*indicates those species found outside sample quadrats) — Continued*

Family	Scientific Name	Common Name
Liliaceae	*Amianthium muscaetoxicum* (Walt.) Gray	fly-poison
	Medeola virginiana L.	Indian cucumber-root
	Smilacina racemosa (L.) Desf.	false spikenard
	**Trillium* spp. L.	wake robin
Amaryllidaceae	*Dioscorea quaternata* (Walt.) J.F. Gmel	wild yam
	**Dioscorea villosa* L.	yam
Iridaceae	*Iris cristata* Ait.	dwarf wild iris
Orchidaceae	**Goodyera pubescens* (Willd.) R.Br.	rattlesnake plantain
Aristolochiaceae	*Aristolochia serpentaria* L.	Virginia snakeroot
Caryophyllaceae	**Silene virginicus* L.	fire pink
Cruciferae	**Streptanthus maculatus* Nutt.	purple cress
Rosaceae	**Rosa carolina* L.	pasture rose
Leguminosae	*Baptisia leucophaea* Nutt.	wild indigo
	**Desmodium glutinosum* (Muhl.) Wood	beggars-lice
	**Desmodium laevigatum* (L.) DC.	smooth beggars-lice
	Desmodium marilandicum (L.) DC.	beggars-lice
	Desmodium nudiflorum (L.) DC.	beggars-lice
	Desmodium rotundifolium DC.	round-leaf tick trefoil
	Lespedeza virginica (L.) Britt.	common lespedeza
Oxalidaceae	*Oxalis* spp. L.	wood sorrel
Euphorbiaceae	*Acalypha* spp. L.	three-seeded mercury
Violaceae	**Viola* pedata L.	bird's-foot violet
	Viola spp. L.	violet
Passifloraceae	*Passiflora lutea* L. var *glabriflora* Fern	passion-flower
Cactaceae	**Opuntia compressa* (Salisb.) Macbr.	prickly pear
Umbelliferae	**Osmorhiza claytonia* (Michx.) Clarke	sweet cicely
	Sanicula canadensis L.	black snakeroot
	**Sanicula gregaria* Bicknell	sanicle
	**Taenidia integerrima* (L.) Drude	yellow pimpernel
	**Thaspium barbinode* (Michx.) Nutt. var *barbinode*	meadow parsnip
Asclepiadaceae	**Asclepias quadrifolia* Jacq.	milkweed
Boraginaceae	**Cynoglossum virginianum* L.	wild comfrey
Labiatae	**Monarda Russeliana* Nutt.	horsemint
	Pycnanthemum spp. Michx.	mountain mint
	Scutellaria elliptica Muhl.	hairy skullcap
Schrophulariaceae	**Pedicularis canadensis* L.	wood betony
	**Penstemon tubaeflorus* Nutt.	beard tongue
Orobanchaceae	*Epifagus virginiana* (L.) Bart	beech drops
Rubiaceae	*Galium obtusum* Bigel. var *obtusum*	bedstraw
	Hustonia longifolia var *tenuifolia* (Nutt.) Wood	mountain hustonia
Campanulaceae	**Campanula americana* L.	bellflower
Compositae	*Antennaria plantaginifolia* (L.) Hook.	pussy's toes
	Aster anomalus Engelm.	anomalus aster
	Aster patens Ait.	spreading aster
	**Erigeron philadelphicus* L.	Philadelphia fleabane
	Erigeron strigosus Muhl.	daisy fleabane
	Helianthus lactiflorus Pers.	prairie sunflower
	Hieracium gronovii L.	hawkweed
	**Lactuca canadensis* L.	wild lettuce
	Liatris squarrosa var *squarrosa* (L.) Michx.	blazing star
	Prenanthes spp. L.	rattlesnake root
	Solidago arguta Ait.	goldenrod
	Solidago flexicaulis L.	bluestem goldenrod

Appendix Table D.—*Stand table (trees/ha) for tree species on the RBRNA*

Dia. (cm)	shortleaf pine	mockernut hickory	northern red oak	white oak	blackgum	post oak	black oak	Amer. beech	black hickory	winged elm	witch-hazel	sweetgum	Amer. holly
4.0- 6.0	5.2	32.3	10.4	38.5	8.3	3.1	3.1	13.5	2.1	2.1	3.1	...	...
6.1- 8.0	3.1	32.3	20.8	34.4	4.2	1.0	4.2	6.2	9.4	2.1	...	...	...
8.1-10.0	1.0	30.2	20.8	27.1	3.1	1.0	6.2	3.1	2.1	...	...	1.0	...
10.1-12.0	3.1	12.5	21.2	18.8	...	...	6.2	1.0	1.0	1.0	...	1.0	2.1
12.1-14.0	4.2	16.7	11.4	10.4	2.1	...	3.1	...	2.1	...	...	...	...
14.1-16.0	5.2	10.4	24.0	6.2	1.0	2.1	5.2	1.0	1.0	...	...	1.0	...
16.1-18.0	...	5.2	10.4	8.3	...	...	7.3	1.0	...	...	...	...	...
18.1-20.0	3.1	5.2	14.6	7.3	1.0	1.0	4.2	...	1.0	...	...	...	...
20.1-22.0	1.0	1.0	15.6	7.3	1.0	...	1.0	...	1.0	...	...	...	...
22.1-24.0	2.1	1.0	7.3	6.2	...	...	...	1.0	...	...	...	...	...
24.1-26.0	1.0	3.1	4.2	4.2	1.0	...	...	...	...	...	...	...	...
26.1-28.0	3.1	1.0	...	3.1	1.0	...	...	...	...	...	...	...	...
28.1-30.0	...	...	5.2	3.1	1.0	1.0	1.0	...	...	...	...	1.0	...
30.1-32.0	...	1.0	2.1	8.3	1.0	1.0	...	...	...	...	...	2.1	...
32.1-34.0	2.1	1.0	1.0	5.2	...	...	2.1	...	...	...	...	...	...
34.1-36.0	1.0	...	1.0	7.3	1.0	...	...	...	...	...	...	...	...
36.1-38.0	1.0	1.0	...	2.1	1.0	...	2.1	...	...	...	...	...	...
38.1-40.0	1.0	...	1.0	4.2	...	...	...	...	...	...	...	...	...
40.1-42.0	...	...	1.0	...	...	...	1.0	...	...	...	...	...	...
42.1-44.0	1.0	...	1.0	4.2	1.0	...	...	...	...	...	...	...	...
44.1-46.0	...	...	1.0	1.0	1.0	...	...	...	...	...	...	...	...
46.1-48.0	1.0	...	...	3.1	...	...	...	...	...	...	...	...	...
48.1-50.0	1.0	...	...	...	...	...	...	...	...	...	...	...	...
50.1-52.0	...	...	...	1.0	...	...	...	1.0	...	...	...	...	...
52.1-54.0	...	...	...	...	...	...	...	...	...	...	...	...	...
54.1-56.0	...	...	...	...	...	...	...	...	...	...	...	...	...
56.1-58.0	...	...	...	...	...	...	...	...	...	...	...	...	...
58.1-60.0	...	...	...	...	...	...	...	...	...	...	...	...	...
60.0	1.0	...	...	1.0	...	...	...	1.0	...	...	...	...	...

Appendix Table D.—*Stand table (trees/ha) for tree species on the RBRNA—Continued.*

Dia. (cm)	gum bumelia	sparkle berry	cucumber tree	hophorn beam	red maple	chinquapin	blackjack oak	service berry	black cherry	dwarf hackberry	black locust	dogwood	red hickory
4.0- 6.0	2.1	4.2	1.0	16.7	14.6	1.0	5.2	13.5	3.1	4.2	...	7.3	2.1
6.1- 8.0	1.0	...	2.1	11.4	11.4	1.0	4.2	3.1	...	...	1.0	4.2	1.0
8.1-10.0	...	...	1.0	2.1	6.2	1.0	...	1.0	...	...	1.0	3.1	1.0
10.1-12.0	...	...	...	1.0	6.2	...	...	1.0	1.0	1.0	1.0	...	1.0
12.1-14.0	...	...	3.1	3.1	4.2	...	1.0	...	...	...	...	...	...
14.1-16.0	...	...	...	...	3.1	...	...	...	...	...	...	...	2.1
16.1-18.0	...	...	...	...	...	...	...	...	...	...	...	...	...
18.1-20.0	...	...	...	...	...	...	...	...	...	...	...	...	...
20.1-22.0	...	...	...	...	...	...	...	...	...	...	...	...	...
22.1-24.0	...	...	...	...	...	...	...	...	...	...	...	...	...
24.1-26.0	...	...	...	...	...	1.0	...	...	...	...	...	...	...
26.1-28.0	...	...	...	...	...	...	...	...	...	...	...	...	...
28.1-30.0	...	...	...	...	...	...	...	...	...	...	...	...	...
30.1-32.0	...	...	...	...	...	...	...	...	...	...	...	...	...
32.1-34.0	...	...	...	...	...	...	...	...	...	...	...	...	...
34.1-36.0	...	...	...	...	...	...	...	...	...	...	...	...	...
36.1-38.0	...	...	...	...	...	...	...	...	...	...	...	...	...
38.1-40.0	...	...	...	...	...	...	...	...	...	...	...	...	...
40.1-42.0	...	...	...	...	...	...	...	...	...	...	...	...	...
42.1-44.0	...	...	...	...	...	...	...	...	...	...	...	...	...
44.1-46.0	...	...	...	...	...	...	...	...	...	...	...	...	...
46.1-48.0	...	...	...	...	...	...	...	...	...	...	...	...	...
48.1-50.0	...	...	...	...	...	...	...	...	...	...	...	...	...
50.1-52.0	...	...	...	...	...	...	...	...	...	...	...	...	...
52.1-54.0	...	...	...	...	...	...	...	...	...	...	...	...	...
54.1-56.0	...	...	...	...	...	...	...	...	...	...	...	...	...
56.1-58.0	...	...	...	...	...	...	...	...	...	...	...	...	...
58.1-60.0	...	...	...	...	...	...	...	...	...	...	...	...	...
60.0	...	...	...	...	...	...	...	...	...	...	...	...	...

Fountain, Michael S.; Sweeney, James. M. Ecological assessment of the Roaring Branch Research Natural Area. Res. Pap. SO-213. New Orleans, LA; U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1985. 15 p.

Provides details of an area that probably represents a natural ecological succession relatively undisturbed by man. The area includes unique vegetative types.