in Pulaski and Russell counties of south-central Kentucky (*Freeman 473, 477, 479,* VDB). In this area the Cumberland Plateau, which spacially isolates *T. cuneatum* in Middle Tennessee from *T. luteum* at its westernmost distributional limits, has been dissected by the Cumberland River, and the ranges of the taxa here come together. The plants in these populations bear mostly yellow colored, lemon scented flowers, although plants bearing purple colored, spice-scented flowers also occur. In addition to the typical plants, occasional individuals are encountered the flowers of which are purple and produce a strong lemon odor.

Serota (1969), in connection with a study of morphological and karyotypic variation among sessile-flowered species of *Trillium* represented in North Carolina, commented on the dependability of fragrance differences between *T. luteum* and *T. cuneatum.* She reported observations of a population near Fontana Dam in Polk County containing putative hybrids between the two taxa. She observed plants with yellow flowers having either a definite spice scent or, more frequently, without any fragrance at all, but she was unable to detect a lemon fragrance in any flowers bearing visible traces of anthocyanin. Serota concluded that the morphological and karyotypic similarities of *T. luteum* and *T. cuneatum* warrant consideration of the two as a single taxonomic species.

Freeman (loc. cit.) discussed the apparent close relationships of the two taxa but concluded, correctly in our opinion, that both must be accorded taxonomic status above that of formae of a single species because of their largely allopatric patterns of distribution. He chose, perhaps somewhat arbitrarily, but not without careful and searching deliberation, to recognize each in species status. This was done so as not to disturb unduly or prematurely the system of hierarchy and the nomenclature of the component elements judged to be the most reasonable for the subgenus as a whole on the basis of currently available information. It is clear that convincing arguments may even now be leveled to justify the treatment of *T. luteum* as a geographical variety or as a subspecies of *T. cuneatum,* but there seems to be insufficient biological evidence at the present time to warrant such manipulation. Indeed, there are obvious practical advantages in retaining *T. luteum* as a taxonomic species.

The results of the present study of flower fragrances do not settle the question of the taxonomic rank of these two plants. Although 12 different fragrance compounds were detected in the two, only two of the compounds occurred in the flowers of both taxa where they exhibited approximately a 3-fold quantitative difference. If these data alone were used as an indication of relationship, the two taxa would appear to be quite different.

But when data relative to the occurrence of flavonoids and other flourescent compounds in the flowers of these plants are compared, (Murrell, 1969), considerable similarity is seen to exist. *Trillium cuneatum* was found to contain some 44 chromatographically recognizable fluorscent components while *T. luteum* contained a total of 43 such compounds. Of this group of compounds 36 were common to both. The possibility of different taxonomic interpretations arising from the separate evaluation of the two types of chemical data emphasizes the importance of a synthesizing approach to the final solution of this taxonomic problem, using information from all possible sources.

Acknowledgements

A postdoctoral fellowship (1968-69) provided the senior author through NIH Training Grant NIH HD00187 to the Laboratory of Quantitative Organismic Biology, University of Miami is acknowledged. The chromatographic analyses were made during the tenure of this fellowship in the laboratory of Dr. C. H. Dodson.

Literature Cited

Freeman, J. D. 1969. A Revisionary Study of Sessile-Flowered *Trillium* L. (Liliaceae). Ph.D. dissertation, Vanderbilt University.

Murrell, J. T. 1969. A Chematoxonomic Study of Sessile-Flowered *Trillium* (Liliaceae). Ph.D. dissertation, Vanderbilt University.

Serota, C. A. 1969. Karyotypes and morphological variation in the sessile-flowered Trilliums of North Carolina. *Can. J. Bot.* 47: 1223-1232.

Journal of the Tennessee Academy of Science

Volume 48, Number 3, July, 1973

BIOMASS AND PRODUCTIVITY ESTIMATES FOR A TEMPERATE MESIC SLOPE FOREST

James N. Skeen[1]

Mid-Appalachia College Council Field Biology Teaching and Research Center, LaFollette, Tennessee 37766

Abstract

Aboveground biomass (420 t/ha) and net annual aboveground productivity (1510 g/m^2/yr) of a mature mixed deciduous forest were estimated from empirically determined stem diameter measurements on 360 canopy ($\geq$10.16 cm dbh) trees and published stem diameter: biomass regression equations. The resulting estimates as well as the basal area coverage (43 m^2/ha) lay within limits encountered in temperate deciduous forests

[1]Present Address, Fernbank Science Center, 156 Heaton Park Dr., N.E. Atlanta, Georgia 30307.

forests by other workers using techniques requiring far more time, equipment, and personnel.

INTRODUCTION

Although there exist, due to the extensive work of Whittaker (1961, 1962, 1963, 1965, 1966) and his associates (Whittaker and Garfine, 1962; Whittaker, Cohen, and Olson, 1963), excellent estimates of forest productivity and biomass accumulation for the various communities of the Great Smoky Mountains, no such estimates exist for the extensive low elevation mixed deciduous forests of eastern Tennessee. The lack of such information is unfortunate since the region is generally considered the center of origin of the eastern deciduous forest of the United States. The primary objective of this study was the estimation of net annual aboveground productivity and aboveground biomass in such a forest.

The study area was located near the confluence of the Clinch and Powell Rivers (36°16′N 84°03′W) in Campbell County, Tennessee. Elevation of the study area ranged from 320-380 m and Norris Lake, a hydroelectric storage reservoir, lay adjacent to the study area below 310 m. Mean annual precipitation in the area is approximately 130 cm with maxima in early spring and late summer.

METHODS

Studies undertaken to estimate biomass accumulation and productivity of forests have typically involved various means of destructive sampling which have entailed large expenditures of time and personnel. However Monk, Child and Nicholson (1970) formulated a set of regression equations, based on destructive sampling in an oak-hickory forest, which allow the estimation of various components (*e.g.*, leaves, current year twigs, *etc.*) of a mixed forest stand from stem diameter measurements. These equations (Monk *et al*, 1970) were applied to stem diameter measurements obtained from 360 canopy ($\geq$10.16 cm dbh) trees in a mature mixed deciduous north-slope forest. The 360 trees measured were selected by means of 90 quarter-points located at 15 m intervals along two transects traversing the stand.

RESULTS

The estimation of net annual aboveground production requires measurements on or estimation of several component parameters. Chief among these are such factors as (1) the weight of leaf material in the stand, (2) the weight of new twigs produced during the current growing season, (3) the weight of material, primarily leaves, consumed by herbivorous animals, chiefly phytophagous insects, (4) the weight of annual increment of radial growth of the various stems (boles and branches), and (5) the weight of material produced during the reproductive phases of the component species' life cycles (*e.g.*, flowers, fruits, seeds, *etc.*).

Forest Leaf Weight: Using the empirically determined stem diameter measurements in conjunction with the regression equations of Monk *et al* (1970) the 26 canopy species were found to have a combined leaf weight (oven-dry) of 9814.3 kg/ha (Table 1). The findings of Monk *et al* (1970) indicated that canopy trees alone account for about 85% of the stand's aboveground biomass. Assuming a similar relationship in the present stand, leaf weight for all strata was calculated to be 11546.2 kg/ha.

Table 1. Biomass of leaves, current year twigs, stems and boles, and total tree (aboveground).[1] Nomenclature follows Fernald (1950).

Species	Biomass (kg/ha)			
	Leaves	Twigs	Stem/Boles	Trees
Fagus grandifolia Ehrh.	2090.0	300.2	85083.1	89068.4
Carya spp. (3 spp.)	1697.3	204.5	61273.4	64443.2
Quercus velutina Lam.	1083.5	158.2	43624.5	45706.3
Liriodendron tulipifera L.	1222.9	138.2	42280.8	44625.6
Acer saccharum Marsh.	887.1	100.2	30501.3	32306.9
Quercus alba L.	483.5	68.7	18530.0	19797.9
Acer rubrum L.	470.2	52.7	14668.7	15596.0
Sassafras albidum (Nutt.) Nees	379.5	42.7	12842.7	13561.5
Fraxinus americana L.	282.3	44.4	10163.1	10698.5
Aesculus octandra Marsh.	170.2	19.2	5432.7	5755.2
Cornus florida L.	172.9	19.0	4235.4	4543.4
Pinus virginiana Mill.	602.7	572.7	2014.0	2651.9
Oxydendrum arboreum (L.) DC.	50.2	5.5	1364.5	1456.8
Quercus rubra L.	36.6	4.0	1025.2	1092.9
Ostrya virginiana (Mill.) K.Koch	37.7	4.2	971.1	1039.4
Platanus occidentalis L.	28.9	3.2	949.7	1005.0
Nyssa sylvatica Marsh.	31.9	3.5	900.6	959.8
Juglans cinerea L.	23.7	2.6	752.1	797.1
Magnolia acuminata L.	21.9	2.4	604.0	644.4
Cercis canadensis L.	15.2	1.6	381.6	408.7
Carpinus caroliniana Walt.	13.9	1.6	356.4	381.5
Morus rubra L.	4.7	0.5	114.2	122.7
Ulmus rubra Muhl.	4.0	0.5	94.2	101.3
Tilia americana L.	3.5	0.3	80.6	86.8
Totals	9814.3	1750.6	338249.9	356851.2

[1]Values computed from regression equations of Monk *et al* (1970) using empirically determined DBH measurements from 360 canopy trees.

Forest Twig Weight: The weight of new twigs produced during the current growing season among the canopy species was calculated (from the equations of Monk *et al* and the stem diameter measurements) to be 1750.6 kg/ha (Table 1). Again assuming that this represents approximately 85% of the weight of the currently produced twigs in all strata, twig weight for the entire stand was calculated to be 2059.5 kg/ha.

Losses to Insects: Several workers have attempted to estimate stand losses to phytophagous insects. Bray (1961) found insect consumption to vary from 3.2-15.0% of total leaf area in three mixed deciduous stands in southern Canada. Rothacher, Blow and Potts (1954), working in the general area of the present study, found a loss of 6.7% of the total leaf area (due to insects and disease) by late in the growing season. Further study by Bray and refinement of his original values indicated that 1.5-2.5% of net annual aboveground production was lost to insects (Bray, 1964). In the same paper Bray applied his corrections to the data of Rothacher *et al* (1954) yielding a value of 1.7% of net annual aboveground production lost to insects by season's end. Monk *et al* (1970) found between 1.6% and 8.7% (mean = 4.7%) of the total forest leaf weight (3.5% of total aboveground production) consumed by insects. Based on these findings a value of 3% of the total leaf weight (2.3% of net annual aboveground production) or 346.4 kg/ha was utilized in the present study to correct for losses to insects.

Radial Growth Increments: The results of Monk *et al* (1970) indicated that the weight of the annual increment of radial growth of the various stems $\geq$2.54 cm dbh was approximately 6% of the weight of the forest leaves (or 4.5% of net annual aboveground production). Applying this relationship to computations of forest leaf weight in the present study yielded a value of 692.8 kg/ha attributable to radial growth of the various stems.

Flower, Fruit, and Seed Production: Whittaker (1966), in the absence of empirical measurements, applied a correction of 5% of total net aboveground production as an allowance for flower and fruit production. The data of Ovington, Heitkamp and Lawrence (1963) indicated flower and fruit production was approximately 2.6% of net annual aboveground productivity. In the present study a value of 3% of net annual aboveground productivity (452.9 kg/ha) was applied to account for production oriented toward reproductive processes.

Net Annual Aboveground Productivity: Net annual aboveground productivity for the forest was estimated by summing (1) the forest leaf weight (11546.2 kg/ha), (2) the current year's twig weight (2059.5 kg/ha), (3) weight lost to phytophagous insects (346.4 kg/ha), (4) weight increases attributable to radial stem growth (692.8 kg/ha), and (5) weight increases oriented toward reproductive processes (452.9 kg/ha). These values sum to 15097.8 kg/ha/yr (4.14 g/m^2/day). The various components of the productivity estimate are summarized in Table 2.

Table 2. Summary of various components of net annual aboveground productivity estimate.

Component	Estimate (kg/ha)
Leaves, Canopy Stratum	9814.3
Leaves, Subcanopy, Shrub and Herb Strata	1731.9
Current Year's Twigs, Canopy Stratum	1750.6
Current Year's Twigs, Remaining Strata	308.9
Insect Consumption	346.4
Radial Growth of Stems	692.8
Flower and Fruit Production	452.9
Total	15097.8

Total aboveground biomass of canopy species was 356851.2 kg/ha (Table 1). Utilizing the finding of Monk *et al* (1970) that the canopy biomass accounted for 85% of the total aboveground biomass, total stand biomass was calculated to be 419824.9 kg/ha.

Total basal area occupied by canopy trees was determined empirically to be 42.64 m^2/ha. Basal area of subcanopy trees (woody species having stem diameters <10.16 cm dbh and heights >2m) was 0.31 m^2/ha. Consequently, with shrubs considered, total stand basal area was approximately 43 m^2/ha.

DISCUSSION

As may be noted by reference to Table 3, the estimates offered in the present study for net annual aboveground productivity and aboveground biomass are compatible with the findings of other investigators working in temperate mixed deciduous forests and lie near the expected maxima for such a forest.

Table 3. Productivity, biomass, and basal area coverage in temperate deciduous forests.

Parameter	Forest Type and Location	Source
Net Aboveground Productivity (g/m^2/yr)		
568-2108 (mean — 1233)	12 Mixed Deciduous Forests, Smoky Mountains, U.S.A.	Whittaker (1966:111)
1510	Mature Mesic Deciduous Forest, Tennessee, U.S.A.	Present Study
819	Oakwood, Minnesota, U.S.A.	Ovington *et al* (1963:61)
730	Closed Oak Forest Minnesota, U.S.A.	Bray (1962:104)
600	Oak-Hickory Forest, Georgia, U.S.A.	Monk *et al* (1970:140)
440	Open Oak Forest, Minnesota, U.S.A.	Bray (1962:101)
Aboveground Biomass (t/ha)		
88-609 (mean — 292)	12 Mixed Deciduous Forests, Smoky Mountains, U.S.A.	Whittaker (1966:111)
420	Mature Mesic Deciduous Forest, Tennessee, U.S.A.	Present Study
164	Oakwood, Minnesota, U.S.A.	Ovington *et al* (1963:59)
145	Oak-Hickory Forest, Georgia, U.S.A.	Monk *et al* (1970:139)
Basal Area (m^2/ha)		
50-64	Mature Climax Forests, Smoky Mountains, U.S.A.	Whittaker (1966:109)
43	Mature Mesic Deciduous Forest, Tennessee, U.S.A.	Present Study
20-35	Disturbed or Small-Tree Climax Stands, Smoky Mountains, U.S.A.	Whittaker (1966:109)
21.3	Second-Growth Mixed Deciduous Forest, Tennessee, U.S.A.	Thor *et al* (1971:118)
13.8	Second-Growth Mixed Oak Forest, Tennessee, U.S.A.	Rothacher *et al* (1954:172)

The regression equations upon which the productivity estimates of the present study are based seemingly offer high estimates of the forest leaf weight when these results are compared to the estimates of other workers. From the equations employed, the forest leaves account for about 76% of the net annual aboveground productivity. This yields a ratio of net annual aboveground production to leaf weight of 1.3 which agrees closely with a similar ratio calculated from the data of Monk *et al* (1970) but is somewhat lower than a value (2.3) based on the data of Ovington *et al* (1963) and the values (averaging 3.0) offered by Whittaker (1966) for mixed deciduous forests. In other words, the productivity estimates offered by these workers are 2-3 times the annual leaf production indicating that according to their measurements leaf production accounts for only 33-50% of net annual aboveground productivity.