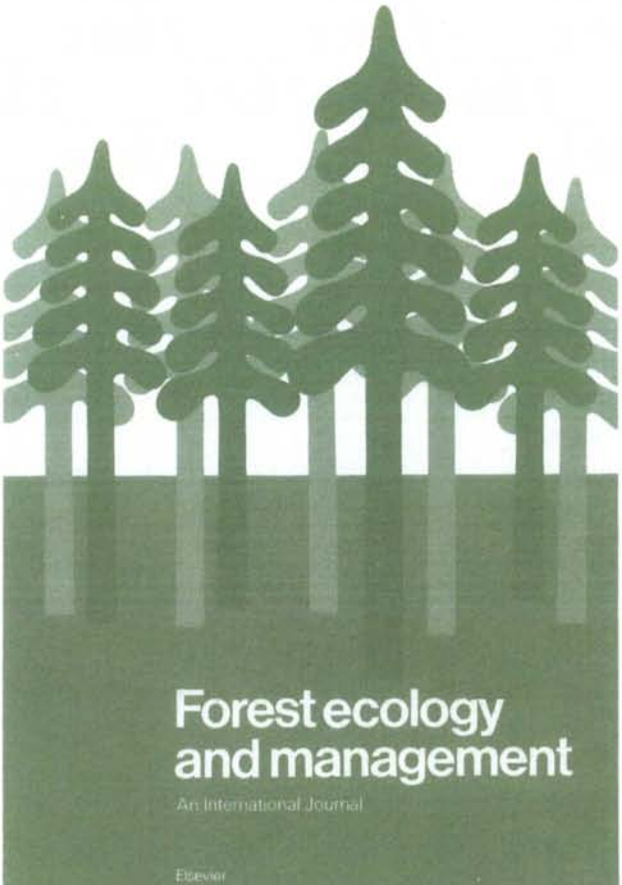
REPRINTED FROM:



ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM

Forest ecology and management

An International Journal

Forest Ecology and Management, 8 (1984) 117—126
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

HARDWOOD GROWTH AND FOLIAR NUTRIENT CONCENTRATIONS BEST IN CLEAN CULTIVATION TREATMENTS

HARVEY E. KENNEDY, Jr.

Southern Hardwoods Laboratory, U.S. Forest Service, Stoneville, MS 38776 (U.S.A.)

(Accepted 29 September 1983)

ABSTRACT

Kennedy, H.E., Jr., 1984. Hardwood growth and foliar nutrient concentrations best in clean cultivation treatments. *For. Ecol. Manage.*, 8: 117—126.

Nine hardwood species were planted at a 3 m by 3 m spacing on a Mississippi River front soil (Aeric Fluvaquents) in western Mississippi and subjected to three intensities of cultural treatments. Because of the death of yellow-poplar during a severe spring flood (1973) and severe iron deficiency in three oaks caused from high soil pH, only five species are discussed in this paper. Periodic disking substantially increased heights, diameters, and survival of trees through 4 years. Disked plots had significantly lower soil N than mowed and control, while Mg was considerably higher in disked than control plots. Cultural treatments did not affect other measured soil nutrient levels.

Trees growing on disked plots had significantly higher N and significantly lower P, K, and Mg concentrations than those in control plots. Foliar concentrations of K and Mg in disked and mowed plots were similar. Cultural treatments did not affect foliar Ca concentrations. Sweetgum had the lowest nutrient concentrations and cottonwood or green ash the highest for most nutrient elements tested. Other species were intermediate, and no ranking was readily apparent.

INTRODUCTION

Most hardwoods grown in plantations are intolerant to weed competition, and sites must be intensively cultivated to eliminate weeds, vines, and other herbaceous material. Quantitative data on the effects of intensity and duration of cultural treatments in plantations on soil nutrient availability and uptake, soil moisture, tree growth, and survival are lacking. Nevertheless, intensive plantation management of hardwoods continues because quality logs are needed for lumber, veneer, and specialties, while other hardwoods are needed for pulp and fuel. This paper reports on soil and foliar nutrient levels, soil moisture, and growth and survival of nine hardwoods through 4 years on an excellent site as influenced by uncultivated, mowed, or disked treatments.

METHODS

A 4-ha plantation at Huntington Point about 24 km north of Greenville, MS, was the test site. The site had been recently cleared of a natural mixed hardwood stand and prepared for planting by shearing, root raking, and disking. Soil is Commerce silt loam, a member of the fine-silty, mixed, nonacid, thermic family of Aeric Fluvaquents that developed in alluvial deposits of the Mississippi River. It is a highly productive soil with a site index for cottonwood (*Populus deltoides* Bartr. ex Marsh.) of about 35 m at age 30 years (Broadfoot, 1976).

A split-plot design was used. Each of four blocks (0.85 ha) were divided into three equal sized plots. One of three cultural treatments, control (uncultivated), mow, or cross disking (clean cultivation) was randomly assigned to a plot. Disks would cut 10—15 cm deep and to within 15—30 cm of each seedling. The remaining square was hoed to completely eliminate any vegetation. Mowing cut the weeds and grasses to about 10 cm tall. Plots were subdivided into nine subplots with one species randomly assigned to a subplot. The species were cottonwood, sycamore (*Platanus occidentalis* L.), Nuttall oak (*Quercus nuttallii* Palmer), cherrybark oak (*Q. falcata* var. *pagodifolia* Ell.), water oak (*Q. nigra* L.), sweet pecan (*Carya illinoensis* (Wangenh.) K. Koch), green ash (*Fraxinus pennsylvanica* Marsh.), sweetgum (*Liquidambar styraciflua* L.), and yellow-poplar (*Liriodendron tulipifera* L.). Twenty-four 1-year-old seedlings or cottonwood cuttings were planted at 3 m × 3 m spacing in each plot in February 1972. Disked and mowed plots were treated five times between late April and early September the first growing season, four times the second, and three times in years 3 and 4.

Soil moisture measurements were made about every 2 weeks in three plots of each cultural treatment, a total of nine locations in the study area. Measurements were made at the surface and at 0.3, 0.6, 0.9, and 1.3 m depths on a volume basis with neutron probes. Subsurface moisture readings were made through aluminum access tubes.

Soil organic matter (OM), N, P, K, Ca, Mg, and pH levels were determined before cultural treatments began and at the end of each growing season. Samples from the 0- to 15-cm layer were collected from five randomly located points within a cultural treatment without regard to species. Collections were made in early September each year and composited to make one sample. Soil nutrient level determinations were made each year. Collections each year were made within 0.6 m of the previous years's samples. Samples were air dried and processed to pass a 2-mm sieve.

All above-ground understory vegetation (weeds, vines, and grasses) from two 0.6 m × 0.6 m areas in each control plot was collected in early September each year and ovendry weights determined. Leaf samples were collected from the mid-crown position of planted trees in early September of each year. Concentrations of N, P, K, Ca, and Mg were determined for each sample.

All tissue was dried at 70°C and ground before chemical analyses. Nitrogen was determined by the standard Kjeldahl procedure; P by colorimetry with molybdenum blue color development; and K, Ca, and Mg by atomic absorption spectrophotometry after samples had been dry ashed and taken up in dilute HCl.

Soil N was also determined by the standard Kjeldahl procedure. Phosphorus was measured with a colorimeter by the Mississippi soil test method (Soil Test Work Group 1974). This is a two-stage extraction: Stage 1 — soak 10 min in 5 ml of 0.05 *N* HCl; stage 2 — add 20 ml buffered acidic (acetic-malic-malonic) AlF_3 solution at pH 4.0. Potassium, Ca, and Mg concentrations were determined by atomic absorption spectrophotometry after extraction in 1 *N* NH_4OAc. Soil pH was measured with a glass electrode in a 1:1 soil/water ratio. Oxidizable OM was established by chromic acid oxidation and titrations with $Fe(NH_4)_2(SO_4)_2$, the Walkley-Black method.

Tree heights, diameters, and survival were measured after each growing season during the 4 years of the study. Diameters were measured at the root collar each year because some species did not reach 1.3 m heights until the second or third growing season. Diameters at breast height were also taken the fourth year. Effects of treatments on measured variables were tested for significance at the 0.05 level of confidence. Comparisons among treatment means were made using Duncan's new Multiple Range Test.

RESULTS AND DISCUSSION

Tree growth and survival

Growth and survival of yellow-poplar was excellent during the first growing season. But the study area was flooded by the Mississippi River in the second growing season to a depth of 1.8 m from late March to late May 1973, and all the yellow-poplar died. None of the other species were harmed by the flood. Nuttall, cherrybark, and water oak were apparently not well suited for the site. Starting in year 1 and in each successive year, oak leaves would begin to yellow 3 to 4 weeks after the growing season began. Yellowing would increase as the growing season progressed and by late summer the leaves were brittle and had a brown, burnt appearance around the edges. At the end of four growing seasons, the oaks had grown very little and survival ranged from only 10 to 40%. The oak failure was probably due to a soil pH of 8.0, which meant that iron was probably unavailable. Because of the oak and yellow-poplar failure, this paper will concentrate on cottonwood, green ash, sycamore, sweetgum, and sweet pecan.

Significant species by cultural treatment interactions occurred for growth and foliar nutrient elements. These interactions are a reflection of inherent differences between species in growth rates and nutrient absorption. The major effects of treatments appear more important than the species by treatment interaction, and will be discussed in this paper.

After four growing seasons, trees in disked plots were significantly taller than trees in mowed and control plots (Fig. 1). There were no real differences between mowed and control. Similar results have been reported for poplars and sycamore (Aird, 1962; McKnight, 1970; Fitzgerald et al., 1975). Heights of trees in disked plots ranged from 35% for sweetgum to 83% for cottonwood over control trees. Depending on species, trees were as tall after the second or third growing season in disked plots as after four growing seasons in control plots. If this growth advantage is maintained throughout the rotation, forest managers could reduce rotation length by disking the first and maybe second growing seasons. Baker and Blackmon (1978) reported 2nd-year cultivation had a significant influence on cottonwood growth during the second and third growing seasons. Growth benefits in tree heights and diameters were still evident after five growing seasons.

Tree diameters at groundline were significantly larger in disked than

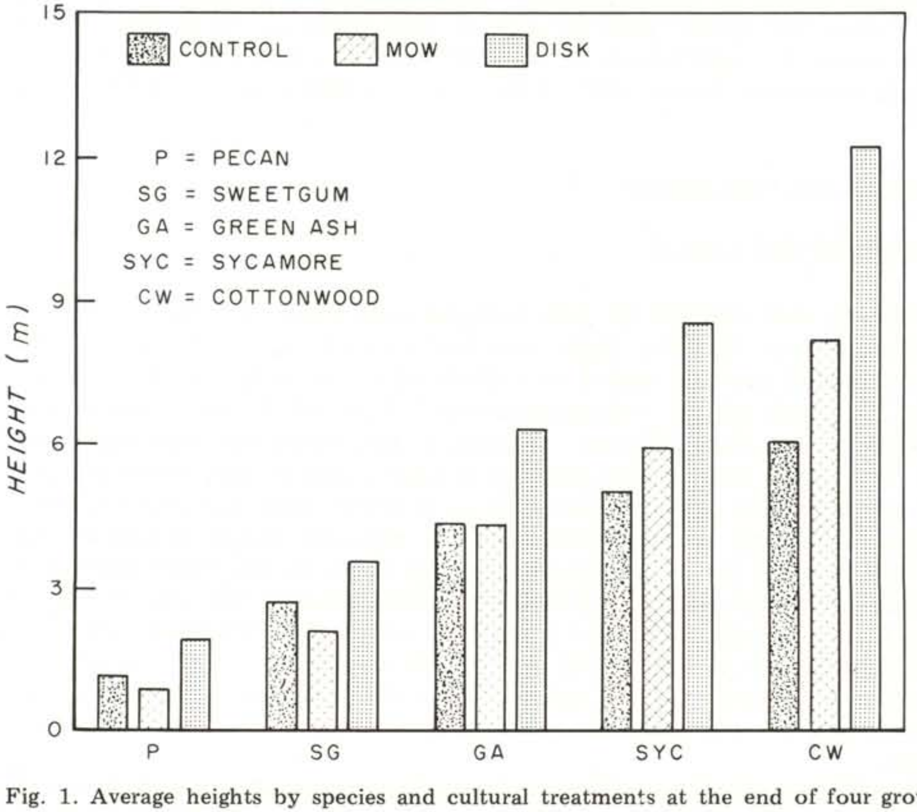


Fig. 1. Average heights by species and cultural treatments at the end of four growing seasons.

in mowed and control plots (Fig. 2). Increases ranged from 72% for cottonwood to 240% for sweet pecan. Diameters at breast height after four growing seasons were 55—60% as large as diameters at groundline.

Survival was significantly higher in disked plots (89%) than mowed (65%) or control (61%). On disked plots, survival ranged from a low of 79% for sweetgum to a high of 99% for sycamore. There were no differences in survival between mowed and control plots. Green ash and sycamore survived best — over 90% — in mowed and control plots.

Dry weight of understory vegetation in control plots averaged 18.5 metric tons per hectare per year. Nutrient concentrations in the understory vegetation were : N, 1.07%; P, 0.23%; K, 1.48%; Ca, 0.83%; and Mg, 0.29%. Disking eliminated the competition for moisture, nutrients, and sunlight, as evidenced by much better growth in disked plots than in mowed and control (Figs. 1 and 2). Competition still exists whether weeds are allowed to grow 3—4 weeks and then mowed or allowed to grow continuously as in control.

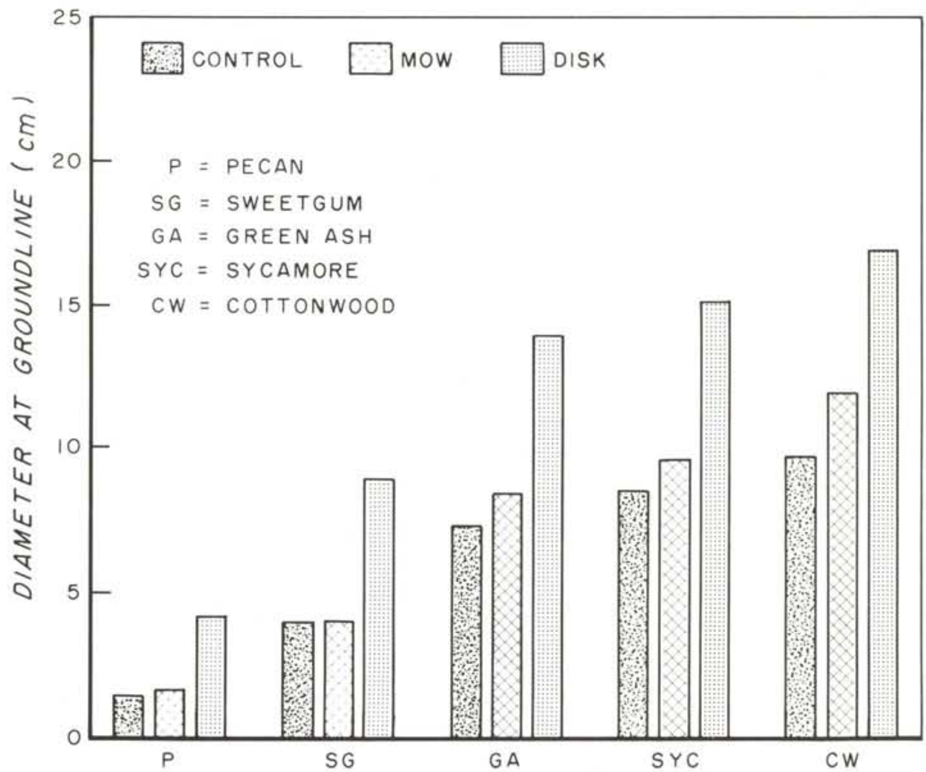


Fig. 2. Average diameters by species and cultural treatments at the end of four growing seasons.

TABLE I

Average foliar nutrient concentrations in percent by species and cultural treatments over the four study years

Species[b]	N[a]			P			K			Ca			Mg		
	C[c]	M	D	C	M	D	C	M	D	C	M	D	C	M	D
GA	1.93	1.97	2.11	0.30	0.30	0.18	0.95	0.86	0.89	1.15	1.18	1.35	0.22	0.25	0.26
SYC	1.62	1.85	2.01	0.18	0.19	0.16	0.81	0.81	0.86	1.24	1.18	1.23	0.25	0.28	0.24
SG	1.50	1.68	1.86	0.35	0.33	0.18	0.79	0.65	0.72	1.05	0.95	0.77	0.37	0.37	0.29
SP	1.71	1.83	2.14	0.18	0.15	0.15	0.82	0.77	0.76	1.75	1.83	1.47	0.43	0.39	0.32
CW	1.75	1.90	2.09	0.17	0.18	0.18	1.01	1.00	1.12	2.15	2.10	2.14	0.37	0.37	0.37
CBO	1.55	1.64	1.52	0.13	0.13	0.14	0.78	0.65	0.54	1.22	1.26	1.14	0.32	0.27	0.32
NO	1.37	1.57	1.81	0.13	0.14	0.13	0.91	0.82	0.74	0.88	0.83	1.03	0.27	0.22	0.26
$\overline{X}$	1.63a	1.78a	1.94b	0.21a	0.20a	0.16b	0.87a	0.79b	0.80b	1.34a	1.33a	1.30a	0.32a	0.30b	0.29b

[a]Treatment means followed by the same letter are not significantly different at the 0.05 level.

[b]GA, green ash; SYC, sycamore; SG, sweetgum; SP, sweet pecan; CW, cottonwood; CBO, cherrybark oak; NO, Nuttall oak.

[c]C, control; M, mow; D, disk.

Foliar nutrients

Without considering the oaks, which should not be planted on this site, then cottonwood or green ash was highest in foliar nutrient concentrations except P and Mg (Table I). Sweetgum was lowest for N, K, and Ca, highest in P and intermediate for Mg. Other species were intermediate with no apparent ranking.

Trees in disked plots had significantly higher foliar N concentrations and significantly lower P, K, and Mg than those in control plots. Foliar concentrations of K and Mg in disked and mowed plots were not different. Cultural treatments did not affect foliar Ca concentrations. Although foliar concentrations of some species were lower in disked plots, if weight is assumed to be proportional to tree size, then more of each nutrient would have accumulated in trees in disked plots because trees were 50—80% larger than those in mowed and control. The higher foliar N concentrations in disked plot trees probably resulted from periodic incorporation of green herbaceous matter (accompanied by release of N during decomposition) and less competition for available soil N. Researchers Carter and White (1971) and Blackmon and White (1972) have suggested a foliage nitrogen level of 2% to be a minimum for best growth in several species of poplars. All species in this study except sweetgum and the oaks were above 2% foliar N in disked plots, but below this level in mowed and control plots (Table I). Data indicate the beneficial effects of disking on N mineralization and a possible N deficiency in mowed and control plots. Baker and Blackmon (1978) reported that 2nd-year cultivation increased N levels in cottonwood foliage as much as an application of 224 kg/ha of N fertilizer.

Over the 4-year period, tissue N was highest the first year but dropped with each year of age. Tissue P appeared to be high the 1st year, decrease the 2nd and 3rd years, and then increase again the 4th year. Year-to-year fluctuations, however, kept any trends from developing clearly. Years had no effect on tissue K. Tissue Ca was lowest the first 2 years with no statistical differences. Year 3 showed substantially higher Ca than years 1 and 2, and year 4 significantly the highest. Mg was significantly lowest the first year with no differences between years 2, 3, and 4. Lower nutrients with increased age could be a result of dilution.

Soil nutrients

Combined treatment by year soil nutrient levels are shown in Table II. Soil N was significantly lower in disked plots than in mowed or control with no difference between the latter. Disking may have created conditions more favorable for the decomposition of organic matter and release of N for uptake by trees or losses by leaching, thus causing lower soil N in the disked plots. Other nutrient levels, except Mg, were not affected by cultural treatment. Mg was significantly higher in disked than in control plots; mowed plots were intermediate in Mg levels. However, even though disking did not increase or decrease levels of most soil nutrients, competition for nutrients by the above-ground, non-tree vegetation in mowed and control plots did not exist in disked plots. Thus, nutrients that would have been taken up by weeds and grasses were available for trees in disked plots.

Commerce soil, such as represented on this study site, consists of deep, somewhat poorly drained, moderately slowly permeable soils that formed in alluvial sediments of the Mississippi River and its distributaries. Geologically, they are relatively young soils and have not developed a distinctive soil profile. They also have not been subjected to severe weathering and leaching that would have caused a loss of nutrients. These soils are high in exchangeable Ca, Mg, and K, and extractable P (Table II). Soil N and OM are average. The good soil nutrient levels combined with excellent physical properties make this a highly productive soil.

TABLE II

Soil nutrient levels averaged over cultural treatments by years

Soil nutrient	Year									
	0[a]		1		2		3		4	
N (%)	0.129	a[b]	0.112	ab	0.109	b	0.119	ab	0.108	b
P (kg/ha)	200	a	190	a	190	a	220	a	190	a
K (kg/ha)	700	a	710	a	680	a	700	a	520	b
Ca (kg/ha)	6800	a	7400	a	6800	a	7800	a	6600	a
Mg (kg/ha	4200	a	4900	b	4300	a	4400	a	3400	c
pH	7.8	a	7.9	a	7.9	a	8.0	a	8.1	a
OM (%)	2.1	a	1.8	ab	1.9	ab	1.9	ab	1.7	b

[a]Year 0 is for nutrient levels before cultural treatments began; others are after each growing season.

[b]Means for a given element followed by the same letter are not significantly different at the 0.05 level.

Averaged over all cultural treatments, soil K, Mg, and OM varied significantly with age of plantation. N, P, Ca, and pH did not change much over the 4 years of this study. Potassium remained constant in years 1, 2, and 3, but dropped significantly in year 4. There was a significant increase in Mg the 1st year after planting. Years 2 and 3 were the same as the preplanting level, but Mg dropped significantly in year 4. Soil OM remained at the preplanting level for 3 years but was significantly lower the fourth year. Year-to-year fluctuations could also be a reflection of field and climatic conditions at time of sampling.

Soil moisture

Cultural treatments did not appreciably affect soil moisture except in August and September at the 1 and 1.3 m depths when there was significantly less soil moisture in mowed plots than control and disked. Weeds and grasses that were periodically mowed may have used more soil moisture late in the growing season because of active growth after mowing than those in control plots which were beginning to senesce and cure by late summer.

Evapotranspiration in a fully stocked forest stand in the Gulf South is about 0.6 cm per day (Zahner, 1956; Metz and Douglass, 1959). In this study, moisture used by the weeds and grasses in the mowed and control plots was not available for absorption by trees. On the disked plots, there was no loss because weeds and grasses were destroyed, and soil moisture that would have been used by the weeds and grasses was available for uptake by the trees. Apparently, there was never more available moisture than trees could use, even in disked plots, since no more soil moisture could be measured in disked plots than the others.

Average 1st-year soil moisture content was lowest (31%) with the other 3 years relatively constant; 36% in 1973, 34% in 1974, and 36% in 1975. Rainfall (January—September) was 82.5 cm the 1st year; 117.1 cm in year 2, 144.5 cm in year 3, and 140.5 cm in year 4. Although rainfall in years 3 and 4 was higher, soil moisture levels remained about the same as in years 1 and 2, which may indicate increased soil moisture absorption with increased tree size.

SUMMARY AND CONCLUSIONS

By eliminating competition, disking directly or indirectly increased soil nutrients and moisture available for absorption by the planted trees, as evidence by better tree growth and higher foliar nutrient levels. Anything less than the degree of site preparation and disking used in this study resulted in lower survival and reduced growth. Disking significantly lowered soil N and increased Mg, but levels of other soil nutrients were relatively unaffected.

Across all cultural treatments, sweetgum had the lowest nutrient concentrations and cottonwood and green ash the highest for most elements tested. Lower nutrient requirements could be a determining factor in the adaptation of sweetgum to a wide range of sites.

REFERENCES

Aird, P.F., 1962. Fertilization, weed control, and the growth of poplar. For. Sci., 8(4): 413—428.

Baker, J.B. and Blackmon, B.G., 1978. Summer fallowing — a simple technique for improving old-field sites for cottonwood. U.S. For. Serv. Res. Pap. SO-142, 5 pp.
Blackmon, B.G. and White, E.H., 1972. Nitrogen fertilization increases cottonwood growth on old-field soil. U.S. For. Serv. Res. Note SO-143, 5 pp.
Broadfoot, W.M., 1976. Hardwood suitability for and properties of important Mid-south soils. U.S. For. Serv. Res. Pap. SO-127, 84 pp.
Carter, M.C. and White, E.H., 1971. Dry weight and nutrient accumulation in young stands of cottonwood (*Populus deltoides* Bartr.). Ala. Agric. Exp. Stn. Circ. 190, 14 pp.
Fitzgerald, C.H., Richards, R.F., Seldon, C.W. and May, J.T., 1975. Three year effects of herbaceous weeds in a sycamore plantation. Weed Sci., 23(1): 32—35.
McKnight, J.S., 1970. Planting cottonwood cuttings for timber production in the South. U.S. For. Serv. Res. Pap. SO-60, 17 pp.
Metz, J.L. and Douglass, J.E., 1959. Soil moisture depletion under several Piedmont cover types. U.S. Dep. Agric. Tech. Bull. 1207, 23 pp.
Soil Test Work Group, 1974. Procedures used by State Soil Testing Laboratories in the southern region of the United States. South. Coop. Serv. Bull. 190, 23 pp.
Zahner, R., 1956. Evaluating summer water deficiencies. U.S. For. Serv., South. For. Exp. Stn. Occas. Pap. 150, 18 pp.

GENERAL INFORMATION

Aims and scope. Forest Ecology and Management publishes scientific articles concerned with forest science and conservation, and in particular the application of ecological knowledge to the management of man-made and natural forests. The scope of the journal includes all forest ecosystems of the world. A refereeing proces ensures the quality and international interest of the manuscripts accepted for publication. The journal aims to bridge the gap between research workers and forest managers in the field to the benefit of both.

Publication schedule. Forest Ecology and Management has four issues per volume, volumes 7, 8 and 9 appearing in 1984.

Subscriptions. Subscription price for 1984 is Dfl. 453.00 (approx. US $174.25). Send your order to your usual supplier or direct to Elsevier Science Publishers B.V., P.O. Box 211, 1000 AE Amsterdam, The Netherlands.

Submission of articles Manuscripts should be submitted in triplicate to the Editorial Secretariat, Forest Ecology and Management, P.O. Box 330, 1000 AH Amsterdam, The Netherlands.

Note to Contributors

Types of papers published in the journal
– papers reporting results of original research – review articles – short communications – (guest) editorials – book reviews – news and announcements.

A detailed *Guide for Authors* is available upon request and is also printed in the first issue of each volume. You are kindly asked to cunsult this guide. Please pay special attention to the following notes:

Language
The official language of the journal is English.
In the latter cases an English translation of the abstract should also be supplied.

Preparation of the text
(a) The manuscript should include at the beginning an abstract of not more than 200 words.
(b) It should be typewritten with double spacing and wide margins. Words to be printed in italics should be underlined. The metric system should be used throughout.
(c) The title page should include: the title, the name(s) of the author(s) and their affiliation(s).

References
(a) References in the text should be cited as the name of the author(s), followed by the year of publication.
(b) The reference list should be in alphabetical order and on sheets separate from the text.

Tables
Tables should be compiled on separate sheets. A title should be provided for each table and all tables should be referred to in the text.

Illustrations
(a) All illustrations should be numbered consecutively and referred to in the text.
(b) Drawings should be completely lettered, the size of the lettering being appropriate to that of the drawings, but taking into account the possible need for reduction in size (preferably not more than 50%). The page format of the journal should be considered in designing drawings.
(c) Photographs must be of good quality, printed on glossy paper.
(d) Figure captions should be supplied on a separate sheet.

Proofs
One set of proofs will be sent to the author to be checked for printer's errors. In the case of two or more authors please indicate to whom the proofs should be sent.

Reprints and page charges
There is no page charge. Fifty reprints of each article published will be supplied free of charge. Additional reprints can be ordered on a reprint order form which is included with the proofs.

All contributions will be carefully refereed for international relevance and quality. Submission of an article is understood to imply that the article is original and unpublished and is not being considered for publication elsewhere.

FOREST ECOLOGY AND MANAGEMENT HAS NO PAGE CHARGES
A FREE SAMPLE COPY OF THE JOURNAL IS AVAILABLE ON REQUEST