DEVELOPMENT OF A CENTRAL HARDWOOD STAND

FOLLOWING WHOLE-TREE CLEARCUTTING IN CONNECTICUT

C. Wayne Martin[1]

Abstract: Little information is available concerning the initial stages of forest regeneration following intensive harvesting of central hardwood stands in the northeastern part of the range. Establishment of commercial species, density, and rate of biomass accumulation of the regeneration are of major concern to both foresters and landowners contemplating a harvest. To help provide this information, a 6-ha forest stand dominated by the central hardwood forest type of Connecticut was mechanically whole-tree clearcut in 1981. Intensive sampling of the regeneration including herbs, shrubs, tree seedlings, and stump sprouts was conducted the first, third, fifth, and tenth years after cutting. This paper will discuss the development of the stand over the first ten years following clearcutting. Prior to harvesting, the stand contained 1,163 stems ha^{-1} $\geq$2.0 cm d.b.h.; at year 10 there were 9,500. At year 10, the trees and shrubs $\geq$2.0 cm d.b.h. had accumulated 20% of the preharvest levels of biomass, 52% of nitrogen, and 21% of calcium. Based on data from the first 10 years after clearcutting, the future forest should be similar to the preharvest forest with red maples, oaks, and birches being the most numerous trees.

INTRODUCTION

The central hardwood forest type is extensive in southern New England. As of 1985, more than 2.1 million acres of Massachusetts, Rhode Island, and Connecticut were classified as the oak-hickory forest type (Brooks et al. 1993). In Connecticut alone, there were 966,000 acres of the oak-hickory forest in 1985 (Dickson and McAfee 1988). Eighty four percent of the oak-hickory type in Connecticut is in non-industrial private ownership. In 1984, 722,000 cubic meters of hardwood wood products were produced in Connecticut including sawlogs, roundwood, and fuelwood (Dickson and McAfee 1988).

Landowners, foresters, loggers, and the general public are concerned about the future productivity and biodiversity of these forest lands. For long-term planning, landowners and foresters need information on the characteristics of the early stages of regeneration, the development of stands, and the expectations for the future mature stands. Little information is available concerning the regeneration and early successional stages of forest development following logging in the northeastern part of the central hardwood range. The first 5 to 10 years after harvest are critical in the development of the new stand and are not well understood (Hornbeck et al. 1990).

The effects of calcium depletion on the long-term productivity of these forests is another reason for studying the regeneration of these stands. Hornbeck and others (1990) found that 10% of the total calcium pool was removed from a central hardwood stand in Connecticut in wood products removed from the site and in soil water leached to streams following mechanical whole-tree clearcutting. They also predicted that calcium uptake by 3 year-old regeneration would exceed the extractable calcium in the soils of the site. They studied the calcium dynamics of 3 forest types in New England and concluded that calcium is potentially a limiting plant nutrient in the forests of Connecticut. Data on calcium uptake by regeneration through year 10 would add new insight to this hypothesis.

During the energy crisis of the late 1970s and early 1980s, the forests of southern New England were viewed as alternative sources of fuel. Fuelwood cutting on a commercial scale was proposed, much of it on state forest lands. To

[1]Research Forester, USDA Forest Service, Northeastern Forest Experiment Station, Hubbard Brook Experimental Forest, RFD #1 Box 779, Campton, NH 03223.

test the potential impacts of fuelwood cutting on state forest lands, the State Forester of Connecticut, requested a study of the effects of mechanical whole-tree clearcutting on site productivity, regeneration, and development of future stands. The purpose of this paper is to report on the development of a southern New England stand over the first 10 years following clearcutting.

METHODS

The Study Site

The study site is a 6 ha forested stand located in the Cockaponset State Forest in Chester, CT. Prior to harvesting, the watershed supported an 80- to 110-year old oak-birch-maple forest typical of Connecticut and southern New England. Oaks (*Quercus Prinus* L., *Q. rubra* L., *Q. alba* L., and *Q. velutina* Lam.) accounted for 47% of the basal area; birches (*Betula lenta* L., and *B. alleghaniensis* Britt.) accounted for 27%; and maples (*Acer rubrum* L. and *A. saccharum* Marsh.) accounted for 13% of the basal area. The remainder included miscellaneous hardwoods. The total basal area of all stems larger than 2 cm d.b.h. was 23 m^2 ha^{-1}, with a density of 1,163 stems ha^{-1} (Tritton et al. 1982).

The soils of the upper slopes of the study site are of the Hollis-Chatfield-Rock association which are loamy, mixed, mesic Lithic Dystrochrepts. These soils consist of shallow, somewhat excessively drained soils with occasional outcrops of exposed bedrock. The bedrock is of the upper Middletown formation, an assemblage of gneisses and schists with inclusions of sillimanite quartz and pegmatite. The soils of the lower slopes are deep, well-drained, coarse, loamy, mixed, mesic, Typic Dystrochrepts of the Chatfield-Canton association. The soils of the valley floor are poorly drained, acidic, coarse-loamy, mixed, mesic Aeric Haplaquepts of the Leicester series (USDA Soil Conserv. Serv. 1981).

In the winter of 1981-82, the entire watershed was whole-tree clearcut. All living and dead trees greater than 5 cm d.b.h. were cut. Trees less than 30 cm stump diameter were cut with a rubber-tired feller buncher. Larger trees were felled with chain saws. Whole trees of all diameters were skidded to the landing outside the watershed by rubber-tired, articulated skidders. Ninety one percent of the aboveground biomass was removed from the site by the harvesting operation (Tritton et al. 1987). Harvesting was completed in March of 1982 and was confined to the dormant season.

Regeneration Surveys

Prior to harvesting, a 25 X 25 m grid was surveyed on the watershed with the corners permanently marked. From this grid, plots were selected at random for the regeneration surveys. These plots were also permanently marked. Three sizes of plots were selected for vegetation sampling: 1 X 1 m plots for herbs, shrubs, and tree seedlings <130 cm tall; 1 X 25 m plots for saplings 0.1 to 9.9 cm d.b.h.; and 25 x 25 m plots for trees ≥10 cm d.b.h. and for following the fate of stump sprouts. Prior to cutting, all trees ≥10 cm d.b.h. were measured and their location mapped.

The first survey was conducted in August 1982, the first year after harvest. Since all vegetation was <130 cm tall, 50 1 X 1 m plots were sampled. Sprouts from the stumps of the mapped trees were also measured. The second survey was conducted in August 1984, the third year after cutting. The third survey was conducted in August 1986, the fifth year after harvest. On both of these occasions, twenty five of the 1 X 1 m plots were remeasured. In addition, 16 of the 1 X 25 m plots were measured.

The fourth survey was conducted in August 1991, the 10th year after cutting. The twenty five 1 X 1 m plots were remeasured. Twenty five paired plots were harvested for biomass and nutrient analyses. The sixteen 1 x 25 m plots for saplings were remeasured, but because saplings in this size range represented a majority of the vegetation on the area, 20 more plots were added, at random, for a total of 36 plots. Because of the density of the foliage, the stump sprouts on four 25 X 25 m plots were remeasured in November of 1986 and 1991.

Biomass

Three individuals of each species were clipped, on separate plots, for biomass and nutrient analyses the first year after cutting. These samples were dried at 65°C to constant weight. The average of the 3 samples was multiplied by the number of stems of that species per hectare. Biomass of the vegetation <130 cm tall the 3rd and 5th year after cutting was estimated by clipping twenty one 1 X 1 m plots selected at random using ranked-set sampling techniques (McIntyre 1952). Biomass of the vegetation <130 cm tall in the 10th year was estimated by taking a simple average of the oven-dry weights of twenty five plots paired with the inventory plots. The first year after cutting there were no stems large enough to have a d.b.h. During the 3rd and 5th year inventories, 3 stems of each species in each 1-cm d.b.h. class were clipped in various areas of the watershed. Each stem was weighed in the field, subsampled, and oven dried at 65°C. The average oven-dried weight of each species and size class was then multiplied by the estimated number of stems of that species and size per hectare. The 10th year after cutting, several individuals over a range of d.b.h. were sampled and dried by species. Then allometric equations were developed for each species for predicting oven-dry weight from d.b.h.

Nutrient Analyses

Vegetation samples collected for biomass estimates were dried to a constant weight at 65°C, and then analyzed chemically. Subsamples were digested in a Technicon BD-20[2] block digestor. Total Kjeldahl nitrogen was measured on the digested samples with colorimetric analyses performed on the Technicon Autoanalyzer. Calcium concentrations of the digested samples were determined by flame atomic absorption spectroscopy (Franson 1975).

RESULTS

Density

The first year after cutting, there were 49 genera of plants inventoried on the clearcut watershed. These genera included 14 tree species in 11 genera, 12 species of shrubs in 10 genera, and 28 genera of herbs. By the 10th year after cutting, the total number of genera had dropped to 47. However, trees had increased to 22 species in 13 genera. Shrubs had increased to 18 species in 15 genera, and herbs had dropped to 19 genera.

By August of the first year after cutting, there were about 788,000 stems ha^{-1} of all types of plants on the watershed with trees, shrubs, and herbs occurring in similar amounts (Fig. 1). By the 5th year after cutting, there were more than 1,000,000 stems ha^{-1} on the watershed with about 60% of them herbs and only 10% of them trees. By year 10, the total number of stems had dropped to less than 500,000 stems ha^{-1} with herbs still more than 60% and trees down to about 6% of the total number of stems. Of the tree genera, birches, primarily *Betula lenta*, dominated the population through year 5 (Fig. 2). By year 10, birches accounted for 45%, maples 33%, oaks 14%, and all other genera of trees combined only 8%.

A decade after harvest, the density of stump sprouts was low -- only 5% of the total number of stems of trees. Red maple was the most prolific sprouter, but sprouts were only 7% of all red maple stems at year 10. Oak sprouts were only 11% of all oak stems at the 10th year after cutting. At year 10, there were about 23,000 tree saplings tall enough to have a d.b.h. and only 7% of them were sprouts.

[2]The use of trade, firm, or corporation names does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that might be suitable.

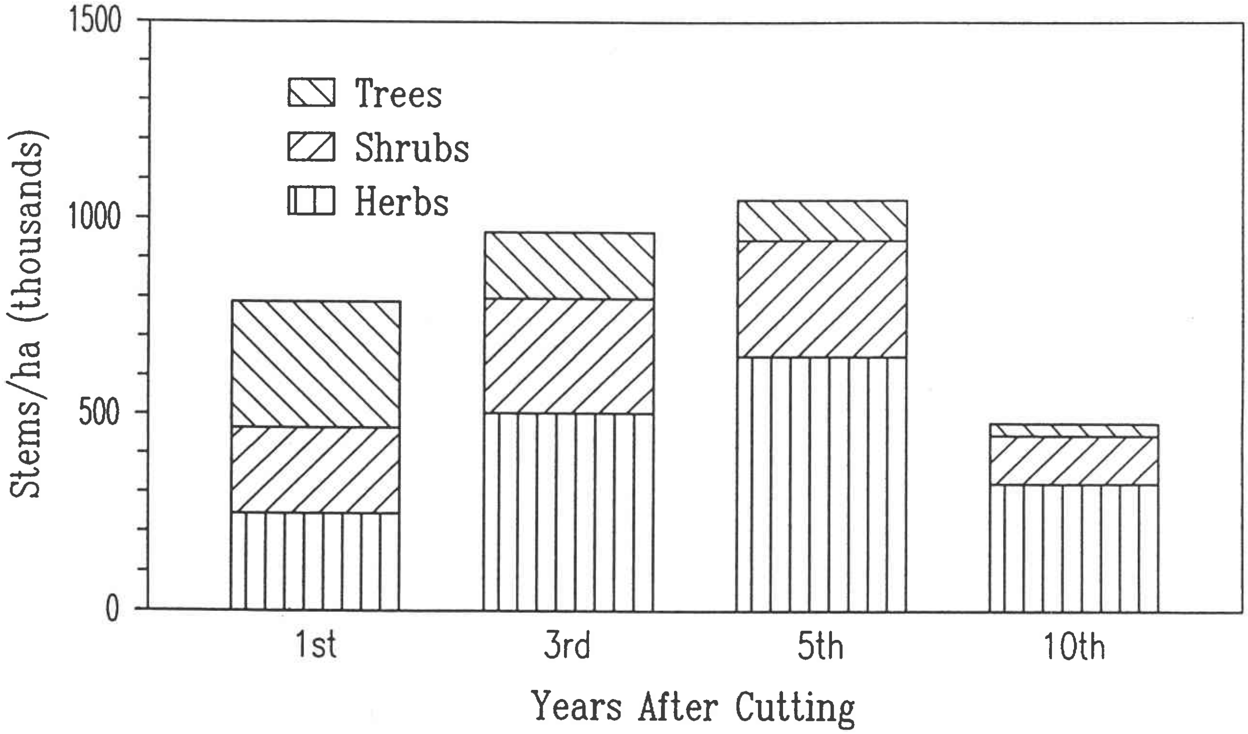

Figure 1. Density of all plants on the whole-tree clearcut at the Cockaponset State Forest, Chester, CT.

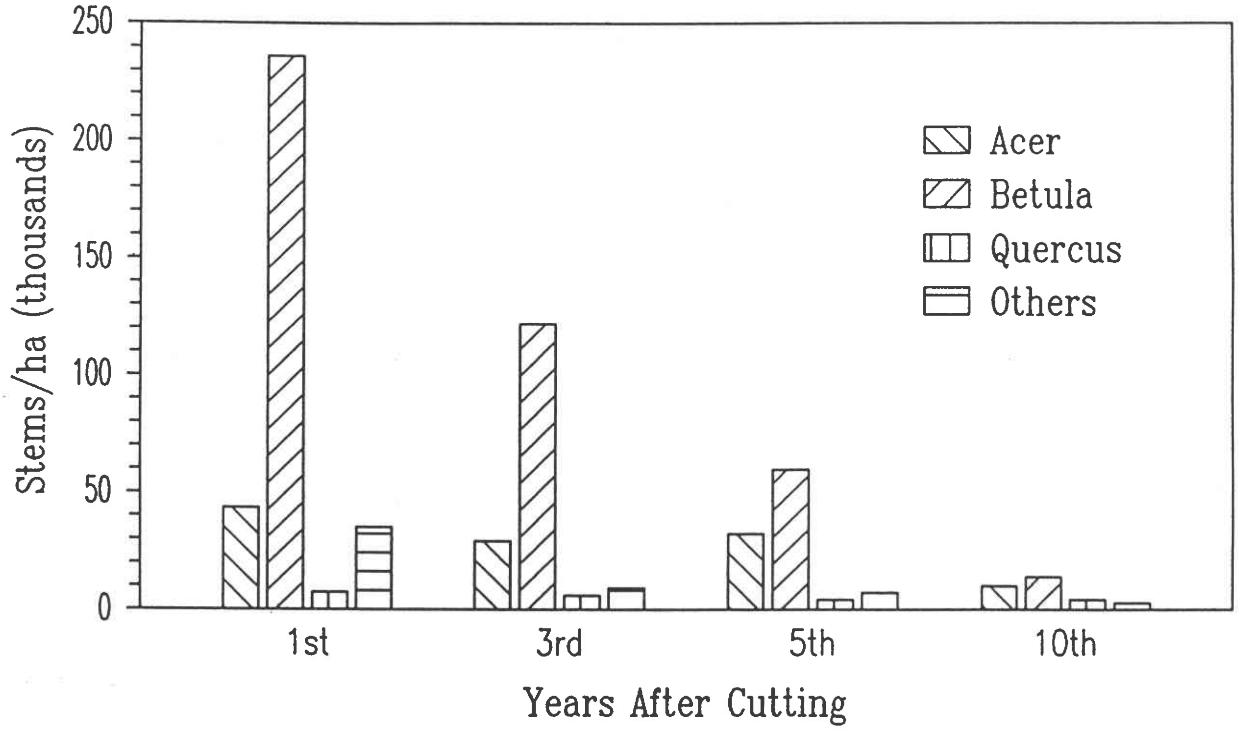

Figure 2. Density of tree genera on the whole-tree clearcut at the Cockaponset State Forest, Chester, CT.

Biomass

By August of the 1st year after cutting, there were nearly 2 tonnes ha^{-1} of aboveground dry weight of biomass with trees accounting for most of it (Fig. 3). By year 5, biomass had increased to 18 tonnes ha^{-1} with trees accounting for two-thirds of it. In the next 5 years the biomass more than doubled to nearly 42 tonnes ha^{-1}, with 88% in trees.

Of the tree genera present one growing season after cutting, the maples produced the most biomass, followed by chestnut (*Castanea dentata*), followed by the oaks, followed by the birches. By year 3, the maples still had accumulated the most biomass, followed by the birches, then by chestnut, and then by the oaks. By year 5, the order had changed again with the maples still dominant, in terms of biomass, followed by the birches, with the oaks in 3rd place and chestnut moved to 4th (Fig. 4). At year 10, the maples, birches and oaks accounted for 90% of the tree biomass with the maples at 45%, and chestnut relagated to 0.2% due to mortality from the chestnut blight. Sprouts accounted for more than 20% of the tree biomass. Maple sprouts were 20% of the maple population, but oak sprouts were nearly 50% of the oak population in terms of biomass. Of the total biomass in tree genera, 99% was in trees tall enough to have a d.b.h. at year 10.

Nutrients

The 1st year after cutting, 9 kg ha^{-1} of Ca accumulated in the above ground biomass with three-quarters of it in trees. Nearly 30 kg ha^{-1} of N accumulated in plant tissue the first year with about two-thirds in trees (Fig. 5). By year 10, about 150 kg ha^{-1} of Ca had accumulated in aboveground living plant tissue with 86% of it in tree genera. Nearly 200 kg ha^{-1} of N was sequestered in plant tissue at year 10 with about 86% of it in trees.

At year 10, the maples accounted for nearly 40% of all of the above ground biomass and contained about one-third of the Ca. The oaks contained only 20% of the biomass of the watershed, but they contained 27% of the Ca (Fig. 6). The maples contained 3.1 kg of Ca per 1000 kg of biomass, while the oaks contained 4.8 kg of Ca per 1000 kg of biomass. Of the total Ca in trees, 24% was in sprouts, but 43% of the Ca in oaks was in sprouts.

At year 10, maples had sequestered 35% of the N, and oaks 26% (Fig. 7). The maples contained 4.0 kg of N for each 1000 kg of biomass. The oaks contained 6.0 kg of N for each 1000 kg of biomass. Sprouts of all genera contained 24% of the N in all tree genera.

DISCUSSION

Prior to harvesting, the central hardwood forest at the Cockaponset State Forest in Chester, CT was a diverse forest with 22 species of trees and shrubs (Tritton et al. 1982). The first year after whole-tree clearcutting with 91% of the above-ground living biomass removed, there were 26 species of trees and shrubs in the regeneration. By the 10th year after cutting, the number of species of trees and shrubs had increased to 40.

The total numbers of stems of all plants increased through the 5th year after cutting and then by year 10 had dropped considerably as the canopy closed (Fig. 1). Trees were the most numerous the 1st year after cutting followed by herbs and then shrubs. Over the 10 year period the numbers of trees declined steadily; shrubs and herbs increased through year 5 and then declined by year 10. Of the tree species, sweet birch (*Betula lenta*) was clearly the most numerous throughout the 10 years of the study followed by red maple (*Acer rubrum*). The oaks were always important and were the 3rd most numerous tree by year 10 (Fig. 2).

The above ground living biomass of all plants on the watershed increased steadily over the 10 years after cutting, more than doubling between years 5 and 10. Tree species have clearly dominated the biomass throughout the post-harvest period inreasing from 67% of the biomass the first year after cutting to 88% by year 10 (Fig. 3). Herbs were a major part of the biomass through year 5. Shrub biomass has increased steadily throughout the period.

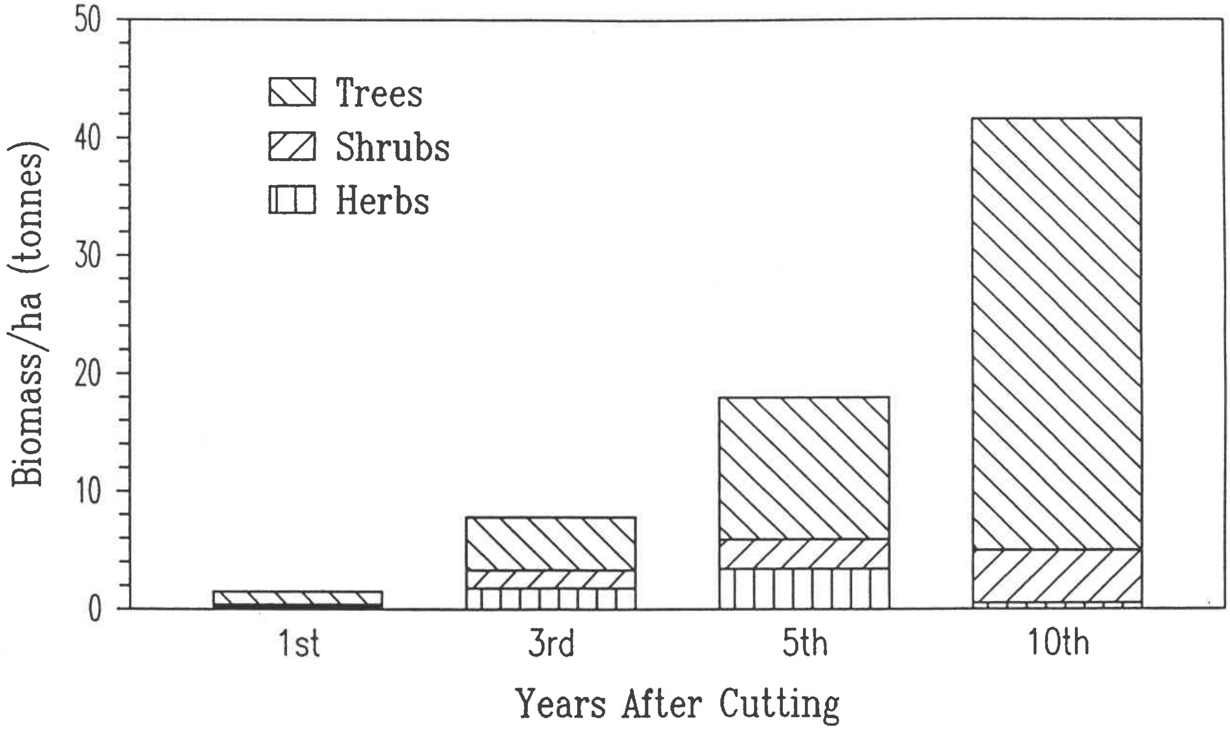

Figure 3. Biomass of all plants on the whole-tree clearcut at the Cockaponset State Forest, Chester, CT.

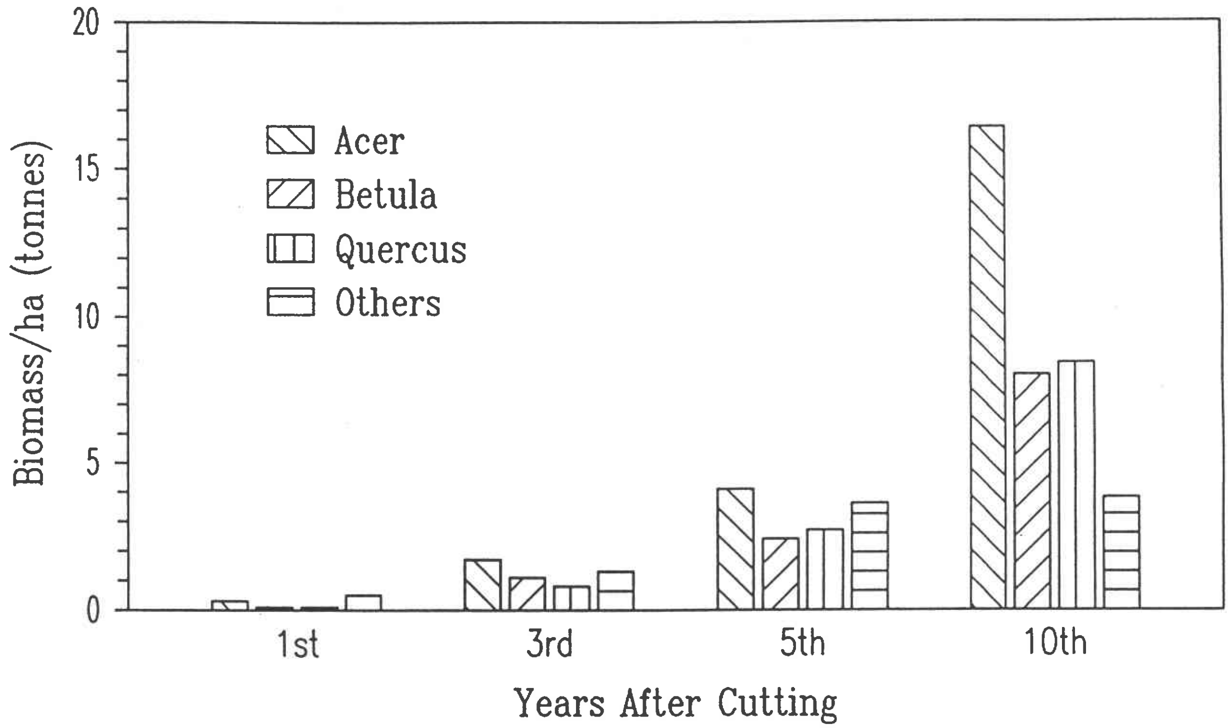

Figure 4. Biomass of tree species on the whole-tree clearcut at the Cockaponset State Forest, Chester, CT.

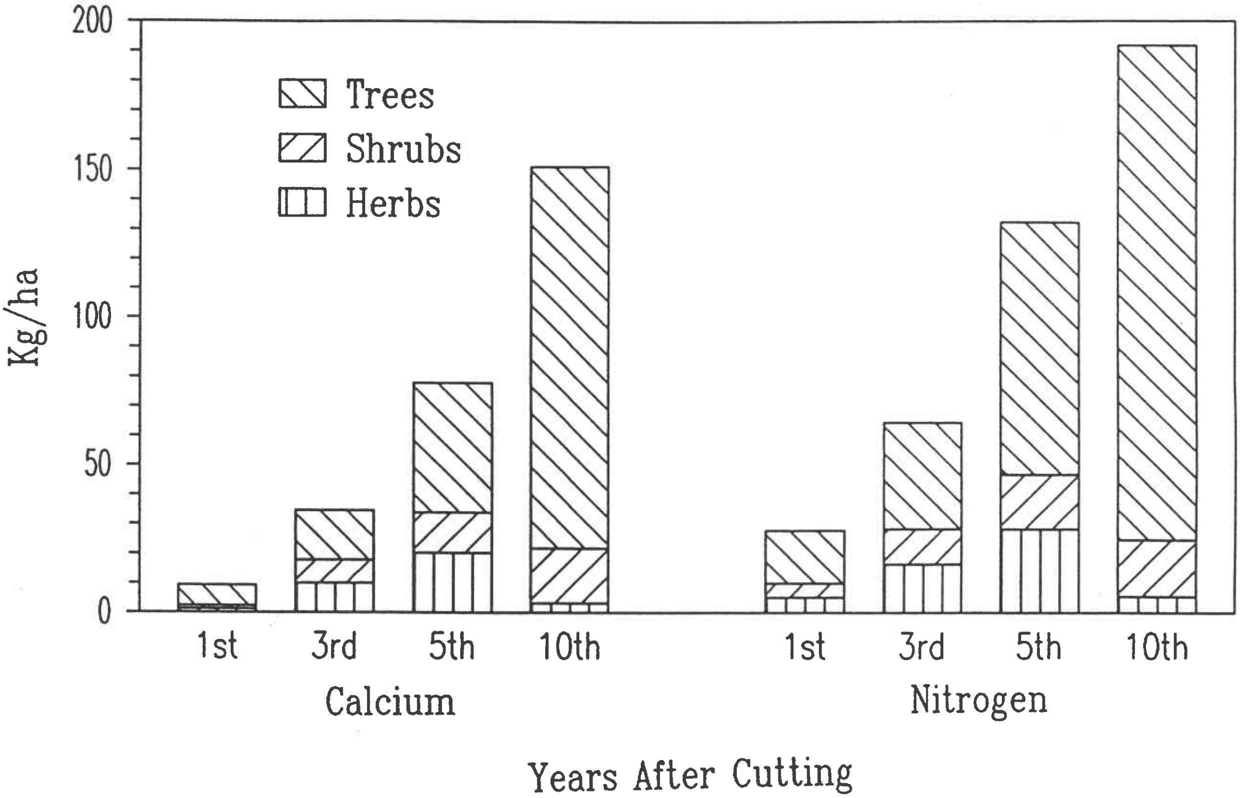

Figure 5. Calcium and nitrogen sequestered in all plants on the whole-tree clearcut at the Cockaponset State Forest, Chester, CT.

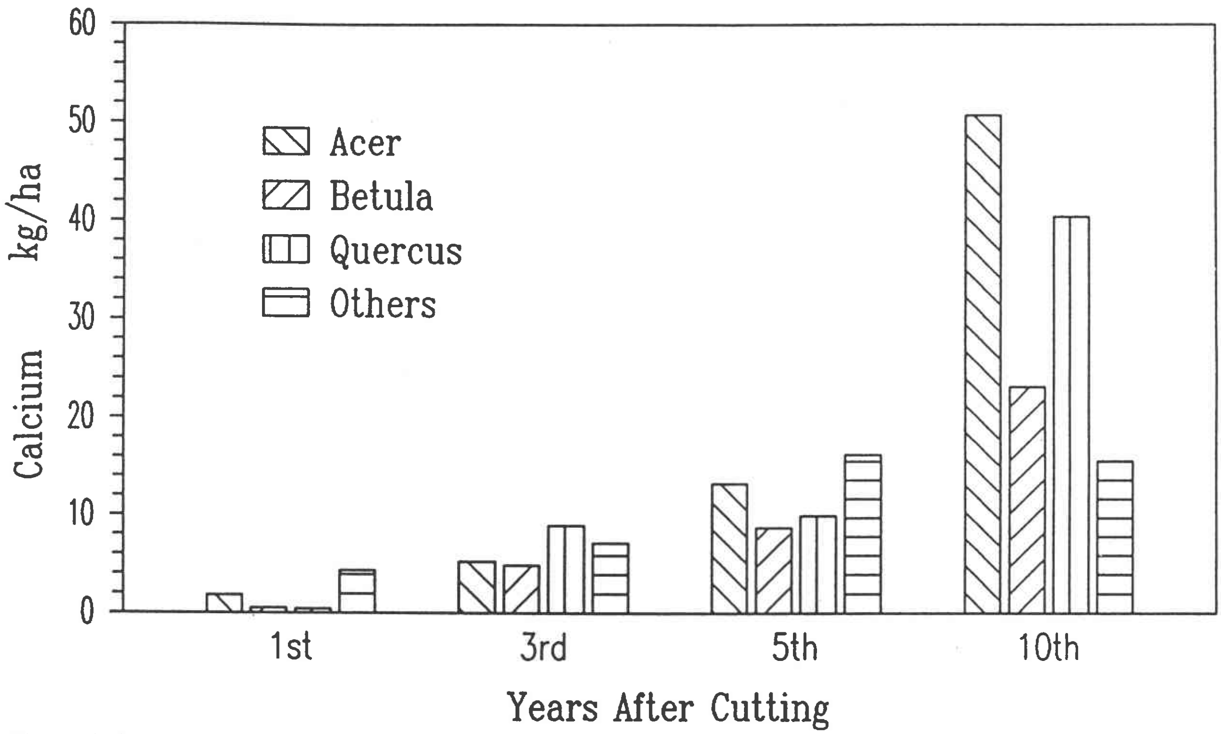

Figure 6. Calcium sequestered in tree genera on the whole-tree clearcut at the Cockaponset State Forest, Chester, CT.

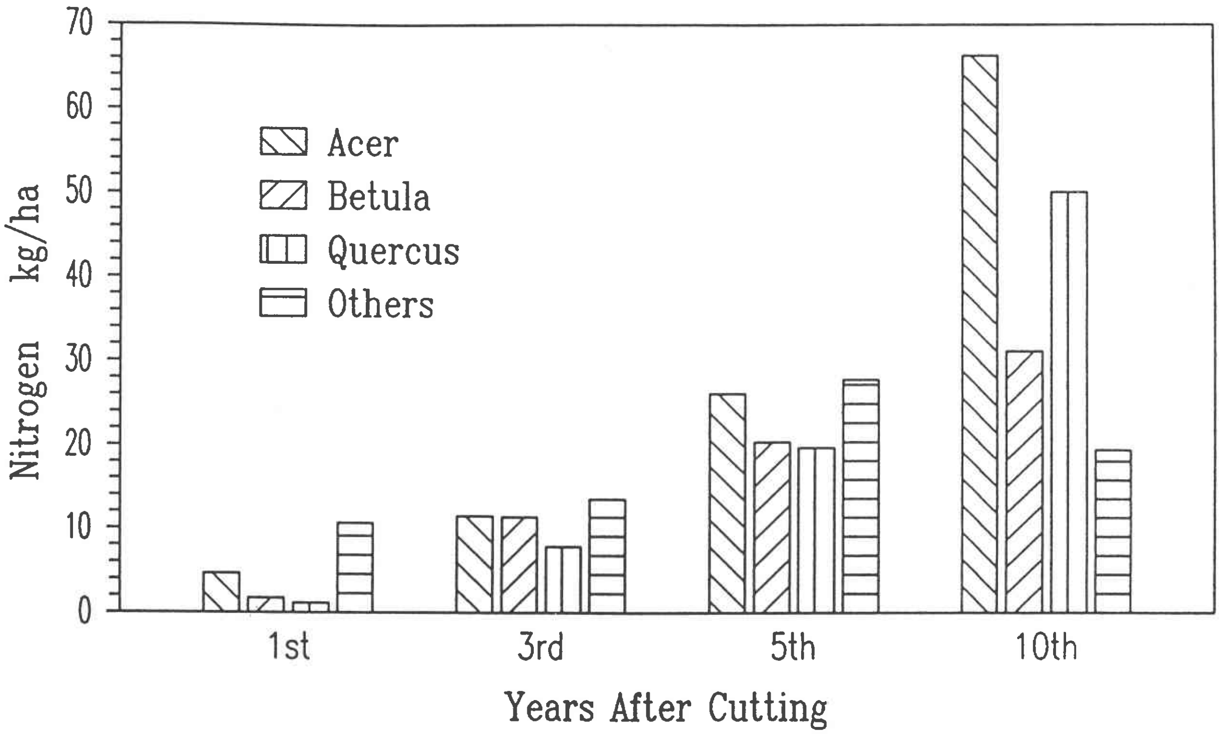

Figure 7. Nitrogen sequestered in tree genera on the whole-tree clearcut at the Cockaponset State Forest, Chester, CT.

Of the trees, red maple accumulated the most biomass of any single species throughout the sampling period followed by sweet birch (Fig. 4). After year 5, biomass of all of the oak species combined exceeded that of the birches.

The accumulation of nutrients in all plants on the site followed the same pattern as the biomass (Fig. 5). Trees sequestered much more Ca and N than did shrubs and herbs from the very first year after cutting. However, no one genus clearly dominated nutrient uptake until year 10, when maple and oaks sequestered the greatest amounts (Figs. 6 and 7).

The Future Forest

Comparisons of living trees and shrubs with stems ≥2.0 cm d.b.h. indicate that prior to cutting, dogwood (*Cornus florida*) was the most numerous tree on the watershed, but was an understory tree with very little biomass (Table 1). Of the major tree species, the maples were most numerous followed by the oaks and then the birches. At 10 years after cutting, the maples were the most numerous trees ≥2.0 cm d.b.h. followed by the birches and then by the oaks. Prior to cutting, the oaks had accumulated more than 50% of all of the biomass, Ca, and N in stems greater than 2.0 cm d.b.h. At 10 years after cutting, red maple had assumed that role. However, the oaks accounted for 24% of the biomass, 31% of the N, and 32% of the Ca.

Prior to cutting, there were more than 1,100 stems ha^{-1}; at year 10 there were more than 9,500 in trees and shrubs ≥ 2.0 cm d.b.h. which are likely to survive. This seems to be adequate stocking. Already by year 10, these trees and shrubs have accumulated 20% of the preharvest biomass; 52% of the preharvest N; and 21% of the preharvest Ca.

Table 1. Living trees and shrubs ≥2.0 cm d.b.h. on a 6 ha watershed on the Cockaponset State Forest, Chester, CT before and ten years after clearcutting.

	Before Cutting				Ten Years After Cutting			
Species	Density Stems/ha	Biomass Tonnes/ha	N ---kg/ha---	Ca	Density Stems/ha	Biomass Tonnes/ha	N ---kg/ha---	Ca
Quercus	202	93.2	176.0	399.3	1,350	8.1	48.4	38.5
Betula	174	39.6	65.7	89.2	2,058	4.2	18.4	13.4
Acer	305	14.4	29.8	51.0	3,717	15.5	62.5	47.2
Carya	58	4.9	9.1	18.6	400	1.3	7.6	5.0
Cornus	339	0.9	7.3	9.6	293	0.7	3.0	3.7
Other	85	15.4	14.8	20.8	1,720	4.0	16.6	14.0
Total	1,163	168.4	302.7	588.5	9,538	33.8	156.5	121.8

CONCLUSIONS

Clearcutting, especially whole-tree clearcutting, is a major disturbance of the forest ecosystem. The rate and success of the regeneration are of concern to forest landowners, foresters, and the general public. The Cockaponset site revegetated rapidly with herbs, shrubs, and tree seedlings during the first growing season after harvesting. Species density increased rapidly for the first 5 years and then declined due to crown closure. Biomass increased exponentially through year 10.

Even though clearcutting disrupts the forest nutrient cycles, regeneration including trees, shrubs, and herbs on the Cockaponset site accumulated nearly 25% of the preharvest levels of biomass, more than 60% of nitrogen, and about 25% of calcium by year 10.

There is always concern about the adequate stocking of commercial species. More than 9,500 stems of trees and shrubs ≥2.0 cm d.b.h. at year 10 seems to be adequate stocking, especially with the oaks playing a prominant role in both density and biomass.

Based on data from the first 10 years after clearcutting, it would seem that the future forest would be similar to the preharvest forest with red maple, oaks, and birches being the most numerous trees.

ACKNOWLEDGMENTS

This study was conducted in cooperation with the Office of the State Forester, Connecticut Department of Environmental Protection, Hartford, CT. The author wishes to thank Jane Hislop for performing the chemical analyses of the plant tissue, and Ian Halm for assistance in plot sampling and the grinding of the plant tissue.

LITERATURE CITED

Brooks, R.T., D.B. Kittredge, and C.L. Alerich. 1993. Forest Resources of Southern New England. USDA For. Serv. Resour. Bull. NE-127, 71 p.

Dickson, D.R., and C.L. McAfee. 1988. Forest statistics for Connecticut --1972 and 1985. USDA For. Serv. Resour. Bull. NE-105, 102 p.

Franson, M.A. (ed.) 1975. Standard methods for the examination of water and wastewater. 14th ed. Am. Public Health Assoc., Washington, DC, 1193 p.

Hornbeck, J.W., C.T. Smith, C.W. Martin, L.M. Tritton, and R.S. Pierce. 1990. Effects of intensive harvesting on nutrient capitals of three forest types in New England. For. Ecol. and Manage. 30:55-64.

McIntyre, G.A. 1952. A method for unbiased selective sampling using ranked sets. Aust. J. Agric. Res. 3:385-390.

Tritton, L.M., C.W. Martin, J.W. Hornbeck, and R.S. Pierce. 1987. Biomass and nutrient removals from commercial thinning and whole-tree clearcutting of central hardwoods. Environ. Manage. 11:659-666.

Tritton, L.M., C.W. Martin, J.W. Hornbeck, R.S. Pierce, and C.A. Federer. 1982. Organic matter and nitrogen content of a central hardwood forest in Connecticut. In: R.N. Muller (ed.) Proc. Central Hardwood Forest Conf. IV, Univ. of Kentucky, Lexington. p. 271-284.

U.S. Department of Agriculture, Soil Conservation Service. 1981. Soil survey of the Cockaponset State Forest research project area, Chester, CT. USDA Soil Conserv. Serv. Storrs, CT.