A LONG-RUN TIMBER OUTPUT PROJECTION MODEL FOR THE NONINDUSTRIAL PRIVATE FOREST SECTOR

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS ii

page

I. INTRODUCTION 1

Importance of the NIPF 2
Historical Perspective on the NIPF as a Forest Problem 3
Relationship to Other Research 12
Outline and Summary 14

II. LITERATURE REVIEW 17

Studies of the Nonindustrial Private Forest Owner . 18
NIPF Landowner Studies 19
Size of Forest Holding 24
Economic Feasibility of NIPF Timber Production . 30
Timber Supply Models 36
Duerr's Timber Supply Model 46
Vaux's Timber Supply Model 52

III. A LONG-RUN TIMBER OUTPUT PROJECTION MODEL 54

Timber Supply 55
Development of Growth and Yield Data 59
Economic Relationships Affecting Timber Output . . . 60
Economies of Tract Size 62
Diminishing Marginal Utility 64
Identification of Homogeneous Timber Output Response Cells 65
Physical Stratification 66
Economic Stratification 67
A Homogeneous Timber Output Response Matrix . . . 69
Policy Analysis 71
Expected Changes in the Commercial Forest Acreage . 75
Homogeneous Timber Output Cell Response Relationships 77
Alternative Rate of Return 81
Timber Removals 82
Timber Demand 84

Net Annual Growth 85
Projection of Timber Output 85
Summary 88

IV. PROJECTION OF LONG-RUN TIMBER OUTPUT FOR THE COASTAL PLAIN OF VIRGINIA 90

The Study Region 90
Antecedent Studies 94
Giauque's Study 94
Hassler's Study 96
Data 98
Forest Type 99
Size of Forest Condition 101
Relationship Between Size of Forest Condition and Stand Age 103
Relationship Between Size of Forest Condition and Timber Value 105
An Incomplete Timber Market Model 106
Developing Subunits within the Study Region 111
Estimation of the Pine Regression Relationships . . 115
Estimation of the Hardwood Regression Relationships 118
Projected Acreage and Size of Forest Condition . . 120
Projection of Long-run Timber Output 122
Discussion 123

V. SUMMARY AND CONCLUSIONS 128

LITERATURE CITED 135

APPENDIX 151

Appendix Table 6 as an Illustration of Duerr's Timber Supply Model 157

VITA 172

LIST OF TABLES

Table | Page

1. Projected pine and hardwood inventory volumes and timber outputs for eastern Virginia, 1976-2000. 124

Appendix Table

1. Growth and yield data for the natural loblolly pine forest type on the Coastal Plain of Virginia (Giauque 1977) . . . 152
2. Growth and yield data for the planted loblolly pine forest type on the Coastal Plain of Virginia (Giauque 1977) . . . 153
3. Growth and yield data for the pine-oak forest type on the Coastal Plain of Virginia (Giauque 1977) 154
4. Growth and yield data for the upland hardwoods forest type on the Coastal Plain of Virginia (Giauque 1977). 155
5. Growth and yield data for the bottomland hardwoods forest type on the Coastal Plain of Virginia (Giauque 1977) . . . 156
6. Rate of return on extra growing stock, for natural loblolly pine on average site in eastern Virginia (Hassler 1978). . 160
7. Rate of return on extra growing stock, for planted loblolly pine on average site in eastern Virginia (Hassler 1978). . 161
8. Rate of return on extra growing stock, for pine-oak on average site in eastern Virginia (Hassler 1978). 162
9. Rate of return on extra growing stock, for upland hardwood on average site in eastern Virginia (Hassler 1978) 163
10. Rate of return on extra growing stock, for bottomland hardwood on average site in eastern Virginia (Hassler 1978). 164
11. Optimum rotations and yields, by guiding rates of interest and forest type for eastern Virginia (Hassler 1978). . . . 165

12. Projections of commercial forest acreage in eastern Virginia to 2020 (Hassler 1978) 167

13. Projections of commercial forest acreage for 2020 by forest type and ownership in eastern Virginia (Hassler 1978) 168

14. Current periodic annual growth and mean annual growth related to implied alternative rate of return 169

15. Projections of commercial forest acreage in eastern Virginia, by forest type, 1976-2000. 170

16. Projections of the percentage of forest acreage in size of forest condition classes greater than or equal to 200 acres. 171

LIST OF FIGURES

Figure | page

1. Determination of optimal rotation age, based upon forest value growth percent and the alternative rate of return. 49

2. Example of a three-dimensional homogeneous timber output response matrix. 70

3. Hypothetical relationship between alternative rate of return and timber output. 72

4. Relationship between the alternative rate of return, size of forest holding, and timber removals. . . . 79

5. Flow chart of the timber output projection system. . . 87

6. Counties and independent (noncounty) cities in the Virginia Coastal Plain. 91

7. The Coastal Plain of Virginia as a timber importing region. 109

8. Ninety-five percent confidence band on the timber output projection. 125

I. INTRODUCTION

This study is concerned with timber output from the nonindustrial private forest (NIPF) sector. The objectives of the study were (1) to develop a model for projecting regional timber output from the NIPF sector and (2) to apply the model to Virginia's Coastal Plain. Desirable characteristics of the model were that it adopt a positive approach to projecting timber output, be amenable to NIPF sector policy analysis, and be operational; that is, be capable of estimation using currently available data.

The study was conducted in four stages. The first stage consisted of a thorough review of NIPF studies, with an aim of identifying the key NIPF landowner characteristics and economic variables that influence NIPF timber output. NIPF studies were divided into two groups: those concerned with NIPF landowner characteristics and those concerned with the economic feasibility of NIPF timber production. The second phase consisted of a review and analysis of previous timber supply models, with the emphasis placed on a comparison of the structural characteristics of each, and an evaluation of their applicability to the NIPF sector. The third phase involved development of a formal projection model for NIPF regional timber output. The fourth stage consisted of applying the formal model to a study region--Virginia's Coastal Plain.

A positive model was developed using a homogeneous timber output response cell approach. Size of forest holding is related to the landowner's alternative rate of return: the larger the size of forest holding, the lower is the landowner's alternative rate of return, and the more likely is the landowner to invest in timber management, resulting in increased timber output. The results of the model suggest that an essential requirement of NIPF economic timber output models is that they be based upon stratification by size of forest holding. The modeling approach should be applicable to any forest region.

Importance of the NIPF

Recent Forest Service reports detail the importance of NIPF lands to national timber output potential (U.S. Forest Service 1980a, 1980b; Wall 1981). In 1977, total forest acreage in the United States was 737 million acres (about one-third of total land area). Nearly two-thirds of this forest area, about 482 million acres, was classified as commercial timberland, almost three-quarters of which is in the eastern United States, about equally distributed between the North and the South.

The NIPF sector holds 58 percent of the nation's commercial forest area, forest industry 14 percent, and public forests 28 percent. Approximately 71 percent of the commercial forest area in the eastern United States is held by the NIPF sector, but only about 20 percent is held by this sector in the western United States.

In 1977, the NIPF supplied 30 percent of the softwood and 78 percent of the hardwood harvest. Nearly 23 percent of the softwood and 70 percent of the hardwood inventory is controlled by NIPF landowners. Softwood timber output is expected to increase by 1.3 percent annually to the year 2030 for the NIPF sector and hardwood timber output by 1.1 percent. The capacity of the NIPF for increased timber growth is considered large, with apparent management opportunities that are more cost-effective in terms of potential growth increases than those of the National Forests (U.S.D.A. 1978).

Historical Perspective on the NIPF as a Forest Problem

There were no forest resource conservation or preservation problems in early America. The land disposition policy encouraged small ownerships, which were expected to be cleared for agricultural production. Recognition of a "forest problem" developed during the early nineteenth century due to timber theft from public lands, fraudulent timberland acquisitions, enhanced forest exploitation as a consequence of steam-powered sawmilling, and vast forest fires. During the second half of the nineteenth century the forest problem developed as one of future timber supply shortages and forest devastation (White 1950). Hough's (1878) first Report Upon Forestry described the forest problem, as do all government reports issued during the rest of the century.

By the early twentieth century, much of the original American forest was considered to be devastated, resulting in predictions of an impending timber famine. Raup (1967) pointed out that this view was a consequence of American foresters using the forest primeval as a biological datum. Through time, the forest problem was to be defined in terms of the departure of actual forest management practices from some ideal subjective measure, often just called "good forest management."

Two problems surfaced in the early years of the twentieth century: constantly rising lumber prices and the concentration of control of the nation's standing timber in the hands of a few large owners. The 1913 Bureau of

Corporations Report (U.S. Department of Commerce and Labor 1913) noted that about 11 percent of the private forest land was held by three owners and nearly 40 percent by 195 owners. Forest management on private forest land was reported as nonexistent and impractical under the existing commercial conditions.

The Capper Report (U.S. Forest Service 1920) was concerned with timber depletion and forest devastation. The concentration of private timber ownership was reported as unchanged since the Bureau of Corporations Report in 1913, but was seen as less of a problem. One-half of America's privately owned timber was held by about 250 large owners. The report set the blame for timber depletion: "The kernel of the problem lies in the enormous areas of forest land which are not producing the timber crops that they should." Public action was seen as needed in the areas of forest protection and property tax systems that discouraged forest management. Forest management was to be developed into "an established national practice," as it was in several European countries.

Strong pressure developed around 1919 for public regulation of all private forests. The movement was unsuccessful, but focused public attention upon the management of private forests. Passage of the Clark-McNary

Act of 1924 represented a victory for the cooperative approach to the private forestry problem. The act provided for federal and state cooperation in forest fire control and in providing tree planting stock to private forest landowners. It also represented the first major public effort to provide technical forestry advice to private forest owners (Stoddard 1961).

The Copeland Report (U.S. Forest Service 1933) represented a departure from earlier concern over the concentration of timber ownership. The report ranked the apparent mismanagement of private forests as a major national problem. It found: "That practically all of the major problems of American forestry center in, or have grown out of, private ownership." Ninety percent of the nation's timber growing capacity was under private ownership, requiring a 250 percent increase in forest capital to meet future national timber supply requirements. Major recommendations called for public purchase of over one-half of the private forest land, increased public aid to the remaining private forest landowners, and more intensive forest management on all public forest land.

Numerous forest resource appraisals took place during the 1930's and 1940's. Industrial firms were gradually being recognized as practicing "good forestry," while the small private forest owner was coming into focus as the key to the forest problem. Generally, improvement in the level of forest management practiced by the small owners was seen to be tied to tax law changes and continued public aid. The idea of public regulation again surfaced, but it gained little support (Woods 1946).

By the time of the 1946 Reappraisal Report (U.S. Forest Service 1946), the concentration of timber ownership was no longer considered to be a problem by the Forest Service. To the contrary, the report found that the poorest forest management was on the small nonindustrial forest holdings, while the larger industrial owners were considered to be practicing much better management.

The 1948 Reappraisal Report (U.S. Forest Service 1948) found that the "heart of the problem" was now the small forest owner. The report even stated that larger forest holdings offered some advantages. The forest problem was now defined as one of mismanagement on NIPF lands. Obstacles to forest management on the small forest properties were said to stem from small tract size, unstable land tenure, lack of capital, and the low incomes of the owners. A more important and divergent view of the NIPF's found in this report was its recognition of the economic basis of the NIPF problem. The report noted that the long-term nature of timber production created unique financing problems for forest landowners; the risky nature of forest investment created a need for greater availability of forest insurance; and property and estate tax systems could adversely affect forest management decisions.

This same economic viewpoint is restated in the Timber Resource Review (U.S. Forest Service 1958) which found forest productivity to be lowest on the small private ownerships, especially in the South. These ownerships were called "the key to adequate timber supplies in the future." Forest owners holding less than 100 acres accounted for 86 percent of the nonindustrial private ownerships. This small size was seen to discourage forest investment because of infrequent and limited forest income and the necessity to manage the holdings on a part-time basis.

In the early 1960's many writers noted that the NIPF problem required an economic definition. Duerr (1960:156) recognized that the basis of exploitative management on these lands "results from owners' high alternative rates of return and low incomes--that it is a feature of a meager propensity to save." Thompson and Yoho (1961) discussed basic misconceptions concerning this problem. They criticized the arbitrary setting of national timber production goals, the idea that all forest resources must be fully employed, and the goal of maximum wood production. Lord (1963) criticized the heavy emphasis on educational programs, technical assistance, and financial subsidies to solve the small forest problem. He considered the small forest as part of an overall farm operation and the limiting input to forest management most likely to be capital or labor.

Timber Trends in the United States (U.S. Forest Service 1965) and The Outlook for Timber in the United States (U.S. Forest Service 1973) both discussed needed improvements on the NIPF lands, but noted that NIPF owners may have rational reasons for not investing in forestry. Rather than predict a future timber supply deficit, the reports treated timber supply as a function of the different possible forest management intensities that could be practiced on the various forest lands.

The President's Advisory Panel on Timber and the Environment (1973) characterized the NIPF's, especially in the South, as having low levels of growing stock and being poorly managed. The panel recommended that public assistance to the NIPF's not be increased, as the past record showed limited results from public investments in the NIPF sector.

The traditional view of the nonindustrial private forest problem, that inadequate future timber supply would result in undesirably high wood product prices and that poor forest management on the NIPF's is the major cause of this timber supply shortfall, came under close scrutiny during the late 1970's. This view is gradually coming into disrepute as research on the NIPF progresses.

McComb (1975) compared the condition of nonindustrial private forest lands with other types of forest ownerships in Georgia. Nonindustrial private forest lands compared favorably with both national forests and industrial private forest land in terms of growing stock, growth and removal, stocking, and mortality. The only unfavorable comparison was in forest planting.

In 1977 the Society of American Foresters and Resources for the Future sponsored a workshop on policy alternatives for the NIPF, which reexamined the traditional view of the NIPF problem (Sedjo and Ostermeier 1977). Marion Clawson (1978), in a background paper for this workshop, analyzed the NIPF's timber production characteristics. Based upon this research, Clawson (1979a) later listed six myths concerning the NIPF's:

1. The nonindustrial private forests have a low biological productive capacity.
2. They are poorly stocked.
3. Wood growth is low in relation to productive capacity.

4. Owners are unresponsive, in their timber growing, to timber prices.

5. The forests are poorly managed.

6. The owners are unwilling to sell their timber, preferring to retain their trees for personal enjoyment.

Clawson, using comparisons on a state-by-state basis, evaluated each of these myths. The realities proved to differ remarkably from the traditional view of the NIPF problem. Clawson (1979b) offers an extensive discussion of the myths.

Recent Forest Service timber situation reports have been tied to the Forest and Rangeland Renewable Resources Planning Act (RPA) Assessment. Timber scarcity is still perceived as a problem in Forest Service reports (U.S. Forest Service 1980a, 1980b). The projected economic timber scarcity is not seen as inevitable. Timber supplies can be increased if intensive management practices are applied to the Nation's commercial forest land. Opportunities for intensifying management exist on 168 million acres (about 35 percent) of commercial forest land. Nearly three-quarters of these economic opportunities are on NIPF land. Public assistance for increased management intensity on NIPF lands is seen as one means to increase timber supply from the sector.

Relationship to Other Research

The approach used in this study is based upon identifying the key economic characteristics that affect timber output, stratifying the forest resource base by these characteristics, and then using the stratum values as observations in a regression analysis to project timber output. Similar approaches have been suggested by Marty (1969), Vaux (1971, 1973), and Mills (1976) and used operationally by Vaux (1973) and Montgomery et al. (1975). The operational studies used forest type and site productivity classes to segregate forest land into type-site classes with similar cost per unit of timber output. Timber volume from the type-site classes were then summed and expanded by the acreage they represented, based upon the assumption that lower cost type-site classes will be utilized before more costly classes (See Chapter II, Vaux's Timber Supply Model). This schedule of annual timber yields, ranked by long-run average cost, constituted a long-run timber supply function; and when a demand equation was specified, an equilibrium timber output could be obtained.

The modeling approach developed in this study uses the Vauxian approach of forest resource base segregation by physical and economic characteristics. However, the present approach deviates from the Vauxian model in using economic characteristics of the NIPF sector, rather than timber production costs to derive a supply curve.

The present study hypothesizes that forest management intensity increases with size of forest holding. Thus, each forest type was stratified by size of forest holding to obtain strata representing forest acreage with similar levels of forest management intensity.

This modeling approach allows for evaluation of the NIPF by both its physical and economic timber output response characteristics. Since the forest resource base is divided into acreages that have known landowner economic timber output response patterns, the effectiveness of public assistance in developing the NIPF resource can be evaluated. In this sense, the modeling approach is unique and different from prior approaches.

Duerr's alternative rate of return model is an integral part of the approach. Duerr inferred specific behavior if landowners are rational and have a profit maximization goal, giving a normative result. The present study uses essentially the same model, based upon observation and supported by statistical inference, to obtain a positive result.

The essential difference between normative and positive models is that the normative model postulates rational economic behavior and then infers certain management behavior in pursuit of profit maximization. The positive model, in contrast, depends upon observed past behavior to project future behavior, while not necessarily rejecting that the landowners may be behaving rationally.

In Duerr's model, the relationship between the physical forest resource and silvicultural costs defines the rate of return expected at the optimum rotation age. This relationship is usually used to generate normative results, but its use is not precluded from a positive model. The implied alternative rate of return inferred from forest management activities can be derived from the actual behavior of forest landowners, giving a positive model result. Thus, Duerr's model, while most frequently used in normative studies, is applicable to positive studies as well.

Outline and Summary

Four chapters follow this introductory chapter. Chapter II is a literature review covering NIPF landowner studies, economic relationships within the NIPF sector, and NIPF timber supply. The NIPF has long been considered a "forest problem" in that alleged mismanagement of the NIPF sector was expected to result in future timber scarcity and unnecessarily high wood product prices. The changing definition of this problem was traced from its beginning to present day Forest Service timber situation reports earlier in this chapter. NIPF landowner studies, as they provide background information for the present study, were thoroughly reviewed within the chronology of Forest Service timber situation reports.

Chapter III describes the NIPF timber output model. The model involves identification of homogeneous timber output response cells based on both physical productivity and economic characteristics of the forest resource. Within each cell, uniform timber output relationships are developed and, after adjusting for land use changes, summing output from each cell produces an estimate of total timber output. The physical productivity stratification centers on forest type, with the main economic stratification characteristic being size of forest holding. A basis for forest policy analysis is provided by developing a relationship between the forest landowners' alternative rate of return and timber output within each stratum.

Chapter IV estimates the timber output model for the Coastal Plain of Virginia. Data limitations make this an example of procedure. Total timber output is expected to increase by about 0.5 percent annually over the projection period. This is mainly due to an expected 0.9 percent annual increase in hardwood output, but pine output is also expected to increase by about 0.1 percent annually.

Chapter V consists of a summary and conclusions. Homogeneous timber output response cells were shown to be a viable approach in developing a timber output model. A positive model of timber output must be based upon past relationships, both physical and economic. Homogeneous timber output response cells provide this basis.

For any NIPF timber output study, a major and logical stratum should be size of forest holding. This study showed that even a simple projection system based upon this statistic will give projections that consider the main economic characteristics of NIPF landowners.

II. LITERATURE REVIEW

That the nonindustrial private forest (NIPF) is mismanaged and makes a disproportionately low contribution to the national timber supply has been alleged to be a forestry problem since the beginning of this century. The relationship between the NIPF and timber supply remains a major forest policy issue today. Duerr et al. (1955) discussed three basic NIPF research needs: "Studies of the owner, studies of the woods enterprise, and studies of the relation of the small woods to the general timber-production problem." NIPF research developed along these lines over the next 25 years and this chapter reviews NIPF literature along the same three lines.

The first section of this chapter discusses, chronologically, the NIPF landowner studies. The first subsection describes studies of the relationship between landowner or forest characteristics and the level of timber production expected from the NIPF sector. These studies began in the early 1940's.

A segment of the NIPF landowner literature is concerned with the size of forest holding as a characteristic affecting timber output. The importance of this characteristic to the present study warrants its inclusion in a separate subsection.

Also of importance are the numerous studies concerning the economic feasibility of NIPF timber production. They provide information on the economic relationships within the NIPF sector and are the subject of a third subsection. These studies cover the period from about 1950 to the present.

The general timber production problem will be discussed in the second section of this chapter. Specific timber supply models of interest to this dissertation are discussed in subsections.

Studies of the Nonindustrial Private Forest Owner

A 1939 survey of research on forest land ownership showed an almost complete lack of research concerning the small private forest problem (Special Committee on Research in Forest Economics 1939). This lack of research was soon to be remedied. In line with the chronological scheme of the changing official definitions of the "forest problem," the NIPF landowner studies complement U.S. Forest Service reports on the timber situation.

NIPF Landowner Studies

The early studies of the NIPF landowner effectively identified the factors that influence the landowners' forest management decisions. Stoddard (1942), in one of the earliest NIPF studies, discussed most of the factors that would be cited in many later studies; for example, lack of knowledge regarding forest markets and forest management, absentee owners, the forest investment's rate of return relative to its riskiness, size of forest holding, and the value and amount of merchantable timber on the holding. Folweiler and Vaux (1944) noted that industrial forest land was more "productive of pine timber" than NIPF land. That the NIPF is poorly managed, relative to the industrial forests, was to be a recurrent theme in future small private forest land ownership studies until the late 1970's.

Many of the early studies used a subjective measure of forest management quality on NIPF land. Usually, "good" forest management was equated with publicly desirable levels of forest management intensity. Folweiler (1944) and Chamberlin et al. (1945) used a pine stocking index to measure the quality of forest management practiced by different forest land ownership classes. Good forest management was associated with higher pine stocking and the studies showed that "ownership and management are intimately associated" (Folweiler 1944). NIPF landowners were found to practice poorer forest management than the other ownership classes. Different variations of this scheme to rate forest management practices by subjectively evaluating certain management practices include the 1946 Forest Service Reappraisal (U.S. Forest Service 1946) and James et al. (1951) which rated management status on the basis of cutting practice and forest fire protection; Yoho et al. (1957) based their evaluation on cutting practice; and the Tennessee Valley Authority (1956) used both cutting practice and stocking. The NIPF consistently was shown to have poor forest management when based upon these subjective measures.

The numerous later NIPF studies served mainly to reinforce the conclusions of the first NIPF studies. Most interesting to the present study is the conclusion of these earlier studies that two physical characteristics of the NIPF, size of forest holding and the value and volume of timber on the forest holding, are commonly associated with management intensity on NIPF lands. This conclusion will be discussed in the next subsection.

A second recurring theme continuing to the present is that the NIPF lands are mismanaged and are characterized by low productivity. This theme was recently questioned (McComb 1975, Clawson 1978), but is still common in the literature.

A third major recurrent theme during the 1960's and 1970's was that NIPF landowners were disinterested in timber production as a primary ownership objective. The many nontimber objectives of the NIPF landowners were seen to make them unreliable as timber producers. For example, research studies that found a high percentage of NIPF landowners with a primary ownership objective other than timber production include 97 percent in Michigan (Schallau 1964), 75 percent in Massachusetts (Babeu et al. 1965), 83 percent in Delaware (Kingsley and Finley 1975), 99 percent in New Jersey (Kingsley 1975), 97 percent in West Virginia (Birch and Kingsley 1978), and 85 percent in Washington (Baumgartner 1978).

Generally, the primary timber production ownership objective appeared strongest in the southern United States. Research on the percentage of southern NIPF landowners with a nontimber primary ownership objective include 60 percent in North Carolina and Georgia (Anderson 1960), 45 percent in Mississippi (Moak 1973, 1978), 36 percent in Louisiana (Fontenot and Marlin 1974), 35 percent in Louisiana (Carothers and Smith 1977), and 44 percent in Louisiana (Marlin 1978). Thus, while this relationship is somewhat regional, most of the NIPF landowners are often thought to be disinterested in forest investment for timber production.

Christensen and Grafton (1966) found a similar lack of timber production goals in West Virginia and noted that "people's goals or aims change and it is extremely difficult, if not impossible, to predict with any reasonable certainty the future nature and degree of such changes." One such change is that NIPF landowners' disinterest in timber production has been hypothesized to decrease as timber crops become merchantable (Finley and Turner 1975).

Stone (1970) noted that the conclusion of many NIPF studies, that NIPF landowners have a variety of ownership objectives and cannot be considered timber producers, did not correlate with actual NIPF behavior. He compared NIPF owner intent with NIPF owner practices in Michigan's Upper Peninsula and proposed a "unifying hypothesis" to explain the timber production behavior described in the various NIPF landowner studies. While NIPF landowner intent to engage in timber production was low, their actual timber production was found to be "much greater than their stated intentions suggest." Timber sales in the study region were found to be positively correlated with both size of forest holding and timber volume on the forest holding, irrespective of the stated intentions of the NIPF landowner.

Stone (1970:81) summarized his hypothesis as:

> This hypothesis may resolve the apparent discrepancy between Forest Survey statistics and the results of the 25 forest ownership studies.

> Many owners have nontimber producing objectives most of the time, but during the short period when their timber is merchantable, they are timber-value oriented. Thus, the small forest owners as a group will tend to dispose of merchantable timber in a regular and largely predictable manner, but due to minimal investments in timber stand improvement at a rate well below the potential of the sites.

Turner et al. (1977) studied the reliability of the woodland owner's intentions regarding timber production in Delaware. These intentions were found to change over time, with the result that "it seems likely sometime during a timber crop's merchantable life most long-term owners will be willing to permit some harvesting." A major determinant of timber production attitudes was found to be the expected profitability of the timber harvest.

Another study of timber production intentions by Kingsley (1979) concluded that nearly all NIPF land will be available for harvest sooner or later. The key NIPF question, according to Kingsley, is how to increase NIPF timber production, rather than NIPF timber availability.

The NIPF landowner studies strongly support the conclusion that NIPF timber supply is highly correlated with timber value and harvesting opportunity. The value of the NIPF landowner studies to the present study is in explaining the interaction between numerous independent variables and NIPF timber supply.

Size of Forest Holding

One NIPF owner characteristic, size of forest holding, has been discussed in almost all NIPF landowner studies and a review of this literature will provide insights into a critical NIPF relationship.

Size of forest holding has consistently been shown to be a major determinant of the forest management intensity practiced on a particular forest tract. Larger forest holdings tend to be in the hands of forest landowners interested in timber value. Timber volume and timber value, when on a per acre basis, are known to be positively correlated with both forest management intensity and size of forest holding.

Size of forest holding, and its relationship to forest management practices, has permeated forestry literature since the earliest NIPF landowner studies. Stoddard (1942) noted that the size of forest holding and the value of merchantable timber influenced a NIPF landowner's decisions on forest management. Barraclough and Bettie (1950) found that larger holdings were likely to be owned by people interested in timber value. Poli and Baker (1953, 1954) showed that the distribution of forest holdings by size affects long-term timber production possibilities. The Tennessee Valley Authority (1956), McDermid et al. (1959), Sutherland and Tubbs (1959), Perry and Guttenberg (1959), Miller and Southern (1960), and Anderson (1960) all noted that "better" forest management was associated with larger forest holdings. Webster and Stoltenberg (1959) found that size of forest holding was the major characteristic related to a NIPF landowner's response to forestry programs.

McClay (1961), in summarizing the results of nine NIPF landowner studies, found that, generally, a belief in the profitability of forest management was positively correlated with size of forest holding. Farrell (1964a) found a positive relationship between tract size and both timber sale frequency and forest management intensity. South et al. (1965) showed that as size of forest holding increased, adoption rates of woodland management practices also increased. Tree planting and thinning were found to be positively related to size of forest holding in North Carolina (Anderson 1968a). Similar conclusions continued to be published throughout the next decade (Holemo and Dyson 1971, Larsen and Gansner 1973, Holemo and Brown 1975, Kingsley 1976, Carothers and Smith 1977, Kingsley and Birch 1977, Koss and Scott 1978, Birch and Kingsley 1978, Birch and Powell 1978, Marlin 1978, Baumgartner 1979, Kingsley and Birch 1980).

Stone (1970:89) focused on a key finding of many NIPF landowner studies:

> ...the rate of cutting of timber and the occurrence of other forest management activities (investments) was directly related to the forest acreage in the property and to the volume of merchantable timber it contained.

Small tract size was one of the first economic problems attributed to the NIPF's. Management intensity and harvest frequency are economic variables; and thus, the explanation for the size of forest holding's influence on forest management intensity has an economic basis.

Clawson (1957) cited several factors that relate to size of forest holding. Volumes of timber produced on small forest holdings are not likely to be optimum from the timber buyer's viewpoint. The owner of small forest holding cannot, therefore, expect as high a stumpage price as the owner of a larger forest holding. Harvesting operations usually become relatively inefficient as tract size decreases. Technical forest management skills are usually less available to small forest holding owners. Small forest holding owners also have problems with capital and labor requirements.

Streyffert (1957) studied the influence of stand size structure on forest management intensity in Sweden. He noted that small forest holdings presented problems of economic inefficiency in the use of mechanization, forest labor, silvicultural practices, and problems of long-term financing requirements for forest investments.

Solutions to the small tract size problem include annual income payments (Hosemann and Waldrop 1971), additional forest credit (Plair 1962), forest industry leasing of NIPF tracts (Sizemore 1976), forest cooperatives (Robertson 1973), and intermediate technology improvements (Gunter 1979).

An explanation for the relationship between size of forest holding and timber output is the concept of the alternative rate of return. Forest investment must compete with alternative investments for limited capital dollars. A forest landowner can be expected to compare the expected rate of return from a forestry investment with the expected rate of return from his best alternative investment. After adjusting for risk, he will invest in forestry only if its expected rate of return is greater than that earned by the best alternative investment. An individual's alternative rate of return tends to be highly subjective, but generalizations can be made.

A forest landowner's alternative rate of return is primarily determined by his level of income and asset position (McMahon 1964). Each can limit a landowner's opportunity to invest in forestry. Size of forest holding and the forest landowner's income level and asset position have been shown to be positively correlated (Duerr 1948, Stoddard 1961, McMahon 1964). Numerous studies were cited by McMahon (1964) to support the positive correlation between size of forest holding and forest management intensity practiced on a particular forest tract.

Haney (1974) found owner income to be the most significant determinant of expected forest management intensity. Size of forest holding was somewhat less significant, but was found to be highly correlated with owner income (as well as most other determinants of forest management intensity). Haney also found woodland size to positively affect site preparation decisions "in a highly significant manner."

Thompson and Jones (1981) classified NIPF land in Oklahoma by tract size based upon cost and revenue relationships. They used three distinct groupings: group 1 included very small tracts with substantial diseconomies for forest investment; group 2 included larger ownerships with some economies of tract size, but with some size related problems; and group 3 included large tracts with no diseconomies of tract size. Analysis of variance was used to identify the tract size acreage boundaries between these groups. Tracts up to 50 acres were included in group 1, tracts from 51 to 700 acres were included in group 2, and tracts with over 700 acres fell into group 3. The statistical differences between groups was significant at the 0.01 probability level. Forest management intensity and propensity to harvest timber varied significantly between groups.

Three important conclusions result from the size of forest holding discussion:

1. Size of forest holding appears to be positively correlated with the volume and value of timber on a particular holding.

2. Size of forest holding and the forest landowner's income level and asset position have been shown to be positively correlated. Thus, the landowner's alternative rate of return is expected to be inversely related to size of forest holding.

3. Forest management intensity and timber output are inversely related to the forest landowner's alternative rate of return, and thus, positively related to size of forest holding.

Economic Feasibility of NIPF Timber Production

In the early 1960's Forest Service reports began to recognize that the alleged mismanagement of the NIPF's had its basis in economics, and all Forest Service reports since have acknowledged that economic criteria are the foundation of NIPF management decisions. The economic studies of NIPF management chronologically complement both the Forest Service timber situation reports and the NIPF landowner studies since about 1950.

Duerr (1948, 1949) was one of the earliest writers to address the economic problems of the NIPF's. Duerr considered one particular hard core of resistance to improved NIPF management practices to be low income, which produced high alternative rates of return for these forest owners and discouraged forest investment.

Worrell (1956) discussed the NIPF problem on a regional basis; and, in 1958 discussed the economic rotations needed on NIPF lands. Barraclough (1957) examined the forest production process from the individual landowner's point of view. He explained that individual forest owners should not be expected to pursue public welfare goals, and discussed the process of guiding private management decisions toward public goals. Barraclough and Gould (1955) recognized that forestry investments must be evaluated by the landowner with respect to total farm investment. Yoho and James (1958) evaluated the effectiveness of public assistance programs in a study region and Webster and Stoltenberg (1959) evaluated the responsiveness of forest landowners to forestry assistance programs. Coutu (1960) evaluated NIPF forestry investments on an economic basis and discussed when forest investment was and was not practical for the NIPF owner. Yoho (1959) and Guttenberg (1959) both pointed out the need for an economic definition of the NIPF problem. These researchers, and others, contributed to the evolution during the 1950's of the concept of a NIPF economic problem. By 1960, the relationship between a NIPF landowner's asset position and his willingness to invest in forestry was well understood.

Economic appraisals of woodlot investment opportunities are common in the literature. Cope (1943) found that farm forestry is likely to be profitable if the timber products are harvested on an annual basis personally by the owner. Carter (1950), in Vermont, and Wrigley (1951), in Pennsylvania, found that the rates of return on farm woodlots were related to the amount of farm labor invested in the woodlot. Other examples of NIPF investment analyses include Gibbs (1958) in Texas, Gould (1960) on the Harvard Forest, Farrell (1964b) in Missouri, Anderson (1968b) in

Georgia, and Montgomery and Strange (1977) in Georgia. A general discussion of rates of return expected on NIPF investments can be found in Cook (1978).

Usually, an implicit objective of the farm woodlot studies was to show that forestry can "pay." That is, to show that forest investment can produce a rate of return satisfactory to the NIPF landowner. Hartung (1975) concluded that for many NIPF landowners a harvest-and-let-grow management philosophy is rational and should be expected. Gould (1975) pointed out that improvements in NIPF timber production will require correction of the many market imperfections in basic forest institutions. Gould (1978) proposed that instead of high-yield forestry, perhaps many NIPF landowner desire high-satisfaction forestry. Porterfield and Moak (1977) also stressed the multiple goals of the NIPF landowner, and showed that forestry sometimes may "pay" in non-monetary terms.

Forest marketing is another heavily researched aspect of the NIPF's. Duerr et al. (1946) is an example of an early study of this type; and Duerr (1949) offers an extensive discussion of this problem in the Appalachian region. Two studies by the Northeastern Regional Technical Committee (1956, 1960) discuss the adequacy of forest products marketing facilities and forest marketing statistics. Use of marketing assistance and information was found to be limited by both buyers and sellers of forest products. The Committee concluded: "In many cases, the only source of information on markets and prices was the buyer of forest products" (Northeastern Regional Technical Committee 1960:53). Adams (1959) noted that a forest landowner's desire for good forest management was positively correlated with a satisfactory experience in actual timber sales. Bruce (1959) suggested that NIPF landowners are willing to forego higher prices for greater satisfaction expected from quality harvesting operations. Frazier (1960) found the main reason for selling timber in Idaho was timber maturity and the need for cash. Bolle (1960) found that the main deterrent to good forest management in Montana was the instability of the timber markets. Casamajor et al. (1960) and Teequarden et al. (1960) provide good analyses of regional marketing problems in California. Larsen and Gansner (1973) used contingency analysis to explain the selling behavior of NIPF landowners. Research into timber marketing processes has continued to the present (for example, Callahan et al. 1979).

Means of motivating NIPF investment is another area of economic research. Worrell and Irland (1976) offer an excellent discussion of available policy instruments to increase NIPF timber production. Most research in this area tends to evaluate the effectiveness of public assistance programs (for example; Webster 1964, Gregersen 1977, Paxton 1977, Mills and Cain 1978).

Keniston (1962) confirmed that a favorable economic status tends to be positively correlated with intensity of forest management. He also noted that even when a stand is established naturally with no cash outlay, the owner must be considered to have an opportunity investment in the forest. Keniston found that the ratio of sawtimber area to total forest area was an indirect but efficient measure of economic well-being.

McMahon (1964) described the practice of forestry as a capitalistic enterprise of an investment character. A NIPF landowner was seen as investing in more intensive forest management only when his expected rate of return was at least equal to his alternative rate of return from nonforestry investments, after allowing for risk. A recent study by Mullaney and Robinson (1980) supports this conclusion.

Thompson (1966) analyzed NIPF "landowners' forest-investment-decision-making-behavior." He concluded that NIPF landowners with low income and poor asset positions are not likely to be interested in forestry investment. The positive relationship between size of forest holding and forest management intensity was found to be strong. Many NIPF landowners considered their forest holding as a source of emergency funds; financial need was highly correlated with timber harvests.

Morgan (1974) showed that the theory of the firm was a valid tool for predicting the behavior of private forest landowners. NIPF landowners act as if they are trying to maximize their wealth. His study suggested that differences in production plans chosen by owners of different size forest properties resulted from economies of tract size.

Two major conclusions from these studies are:

1. NIPF timber supply can be considered a consequence of forest management intensity that results from a capitalistic enterprise of an investment nature.

2. An NIPF landowner will be induced to intensify forest management only when his expected rate of return exceeds or equals the alternative rate of return of any nonforestry alternative.

Timber Supply Models

Stebbins (1975) described three general approaches for projecting long-term timber supply: mensurational, normative, and positive. The mensurational approach is used to describe a trend in the forest situation by observing changes in its physical condition over time. Usually, trends are developed from repeated regional timber inventories. This approach is most evident in the U.S. Forest Service "timber trend" type studies. Most of the Forest Service studies discussed earlier in this chapter fall into this category. Typically, these studies identify significant trends in land use, land ownership patterns, forest type, and timber production (Knight and McClure 1978). Examples of this approach include Knight and McClure (1974), Cost (1976), and Sheffield (1978).

The normative approach, like the mensurational approach, examines the physical condition of the forest resource, but goes one step further and examines its financial potential. Usually, a normative study is based upon the theory of the firm; that is, forest landowners are assumed to act as if they are trying to maximize their wealth. Once the economic factors that control a forest landowner's decision on forest management intensity are identified, these factors are incorporated into the long-run timber supply model. Thus, projected long-run timber output will be a function of both the physical characteristics of the forest and financial criteria. Examples of this approach include the Division of Forest Economics Research (1963), Miville-Deschênes (1975) and Gedney et al. (1975).

The positive approach recognizes all the foregoing estimates, but also examines the management behavior of the forest landowner. A positive study responds to the question, "What will the timber supply be in the long-run?"; in contrast to the normative study which address the question of what the timber supply should be if all owners behaved rationally. While normative analyses are relatively common, few empirical positive studies of forest behavior exist (Duerr 1974). The positive approach is based upon the observed behavior of forest landowners and projects expected timber output without the constraint that this output be economically optimal.

Timber supply models are still in an evolutionary stage of development. From the early "timber requirements" analyses, to the current Timber Assessment Market Model (TAMM), timber supply analyses have been criticized as lacking a sufficient economic base. Particularly, timber supply models have tended to have difficulty in explaining NIPF landowner behavior.

Vaux and Zivnuska (1952:323) pointed out that the mensurational approach used in the U.S. Forest Service timber requirement models failed to "recognize that both demand for and supply of timber products are continuous functions running through an infinite time continuum." They showed that a complete timber supply model must include estimation of both demand and supply curves; and, that equilibrium price and quantity will occur at the intersection of these curves.

Gregory (1955) identified two major shortcomings in Forest Service methodology for setting production goals: Forest Service analyses ignored costs of production (supply factors) and did not consider the temporal nature of stumpage production. Worrell (1966) proposed that timber supply and demand relationships be estimated on a regional basis and that the dynamics of interregional forest products trade be identified.

Economic timber supply projection models have been developed. Marty (1969) outlined a timber supply projection model that would classify forests by physical productivity and economic characteristics, based upon ownership characteristics. Timber supply could then be projected using stand table projection methods. The economic classification would be based upon an assumption "that at least certain owner groups respond to changes in input costs and product prices, and that this response can be related, at least approximately, to the resulting changes in investment cost and profitability" (Marty 1969:90). Marty (1969:89) described the product of this model as:

> The resulting cross classification of timberlands, made on the basis both of physical productivity and economic characteristics, would provide relatively homogeneous resource cells or timber production sources containing timberland acres having similar physical production functions and operated under similar economic conditions and restraints, which might be expected actually to absorb similar inputs and produce similar outputs.

Vaux (1971, 1973) described a similar cross classification approach for determining the amount of land needed to produce the long-run timber supply in California. Vaux's model, described in detail later in this chapter, classified California's forest land by forest productivity and average long-run timber production classes. The resulting cells were summed to produce a long-run timber supply function for California.

Duerr (1960) developed a timber supply model that is also discussed in detail later in this chapter. Duerr's basic model has formed the basis of several recent timber supply projection studies (Division of Forest Economics Research 1963, Miville-Deschênes 1975, and Hassler 1978).

Canham (1971, 1973) presented a theoretical timber supply model based upon Duerr's alternative rate of return concept and the theory of expectations. The alternative rate of return concept explained some practices and attitudes in the New York study region, but the theory of expectations was needed to explain behavioral differences among the various forest landowners. The combination of the two concepts produced a four-way classification scheme based on purpose of ownership, allowing for the projection of forest landowners' management decisions.

Stand table projection techniques are often used to project timber supply. An example is TRAS (Timber Resource Analysis System), the current Forest Service timber volume projection model (Larsen and Goforth 1970, 1974). Leuschner (1972a, 1972b) combined an economic model of timber demand and supply with stand table projection techniques to project aspen timber supply in the Lake States. Gedney et al. (1975) produced timber supply projections for the Pacific Coast States using TRAS and Holley et al. (1975) used TRAS in the Interregional Timber Model (ITM). The Timber Assessment Market model (TAMM) developed by Adams and Haynes (1980) uses TRAS as its private stumpage supply inventory projection submodel.

Timber harvest scheduling techniques, for example, timber RAM (Navon 1971), Maxmillion (Ware and Clutter 1971) and TREES (Tedder et al. 1980), commonly use linear programming techniques to optimize some harvest objective subject to a set of constraints. They tend to be long-range models, capable of analyzing multiple rotations, and usually have timber volume projection capability. Beuter et al. (1976) used TREES to project timber output in Oregon. TREES allowed the forest resource to be stratified by differing physical characteristics and management intensities, and used economic criteria to schedule harvests.

Several recent timber supply models investigated the theoretical foundation of NIPF landowner behavior (Binkley 1979, Berck 1979, Hyde 1979). Empirical results usually verified behavioral relationships implied by the model, rather than provide actual timber supply estimates.

Binkley (1979, 1981) developed a microeconomic model which incorporated both timber and nontimber objectives. The forest landowner was assumed to derive utility from the consumption of nontimber outputs such as recreation and timber income for the consumption of all other goods. Maximization of utility was the basis of timber harvest decisions, subject to two constraints. First, the landowner's total outlay could not exceed timber receipts and exogenous income minus land holding cost. Second, timber and nontimber outputs were limited to technically feasible combinations by a multiple use constraint.

Binkley concluded that price is a major short-run determinant of timber harvest, and that size of forest holding and economic well-being of the landowner affected the propensity to harvest timber.

Berck (1979) tested the hypothesis that private forest landowners cut their timber more quickly than was economically optimal. Berck's model used a 150-year time horizon and for each of seven quarter-centuries private entrepreneurs were assumed to use nominal price expectations (P) and a nominal discount rate of (r). The nominal discount rate was the sum of an expected rate of inflation and a real rate of interest, adjusted for risk, and is called the "nominal rate of time preference of the entrepreneur." Forest landowners were assumed to maximize the present value of profits.

The present value function was dependent upon the nominal discount rate, r, which reflected the time preference of the forest landowner. Given the past actions of the forest landowners, the model can be used to determine the implied real interest rate used by the owners to discount the future forest revenues. The model, applied to the Douglas-fir region, showed that NIPF landowners holding rational expectations have been historically discounting the future at a real interest rate of 5 percent. This implied that these landowners have been cutting their timber prematurely, if their objective was to maximize the relevant profit function. Berck's model, while not operational, is the only study that has developed "empirically testable models of long-run supply behavior" (Adams and Haynes 1980).

Hyde (1979, 1980) reviewed timber production in the Douglas-fir region using a static profit maximization model based upon the competitive theory of the firm. This application of the competitive model compared, in net present value terms, an array of costs (including land cost) and revenues. Economic rent, or return to land ownership, is the revenue remaining after payments to labor, capital, and managerial expenses. Landowners are assumed to be efficient; that is, timber will be produced from the combination and timing of inputs that will maximize rent. Where rent from timber production is positive, forest land will be profitably used in timber production.

Timber production was expected to vary by level of management (silvicultural) intensity and over time. Higher expected prices attract higher management intensity which results in increased timber harvests. Timber production was also expected to increase over time, independently of management intensity. For a given forested acre and stumpage price, there will be only one optimal level of management intensity and only one optimal rotation. Thus, there will be only one optimal harvest volume that will maximize economic rent. Hyde found the loci of prices and associated optimal annual volumes and derived a single-acre supply schedule. The aggregate supply schedule was these optimal annual harvests.

The model assumed that the landowner always intends to maximize economic rent; that is, economic efficiency was the guiding criterion. Changing stumpage prices, varying forest productivity, and accessibility were used to determine timber supply and optimal land allocation. "In general, price increases (more precisely, increases in the ratio of stumpage price to the cost of a unit silvicultural effort) justify increasingly intensive silviculture as well as expansion of production to previously inefficient timberland, and result in expanded annual harvests" (Hyde 1979).

Three general types of long-term timber supply models have been discussed. Most common are the mensurationally based models. These models are usually based upon inventory changes over time projected on the basis of past silvicultural trends. Also common are the theoretical models based on the traditional relationships of mainstream economics. For examples, Binkley's (1979, 1981) model is based on utility theory, Hyde's (1979, 1980) model is based on the competitive theory of the firm, and Canham's (1971, 1973) model is based on the theory of expectations. The theoretical models are usually not operational for use in estimating timber supply, but instead provide a basis to test if certain economic relationships may apply to the NIPF sector. Least common are operational timber supply projection approaches that are based in economic theory. Probably, the two most important models in this category are the models of Duerr and Vaux.

A main reason that NIPF timber supply models have tended to remain theoretical is that data for this sector are difficult to obtain (Mills 1976). Often when data are collected for the NIPF sector, they are collected from the NIPF landowners or on the physical forest resource, and little effort is made to tie the two directly together. The great number and variety of NIPF landowners make data collection for this sector more difficult and necessarily expensive. Such factors lead to the lack of positive operational long-run timber supply models for the NIPF sector.

Duerr's Timber Supply Model

Duerr (1960) described a model that related long-run timber supply on a particular forest to the landowner's alternative rate of return. Duerr's model differs from the traditional supply models in holding that the crucial independent variable influencing long-run timber supply is the interest rate, not price. Once the original forest management intensity decision is made and a forest stand is established, the main cost of growing timber becomes the opportunity cost of holding the timber capital. Over time, as the timber matures and the growth rate slows, the rate of return on the timber investment decreases. When the rate of return from the timber investment equals the landowner's alternative rate of return, the landowner can be expected to harvest his timber crop.

Duerr's timber supply model is based on the assumption of a regulated, sustained yield forest under even-aged management. Such a "normally-regulated" forest is expected to produce equal, periodic timber outputs in perpetuity (Miville-Deschênes 1975). Once normality is assumed, normal yield tables can be used to represent "points on the forest's developmental trend" (Duerr 1960). These provide a basis for calculating current growth for each decade and mean annual growth. Current growth can then be expressed as an annual percentage of growing stock and applied to an alternative rate of return analysis. Thus, normality is a key assumption of Duerr's model.

Long-run timber production depends mainly on the quantity and quality of land employed in timber production and the management intensity applied to the forest capital. Forest capital is usually termed growing stock: the volume of trees growing wood in a forest. Management intensity, or investment in growing stock, includes site preparation; tree planting; improved tree planting stock; intermediate thinnings; protection from fire, insects, and disease; fertilization; and the opportunity cost of holding timber over time.

Forest capital--the holding of growing stock--dominates the costs of growing timber (Duerr 1960). Since the tree doubles as both forest capital and the inventory of forest products, the cost of holding forest capital is the opportunity cost of withholding the inventory from sale. This cost is measured by the alternative rate of return. Investment in forest capital is only rational when its expected rate of return exceeds the rate of return available from alternative investment opportunities. Thus, the alternative rate of return will control investment in forest capital and is related to timber output. The landowner will adjust his alternative rate of return to account for differences in taxes and risks between investments. The alternative rate of return forms the backbone of Duerr's timber supply model.

Management intensity decisions are based on forest management costs and revenues. Costs and revenues will mainly affect decisions on the holding of timber capital and investments in silvicultural practices to increase timber production. Duerr's model assumes that the forest landowner desires to maximize net revenue. In order to maximize net revenue, the landowner will harvest his timber when its value growth rate is less than the rate of return available on alternative investments. Investments in silvicultural and protection practices will be based on expected future timber prices. Investment in these practices will require expected discounted revenues resulting from the practices to be greater than the current costs.

Figure 1 shows an example of the concept outlined above. As rotation age increases, the growth rate decreases and, thus, the marginal value growth percent of the forest or its expected rate of return from the forest investment decreases. The alternative rate of return is independent of the investment decision and is fixed at 3 percent in the example. Determination of rotation age and, thereby the

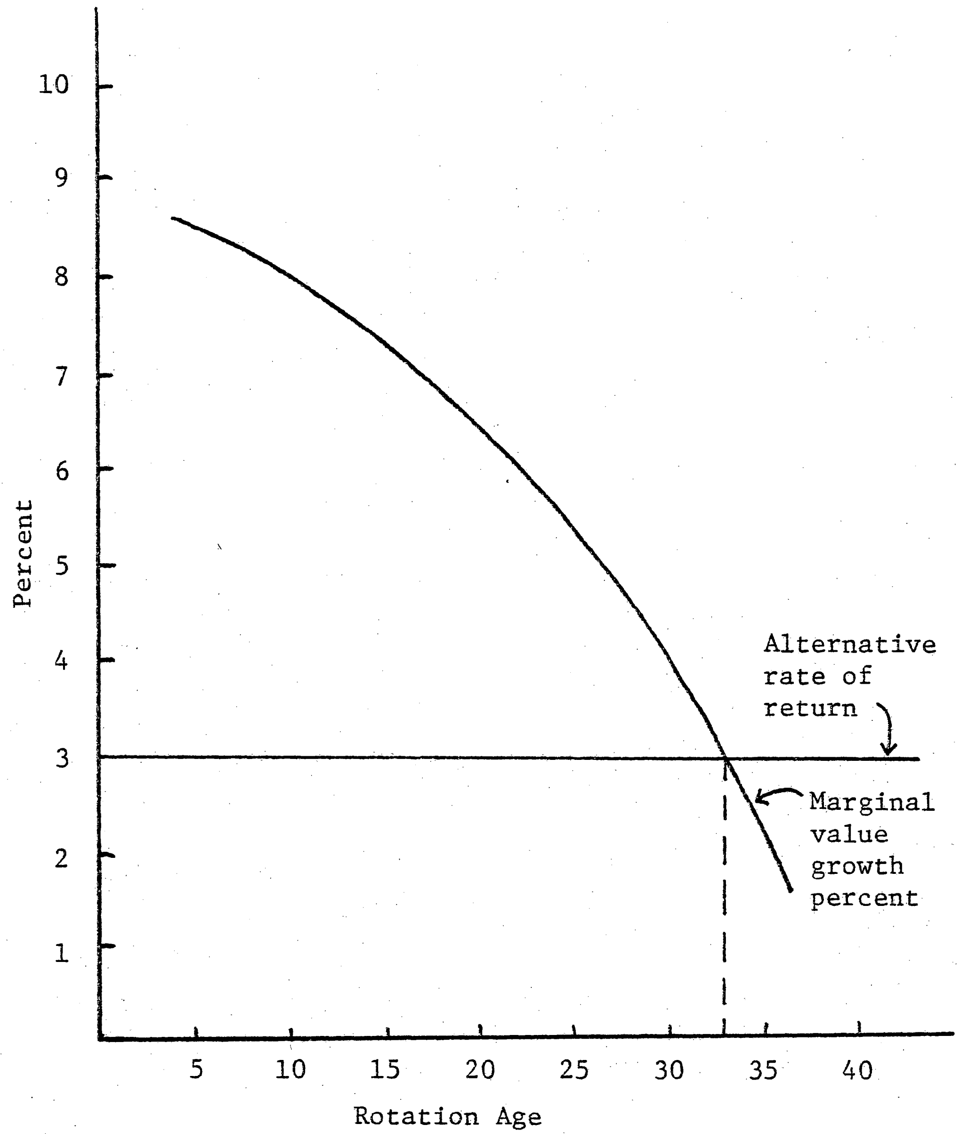


Figure 1. Determination of optimal rotation age, based upon marginal value growth percent and the alternative rate of return.

level of timber output, is based on equating the marginal value growth percent with the alternative rate of return. The optimal rotation length in the example is 33 years. In even-aged, sustained yield management, the determination of rotation simultaneously determines the level of output, or long-run supply.

The higher a forest landowner's alternative rate of return, the shorter the rotation age (see Figure 1). The point at which the marginal value growth percent falls below the alternative rate of return is called the "financial maturity" of the forest (Chappelle 1966). This can be expressed as:

$$MVG = \frac{MVY}{MVGS} * 100 \qquad (II.1)$$

where:

MVG = rate of return on the marginal growing stock, expressed as a percentage,

MVY = value of the extra yield for the lengthened rotation under consideration, in dollars,

MVGS = value of the extra growing stock needed to produce this extra yield, in dollars.

Financial maturity will occur when:

$$MVG < ARR \qquad (II.2)$$

where:

ARR = alternative rate of return.

The optimum timber output is not affected by the past costs incurred in growing the stand or by current prices. Past costs are sunk costs and irrelevant. Fixed costs that do not vary with production level are equally irrelevant. Current prices will affect product prices (i.e., sales value) and the value of the growing stock (i.e., inventory) in the same proportion, leaving the rate of return on the marginal growing stock unchanged. Due to the dual nature of timber, that of both product and timber producing machine, price changes are exactly offset on the cost and revenue sides, leaving the interest rate as the decisive element in long-run timber output decisions.

However, anticipated changes in prices of timber products relative to production costs will affect the management intensity practiced on a particular forest. The higher the expected timber prices are relative to current costs, the more intensive will be timber management.

The essence of Duerr's timber supply model is that the optimum amount of growing stock held by a forest landowner is predominately controlled by the relation between rate of return expected on the marginal growing stock and the owner's alternative rate of return. Current prices will not affect long-run timber output, but expected changes in the relation between prices and silvicultural costs can induce a change in the level of investment in timber management.

Vaux's Timber Supply Model

Vaux (1971, 1973) described a model for determining the amount of land needed to produce the long-run timber supply in California that would support wood products price stability. Vaux's approach involved stratification of the forest resource by forest type and site productivity. For each type/site stratum, acreage, average annual yield per acre, and long-run average cost of timber production were calculated. These costs were then used to construct a long-run timber supply schedule by assuming that strata with lower costs of production will be used for timber production before those with higher costs of production.

That is, the model assumes that the long-run supply of any commodity "is a direct function of the long-run average costs of its production" (Vaux 1973). The supply schedule consisted of a summation by least-cost type/site strata of annual yields; cummulative yield increased with increasing average costs. The schedule showed the aggregate amount of timber that could be grown at or below various alternative limits of maximum average cost per unit of output. The price elasticity of long-run demand and the interest rate were assumptions used to develop an exogenous demand function. This model answered the policy question: "How much land do we need for timber growing?"

GASPLY, an operational version of this model, has been developed for the state of Georgia (Montgomery et al. 1975, 1976; Robinson et al. 1978). The supply equation was obtained as in Vaux's model and the demand equation was based upon regression analysis.

III. A LONG-RUN TIMBER OUTPUT PROJECTION MODEL

The positive approach to predicting timber output within a region consists of a set of predictive relationships derived from the observed past behavior of forest landowners, and upon the assumption that these relationships will continue into the future. The approach requires identification of the variables that influence timber output; statistical estimation of the empirical relationships between these variables and timber output, based upon observed past behavior; projection of expected changes in the key exogenous variables affecting timber output over the projection period; and substituting the projected values of the exogenous variables into the behavioral relationships to obtain estimates of timber output over time.

The positive timber output projection model developed in this chapter is based upon a Vauxian approach combined with Duerr's financial maturity model. The approach involves the following steps: (1) development of biological growth and yield data for the study region, (2) identification of the key economic relationships affecting long-run timber output in the study region, (3) identification of homogeneous timber output response cells based upon stratification of the region's forests using both biological potential and economic characteristics identified in steps 1 and 2 above, (4) estimation of expected changes in commercial forest acreage (land use changes) for each homogeneous timber output response cell over the projection period, (5) estimation of expected timber output levels based upon behavioral relationships using the values of each cell as an observation for regression analysis, and (6) projection of timber output (using the regression equations from step 5 and a stand table projection system) over the relevant planning horizon.

Timber Supply

The supply of a commodity is the quantity supplied in relation to some independent variable or variables. When discussing timber supply, the supply condition must be specified: stock (market) supply, short-run supply, or long-run supply. Also, a distinction must be made between biological potential, physical, and economic supply.

The stock supply response in forestry is complicated by the fact that the timber growing stock is, at the same time, both the "factory" growing wood and the product being produced. Stock supply is a timber flow from an existing growing stock. It is the immediate available supply from the existing inventory of growing stock; that is, all agents of production other than growing stock are considered fixed. A positive stock supply response implies a reduction in the timber production base (growing stock). A stock supply response might occur, for example, when ownership of a forest tract changes. If the previous and new owners have different alternative rates of return, the optimum stocking level would change, resulting in a positive or negative timber supply response, depending upon the relation between the new owner's alternative rate of return and the forest's marginal value growth percent.

Short-run supply is based upon the amount of timber production that flows into stock, with most agents of production, except the level of growing stock, variable. It is short-run because there are limited opportunities to vary the level of growing stock (i.e., the size of the plant). Basically, in the short-run, timber flow can be affected by varying silvicultural inputs, thereby changing forest productivity. Examples include fire control, fertilization, and drainage.

The long-run supply condition involves allowing all agents of production to vary, including the level of growing stock and forest acreage. Since the amount of timberland is allowed to vary, long-run timber supply is affected by forest land-use change. Long-run timber supply decisions center on a landowner's decision to invest or disinvest in forestry.

Timber supply is distinguished from other more conventional supply analyses by the inescapable linkage between stock supply and the long-run supply response. A stock supply response automatically triggers a long-run supply response in the opposite direction. For example, a positive stock supply response (i.e., a reduction in timber inventory) implies a negative long-run supply response (i.e., a reduction in the level of growing stock and, hence, the long-run timber output potential). Thus, changes in long-run timber supply are accomplished primarily by (1) changes in the level of growing stock (size of plant) and (2) changes in the amount of land devoted to forestry (entry or exit into forestry investment).

Long-run timber supply is strongly influenced by the biological potential of the forest. From any particular forest area, there is a maximum biological level of timber output that can be harvested from the land. Of course, this level of output is a function of productive inputs besides land, but a biological maximum will exist. Potential biological timber supply serves as an upper limit on timber production and will seldom, if ever, be obtained within a region. The biological potential corresponds loosely to the concept of plant capacity in conventional supply analysis.

A subset of biological potential timber output is the physical timber supply, or the total inventory of commercial timber in the forest. The physical timber supply will rarely, if ever, be available for harvest within a region at any specific point in time. The harvest of the forest inventory--the stock supply--will be determined primarily by a combination of the owner's alternative rate of return, the value growth of the inventory, and expectations about future timber prices.

Economic timber supply is the quantity of timber that will be supplied under a given set of economic conditions. The physical timber inventory includes much timber that is inoperable or inaccessible, due to high harvesting costs, low stumpage prices, or landowner objections to timber harvesting. Economic timber supply is the timber available under existing market conditions and is the relevant supply concept.

Development of Growth and Yield Data

Biological potential data are a basic requirement for any timber output study. Usually, such data are available to the analyst from other sources, but may require some transformation to make them suitable for use in timber supply analyses.

In order to analyze the physical response of the forest resource to different levels of forest management intensity, the relationships between the various inputs and the expected physical timber output of the forest must be specified. In a sense, we are talking about the estimation of a timber production function. In the case of timber production, there are two main inputs: initial silvicultural treatment and time. After stand establishment, the main input will be time, or the opportunity cost of holding growing stock from the market. Growth and yield data will provide this vital information. Yield tables give the incremental timber output (growth) for an additional year in growing time (i.e., rotation length).

The economic efficiency of forest management alternatives can be measured as the percentage rate of return earned by a particular forest investment. Since the major investment in growing timber involves the opportunity cost of holding growing stock, it is convenient if both stock and output from growing stock are measured in similar units. Also, these units should be the same units that are valued in the market. If the growth and yield tables are to be used in conjunction with Forest Survey data, they must be compatible with Forest Survey data. This means that measurement classes, such as site quality and stocking, must be based on Forest Survey definitions.

Economic Relationships Affecting Timber Output

Just as the relationship between timber output and the physical characteristics of the forest resource must be specified, so must the relationship between timber output and the economic characteristics of the forest resource and its owners. Long-run timber output is directly related to the landowner's investment in the forest resource. Decisions involving management intensity are economic decisions. Forest landowners consider investment in management intensity as one of many potential uses for their capital. The level of management intensity will vary by type of forest ownership because of differences in landowner characteristics and objectives.

The timber output projection model developed in this study considered only the nonindustrial private forest (NIPF) sector. Two economic relationships are critical to such a model; one dealing with the relationship between the size of forest holding and the landowner's income and asset positions, and the second concerning the relationship between the alternative rate of return and the level of management intensity. These two basic relationships are, in turn, linked together as follows. As discussed in Chapter II, the NIPF landowners' income and asset position are known to be positively related to size of forest holding, and inversely related to his alternative rate of return. Management intensity is negatively correlated with a landowner's alternative rate of return. Thus, as the size of forest holding increases, the income and asset positions of the owner improve, resulting in a decreasing alternative rate of return. Lower alternative rates of return encourage increased management intensity (including the holding of higher levels of growing stock). The level of management intensity--or the holding of growing stock--determines the long-run timber output potential of the forest.

Explanations in the literature for the observed relationship between size of forest holding and forest management intensity center on silvicultural costs and utility theory. Both are discussed below.

Economies of Tract Size

The relationship between the cost of silvicultural treatment and tract size is one of the most important factors affecting management intensity (Row 1977, 1978). Site preparation and regeneration are usually the major costs involved in forest investment. These costs are crucial determinants of the economic return from forest investment because they occur at the beginning of the investment's life and must be carried until the harvest period, several decades into the future.

Each silvicultural operation incurs high fixed costs (administration, equipment transportation costs, and set-up costs). Variable costs (fuel, equipment operator's labor, maintenance, etc.) vary with tract size. Thus, on a per acre basis, variable costs will be constant. However, on a per acre basis, the fixed silvicultural treatment cost attributable to each timber sale area decreases with increasing tract size. Hence, on a per acre basis, the average cost of silvicultural treatment will decrease with increasing tract size (Row 1977).

Timber revenue per acre is also related to tract size. Total revenue from a timber sale is dependent upon stumpage price, timber volume per acre, and sale acreage. Row (1978) showed that as the timber sale size increases, the stumpage price received tends to increase. Stumpage price will reflect the impact of a fixed transaction cost (e.g., administration and timber volume estimation costs). The significance of this fixed cost tends to decline as the size of the timber sale increases, leading to higher stumpage prices being offered for larger sales.

Owners of small tracts also gain less income per acre than owners of larger tracts from the time and effort they expend on the administration of their forest property. This includes time spent with public foresters, forestry consultants, loggers, private contractors, and forestry education programs. Small tract size increases delivery costs for state or forest industry landowner assistance programs, making the attractiveness of introducing such programs to an area less as the number of small tracts increases.

Row used simulation methods to define the relationship between tract size, site productivity, and financial return (annual payment equivalent). Financial return was shown to have a significant positive relationship with tract size. This result supports the basic premise that forest management intensity is positively correlated with size of forest holding. Higher expected returns, as tract size increases, will encourage greater forest investment and more intense forest management.

Diminishing Marginal Utility

The concept of diminishing marginal utility allows for another explanation of the relationship between size of forest holding and timber output. Owners of small forest holdings tend to be farmers or individuals who hold their forest land for recreation, aesthetic, or other reasons, as well as for timber production. Most of these nontimber benefits can be satisfied from rather small forest acreages. As the size of forest holding increases, the marginal utility derived from the additional nonmarket outputs generated by the larger forest are likely to be negligible. Thus, for larger forest holdings, total nontimber benefits are likely to remain essentially unchanged following a harvest of only part of the total forest. The reduction in total utility from the nontimber outputs of the forest would be minimal. Owners of large forest holdings have the option of harvesting a portion of their entire holdings and retaining the remainder for nontimber uses. Owners of small forest holdings often do not have this option.

A slightly different case could also be made, once again using utility theory. A NIPF landowner may be able to satisfy his nontimber benefit objectives on a small acreage (the marginal utility of nontimber benefits may decline rapidly as acreage increases). In contrast, timber benefits tend to enjoy economies of scale up to significant tract sizes. A NIPF landowner whose primary ownership objective is the nontimber benefits will achieve an optimum size of "plant" (forest) at a much lower acreage than owners whose primary ownership objective is timber production. Thus, one would expect forest landowners with nontimber ownership objectives to be associated with small forest holdings and forest landowners with timber production objectives to be associated with large forest holdings.

Identification of Homogeneous Timber Output Response Cells

Stratification of the study region's commercial forest land by the variables that influence long-run timber output form the basis of the timber output model. Stratification dimensions must include both the physical (related to the forest) and economic (related to the landowners) characteristics of the forest resource. Each stratum will include commercial forest acreage with uniform biological potential and uniform economic characteristics and, thus, each stratum will represent NIPF landowners with similar alternative rates of return and functional relationships between the rate of return and timber output. The stratification will produce a "matrix" with each cell possessing an unique relationship between the timber output response of that cell and changes in the variables that influence timber output.

Physical Stratification

The physical characteristics of the forest are most readily obtained, as they are usually of the kind gathered by Forest Survey crews. These physical characteristics can be divided into site conditions and resource conditions (Mills 1976). Site conditions relate to the physical site upon which the forest grows. Resource conditions relate to the physical condition of the forest resource itself.

Site conditions have a major impact in that they determine forest productivity and the economic potential of the site. Measures of site condition include site index (site quality), physiographic classes (based upon topography and soil-water relationships), size of forest holding, and soil type. Site conditions reflect the environment that the trees will grow in and, as such, will determine the trees' growth potential. Site conditions can also affect the economic potential of the forest. Harvesting costs can be affected by slope, aspect, water relations, and accessibility. For example, harvesting costs are usually greater in a swamp than on a sand hill. Accessibility problems can also add costs to timber management operations such as site preparation, timber cruising, or hazard reduction burning. Size of forest holding will affect the economies of scale for harvesting operations and can be expected to affect the economic potential of a site.

Resource condition describes the physical condition of the forest resource itself. Forest type, timber quality, timber volume, stand age, operability (condition of the timber as it relates to harvesting operations), and stocking are measures of resource condition. Forest type, because of its obvious impact on yield and product values, is a key stratification variable. Resource condition also affects the economic potential of the site. The quality and amount of timber must be sufficient before a harvesting operation will be considered for a particular stand.

The physical and economic relationships developed within each homogeneous timber output response cell cannot be expected to hold over large geographic areas. Thus, geographic area will become another stratification dimension as size of the study region increases.

Economic Stratification

Although size of forest holding is a physical characteristic, stratification by size of forest holding constitutes an economic stratification. Larger forest holdings are expected to contain larger volumes and a greater value of timber than smaller forest holdings. Larger forest holdings also tend to belong to landowners with higher incomes and better asset positions.

Other economic variables must be considered as stratification dimensions as the economic environment of any forest resource is certain to affect timber output. For example, the forest resource on a specific site is related to the forest resources on adjacent areas. The structure of the entire forest region can affect the marketability of forest resources on a specific tract. Within a region, demand for wood might come from several major pulp and paper mills and many smaller lumber or plywood mills. Distance from a mill and logging conditions on a tract, when coupled with forest resource availability on neighboring areas, will be a major determinant of the economic value of a particular forest resource.

Ownership is another necessary stratification dimension. Different classes of owners have different ownership objectives. Major ownership classes are public forest industry, and NIPF ownership. This study addressed only the NIPF sector. However, further stratification was possible even within the NIPF sector. For example, Binkley (1979) found major differences in management objectives within the NIPF sector between farm owners and miscellaneous private owners.

A Homogeneous Timber Output Response Matrix

Each stratification variable will add another dimension to the homogeneous timber output response "matrix." That is, the total forest resource will be subdivided by each stratification variable, creating a matrix with smaller and smaller "cells" as dimensions are added. An objective is to determine key response variables in such a way as to keep the matrix at a manageable size.

Figure 2 illustrates a homogeneous timber output response matrix. Forest type, size of forest holding, and site quality are the three stratification dimensions. Forest type is stratified by pine, pine-oak, and hardwood; size of forest holding is stratified by small, medium, and large; and site quality is stratified by low, medium, and high. The resulting three-dimensional matrix has 27 cells (3 x 3 x 3).

The matrix represents the total forest resource as divided along strata lines; with each acre of forest land allocated to its corresponding cell. Timber output response then can be projected on the basis of timber output response functions estimated via regression analysis using average cell values as independent variables.

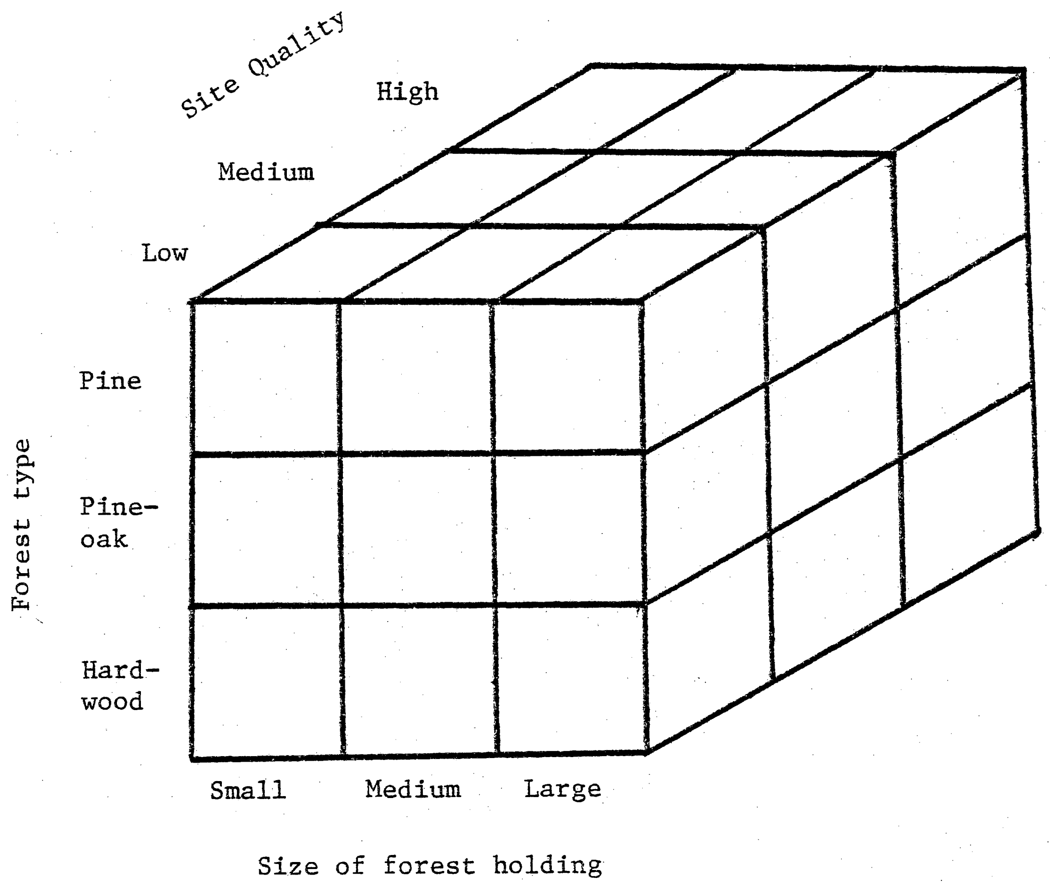


Figure 2. Example of a three-dimensional homogeneous timber output response matrix.

Policy Analysis

Each homogeneous timber output response cell represents forest acreage that is physically uniform, resulting in an identical marginal value growth percent for each acre within a cell. This means that the relationship between the marginal value growth percent and rotation length (and the corresponding long-run timber output level) is fixed within each cell.

Since the acreage within a cell is economically uniform, the alternative rate of return is also fixed within each cell. Equation II.2 shows that a landowner will harvest a forest stand when its marginal value growth percent equals his alternative rate of return. Thus, a functional relationship can be established between the alternative rate of return and long-run timber output.

The relationship between the alternative rate of return and timber output is shown in Figure 3. The inverse function represents timber output at any expected rate of return (hence, based on the marginal value growth percent of the forest). Since the level of timber output is determined by the equating of the expected and alternative rates of return, this function represents long-run timber output at specific alternative rates of return.

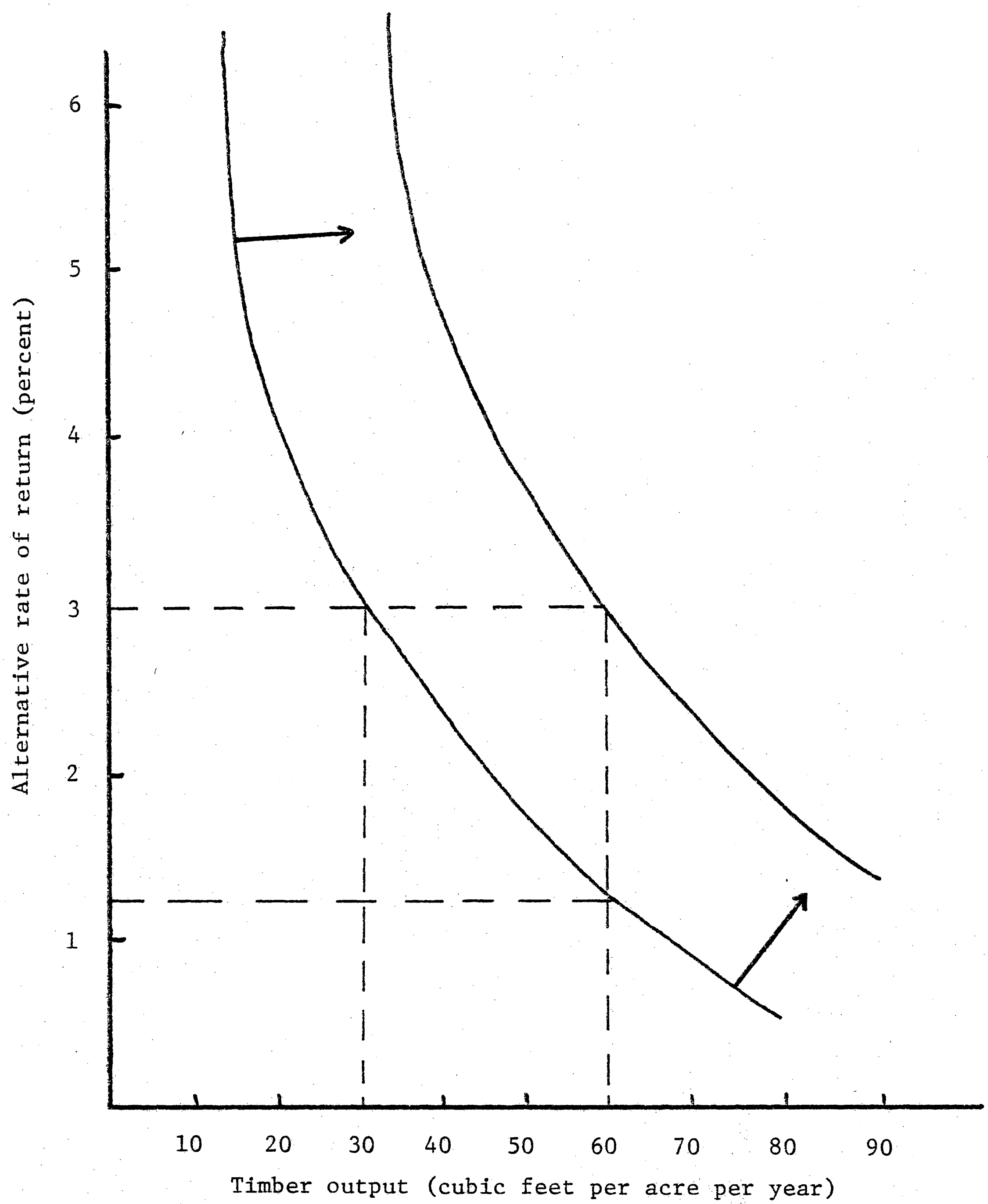


Figure 3. Hypothetical relationship between alternative rate of return and timber output.

Using the model in Figure 3, changes in timber output can come from two sources. First, a shift in the functional relationship between the alternative rate of return and timber output can cause timber output to change. The relationship between rate of return from a forestry investment and timber output is based upon the physical growth characteristics of the forest resource and the costs and revenues associated with the forest investment. Changes in costs or revenues will cause this relationship to shift (for example, costs and revenues can be affected by public subsidy or improved technology for harvesting timber from small forest holdings). Shifts in this functional relationship will allow for policy analysis of government efforts to change these cost and revenue relationships in order to affect timber output.

A second source of change in expected timber output is a change in the landowner's alternative rate of return. Changes in the landowner's alternative rate of return will result mainly from changes in land tenure represented by the consolidation of forest holdings into larger holdings (i.e., the purchase of additional small tracts by a landowner with a low alternative rate of return); this will cause the acreage to move into a matrix cell representing a lower alternative rate of return class.

In Figure 3, The inverse function in the graph is the timber output which would equate the landowner's alternative rate of return with the marginal value growth percent of the forest. Suppose a forest owner's alternative rate of return is 3 percent. In order to maximize profits, he would choose a level of output where the marginal value growth percent of the forest equals his alternative rate of return. According to Figure 3, he would choose an anual output of 30 cubic feet per acre. To increase the annual timber output to, say, 60 cubic feet per acre requires either the lowering the forest landowner's alternative rate of return to 1.25 percent by some external means (e.g., by consolidation of forest holdings) or by shifting the functional relationship between rate of return and timber output outward (e.g., by public subsidy).

The relationship illustrated in Figure 3 is unique to the acreage assigned to each homogeneous timber output response cell, due to stratification by the forest's physical characteristics. This creates a useful forest policy analysis tool. The policy analyst will possess a known timber output response for the forest acreage assigned to each cell, allowing for a two-part analysis.

First, changes in the alternative rate of return over time can be related to expected changes in timber output.

The analyst will have negligible (if any) control over this projected change in timber output. However, he would monitor the projected change in timber output due to changes in the different cell's alternative rates of return as a component of an overall analysis.

Second, the analyst would project shifts in the inverse functional relationship between the rate of return and timber output (changes in the marginal value growth percent of the forest). Such shifts will result mainly from changes in silvicultural costs (e.g., by public subsidy or technology changes) or changes in expected harvest value (e.g., by changes in price expectations or changes in tax laws). Public forest policy can cause changes in these factors and the policy analyst will concentrate his efforts to effect timber output changes in this area.

Expected Changes in the Commercial Forest Acreage

Timber output is intricately related to the amount and kind of forest acreage that supports timber production. The amount of forest acreage may change from one period to the next due to forest acreage taken out of timber production to supply land for agricultural purposes, urban development, or transportation systems; or, conversely, acreage added to forest acreage (e.g., by agricultural land abandonment).

Land use changes may be treated as an exogenous input into a timber output model if reasonable estimates are available from outside sources. Estimates of land use changes are often available from government sources. Such projections are usually based on trends in population, agricultural development, urbanization, and ownership class distributions.

While basic land use change projections may be available, any timber output study dealing with the NIPF sector will likely require additional data on shifts in the distribution of commercial forest acreage by size of forest holding. Size of forest holding has only recently become a statistic collected by Forest Survey crews, and size of forest holding trend information is currently available for limited Forest Survey units. However, census of Agriculture data are available on a county-by-county basis to show trends in woodland acreage (U.S. Department of Commerce 1980). Trends developed from Census of Agriculture data can be applied to Forest Service data to derive changes in the distribution of commercial forest acreage by size of forest holding over time.

Homogeneous Timber Output Cell Response Relationships

Timber removals was the measure of timber output used in this study. Timber removals is defined in the Forest Survey as "the net volume of growing-stock trees removed from the inventory by harvesting; cultural operations, such as stand improvement; land clearing, or changes in land use" (Sheffield 1978). These timber removals include "(a) harvests of roundwood products such as saw logs, veneer logs, and pulpwood; (b) logging residues; and (c) other removals from changes in land use" (U.S. Forest Service 1974). Net annual growth was also available from the Forest Survey and is defined as "the increase in volume for a specific year" (Sheffield 1978). Net annual growth includes a reduction in volume due to mortality. These two components define the annual change in inventory; that is, net annual growth minus timber removals equals the annual change in inventory.

Regression analysis is used in this model to estimate timber removals, timber demand, the alternative rate of return, and net annual growth. Each cell will have a value for every dimension of the matrix (e.g., owner = NIPF, forest type = planted pine, site index = 90, etc.). These cell values will be the independent variable observations used in the regression analysis. The values for each of the dependent variables (timber removals, timber demand, the alternative rate of return, and net annual growth) must also be estimated for each cell. The sets of independent and dependent variables will form the basis of regression analysis.

For the NIPF sector, the alternative rate of return is known to be inversely related to both the size of forest holding and timber removals per acre. Stratification by size of forest holding constitutes stratification by the alternative rate of return, and thus, by expected timber removals per acre. This is illustrated in Figure 4. The functional flow is from the size of forest holding to the alternative rate of return, to expected rate of return, to long-run timber output. In the upper graph, NIPF landowners with a 200 acre size of forest holding behave as if their alternative rate of return is 2.25 percent. The result, in the bottom graph, is expected timber removals of 60 cubic feet per acre per year. The relationship between graphs assumes a NIPF landowner will invest in timber production to the point where the expected rate of return from the investment equals his alternative rate of return.

Changes in either functional relationship will result in changes in expected timber output: a change in the size of forest holding/alternative rate of return relationship

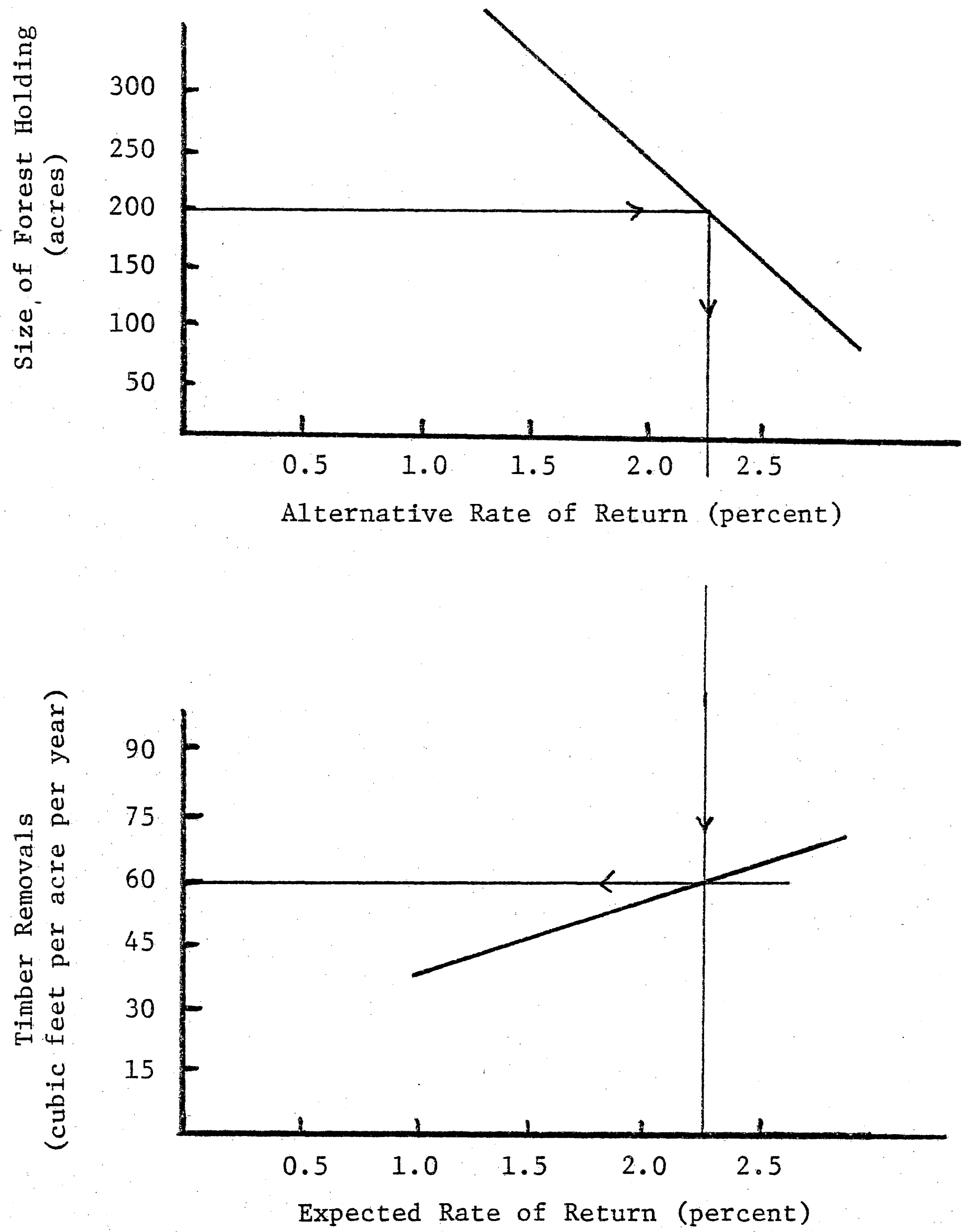


Figure 4. Relationship between the alternative rate of return, size of forest holding, and timber removals.

(upper graph) or a change in the expected rate of return/timber output function (lower graph). The lower graph is the major basis of policy analysis. A change in forest policy can modify the cost and revenue relationships of a forest investment, affecting the expected rate of return. Of course, changes in the size of forest holding/alternative rate of return relationship will also affect timber output. The interrelationship illustrated in Figure 4 will allow for projection of changes in timber output based upon almost certain temporal changes in forest land ownership; and, at the same time, permit simulation of different forest policy alternatives.

The model proposed in the remainder of the chapter hinges on the relationships shown in Figure 4. The upper graph, the alternative rate of return as a function of size of forest holding, will be represented by equation III.1. The lower graph represents the relationship between expected rate of return and timber removals, and will be represented by equation III.2. Equation III.3 will be a demand equation, allowing for a simultaneous solution of supply and demand equations (III.2 and III.3). A fourth equation will estimate net annual growth. Together, the equations form the timber output projection system.

Timber removals is a function of a landowner's alternative rate of return, and the alternative rate of return is a logical independent variable in the timber removals regression equation. However, the alternative rate of return must be estimated on the basis of related forest attributes (e.g., asset position, income position, or the size of forest holding). That is, the alternative rate of return will be fitted recursively into the timber removals per acre regression equation.

Alternative Rate of Return

The alternative rate of return is the dependent variable in the first regression equation of the recursive system; size of forest holding is the primary independent variable. Additional variables may well be related to the alternative rate of return (e.g., timber volume per acre, timber value per acre, stocking, or the asset or income position of the forest landowner). However, all of these variables are expected to be highly correlated with size of forest holding and their inclusion in the regression equation may introduce multicollinearity problems. The relationships need to be established in an empirical study; most likely, within a specific study region some of these additional variables will be useful as independent variables. The size of forest holding can be quantified by using average tract size or the percent of forest acreage falling in certain size classes (for example, the percentage of forest acreage in holdings of more than 200 acres). The basic equation relating the alternative rate of return to size of forest holding and other relevant variables is:

$$ARR = f(SFH, INCOME, ASSET, OWNER, VOLUME, VALUE, STOCKING, a_1, a_2, a_3, \ldots) \qquad III.1$$

where:

ARR = alternative rate of return,
SFH = size of forest holding variable(s),
INCOME = landowner's income position,
ASSET = landowner's asset position,
VOLUME = timber volume per acre,
VALUE = timber value per acre,
STOCKING = average stocking,
a_i = other variables related to ARR.

Timber Removals

Timber removals per acre (or timber output) is the dependent variable in the second equation of the system. Key independent variables are expected to be stumpage price, timber volume per acre, and the alternative rate of return. Other relevant variables will exist in any specific study region. Timber output is expected to be positively related to stumpage price and timber volume per acre, and negatively related to the alternative rate of return. Classical economic theory predicts the relationship between output and price. More timber volume per acre is expected to support more timber removals per acre. The alternative rate of return from equation III.1 appears in the timber output equation. This constitutes a simple recursive system and ordinary least squares can be used to estimate its parameters. The basic timber output equation is:

$$TR = f(ARR, Price, Volume, r_1, r_2, r_3, \ldots) \quad III.2a$$

where:

TR = timber removals per acre (timber output),
ARR = alternative rate of return,
Price = stumpage price per unit volume,
Volume = timber volume per acre,
r_i = other supply variables related to TR.

If more than one region or ownership class is considered, geographic or ownership variables might need to be included in Equation III.2a. However, for a regional NIPF sector study, equation III.2a is more correctly specified as:

$$TR = f(ARR, Price, Volume, r_1, r_2, r_3, \ldots \mid O, G) \quad III.2b$$

where:

O = ownership class (NIPF),
G = geographic class.

The proposed timber outut model is a regional model considering only the NIPF sector. Thus, data for the model was automatically stratified by ownership class and geographic class.

Timber Demand

Equilibrium timber output and stumpage price are determined by the simultaneous solution of timber demand and timber supply equations. Timber demand can be estimated by regression analysis using standard measures of economic activity that are known to affect timber demand. The researcher would need to construct the timber demand equation to reflect economic conditions in the relevant study region. The timber demand equation proposed here is an example of one of the many possible forms this equation might take:

$$TR = f(\text{Price}, \text{PCI}, \text{Capacity}, d_1, d_2, d_3, \ldots) \qquad \text{III.3}$$

where:

Price = stumpage price per unit volume,
PCI = per capita disposable income (constant dollars),
Capacity = measure of pulpwood and lumber mill capacity in the study region,
d_i = other demand variables related to TR.

Net Annual Growth

Net annual growth is needed to adjust the annual growing stock inventory from one time period to the next in the projection phase of the model. Net annual growth minus annual timber removals equals the annual change in inventory. The regression equation below is an example of the type that might be developed for a study region:

$$NAG = f(\text{Volume, Stocking, Age, Site}, g_1, g_2, g_3, \ldots) \qquad \text{III.4}$$

where:

NAG = net annual growth per acre,
Volume = timber volume per acre,
Stocking = average stocking,
Age = average age,
Site = site quality (site index),
g_i = other variables related to NAG.

Projection of Timber Output

Projection of timber output is accomplished via equations III.2 through III.4. For each year in the projection period, the change in commercial forest acreage by forest type and the change in the size of forest holding distribution are obtained exogenously. Annual inventory change is given by:

$$\text{Annual Inventory Change} = NAG - TR \qquad \text{III.5}$$

where:

NAG = net annual growth,
TR = timber removals.

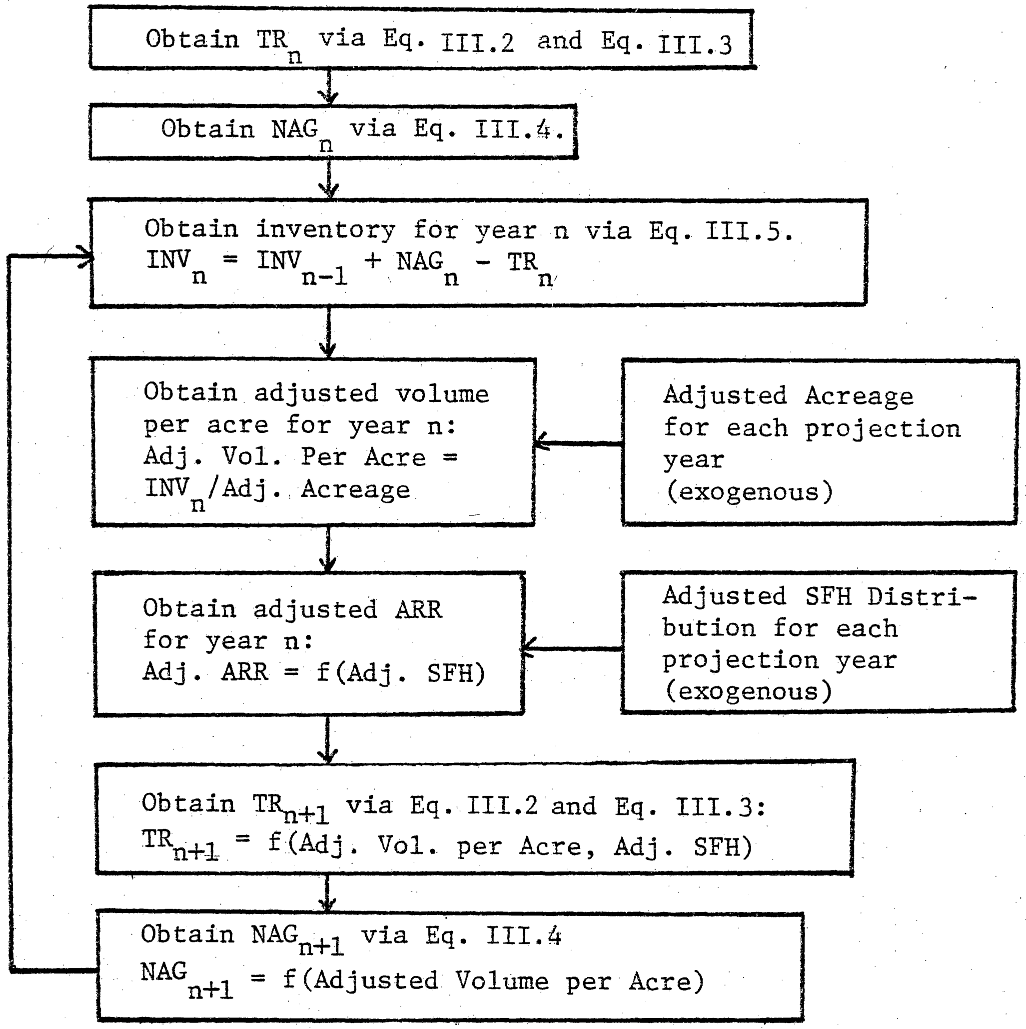
Each homogeneous timber output response cell is assigned the forest acreage it represents; timber output per acre times the number of acres in the cell will give timber output per cell; cell timber outputs can be summed to give total annual timber output. Projection is based upon simple mathematical relationships. Figure 5 is a flowchart of the projection system. The steps in the procedure are:

1. Timber removals is obtained for the first year via equations III.2 and III.3.

2. Net annual growth is obtained for the first year via equation III.4.

3. For the next year the adjusted commercial forest acreage and the adjusted size of forest holding distribution are obtained from an exogenous source.

4. The inventory is obtained for the next year using the information from steps 1 and 2 via equation III.5.



TR = Timber removals per acre
NAG = Net annual growth per acre
INV = Annual inventory
ARR = Alternative rate of return
SFH = Size of forest holding variable
n = projection year under consideration

Figure 5. Flow chart of the timber output projection system.

5. Adjusted volume per acre is obtained by dividing adjusted inventory (from step 4) by adjusted acreage (from step 3).

6. Adjusted alternative rate of return is obtained using equation III.1 and the adjusted size of forest holding distribution (from step 3).

7. Timber removals for the next year is obtained from equations III.2 and III.3 using adjusted volume per acre (from step 5) and the adjusted alternative rate of return (from step 6).

8. Net annual growth for the next year is obtained via equation III.4 using adjusted volume per acre (from step 5).

9. The procedure is repeated starting from step 3 for the next year in the projection period.

Summary

This positive timber output projection system is based upon two key assumptions:

1. Forest management intensity and timber output are inversely related to the forest landowner's alternative rate of return.

2. For the NIPF sector, the alternative rate of return is inversely related to the size of forest holding.

The distribution of forest holdings by size can be used to stratify forest acreage by forest type into homogeneous timber output response cells with equivalent alternative rates of return. Stratification by forest type assures similar physical timber production functions and equivalent expected timber outputs for equal alternative rates of return. Timber output response relationships can easily be developed within these stratifications using the alternative rate of return as an independent variable in a regression equation. The essence of this projection system is to relate timber output to shifts in the alternative rates of return of forest landowners via shifts in forest acreage among size of forest holding classes.

IV. PROJECTION OF LONG-RUN TIMBER OUTPUT FOR THE COASTAL PLAIN OF VIRGINIA

The purpose of this study was to identify and analyze the key variables influencing nonindustrial private forest (NIPF) timber supply in a study region and to develop a model for the projection of timber output per unit time using the positive approach as outlined by Stebbins (1975). The model should also have the capacity to supply policy guidelines for the NIPF sector and is intended to be operational. A model that requires a specialized data base would be of limited operational value. An additional requirement was, therefore, that the model use existing data or require a minimum of supplemental data generation.

The Study Region

The study region was Virginia Forest Survey Unit 1, the Coastal Plain of Virginia (Figure 6). This region consists of 34 counties and independent cities and extends from the Atlantic Ocean inland approximately 125 miles. The region has 43 percent of Virginia's population, 25 percent of Virginia's commercial forest land, and is 64 percent

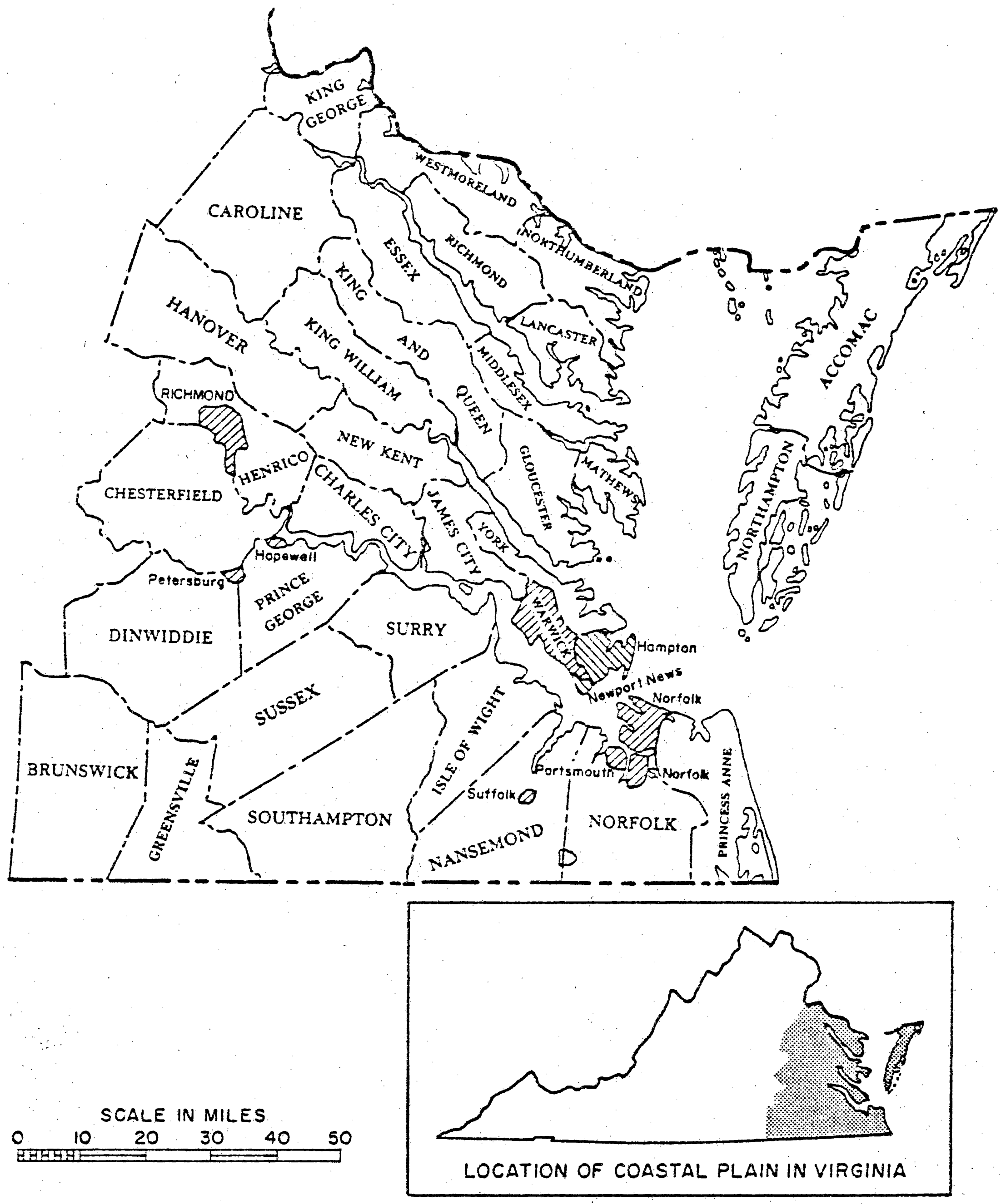


Figure 6. Counties and independent (noncounty) cities in the Virginia Coastal Plain.

forested (Knight and McClure 1978). The Coastal Plain is characterized by very flat topography near the coast and Chesapeake Bay and gently rolling topography near its boundary with the Piedmont (Bryan 1957).

The study region is a typical southern Forest Survey Unit. In 1975, the NIPF controlled 77 percent of the region's commercial forest acreage, produced 75 percent of total timber output, accounted for 76 percent of net annual growth, and held 76 percent of total growing stock (Cost 1976). This timber output supported the state's major pulp mills and larger sawmills (Giauque 1977).

Forestry is a major industry in Virginia, employing 16 percent of the labor force and generating 2.5 billion dollars annually (Custard 1981). Increased forest management intensity is a serious need on Virginia's NIPF lands, particularly on the Coastal Plain, due to ever increasing forest industry demand for raw materials (Virginia Division of Forestry 1980).

The Coastal Plain is a highly productive forest region and "is the hub of the State's forest industries" (Welch and Bellamy 1980). Welch and Bellamy (1980:4) go on to say:

> ...The region accounts for 46 percent of the State's timber output and 57 percent of the roundwood receipts. The region leads in all softwood products and in all hardwood products except pulpwood and those in the miscellaneous group. Saw logs were the leading product in 1978, accounting for 54 percent of the total output.

> Pulpwood accounted for 38 percent of the total output, while veneer logs and the miscellaneous group each contributed about 4 percent. The distribution of products output, by species, was 61 percent softwoods and 39 percent hardwoods. Over 80 percent of the total output came from roundwood and the remainder from plant byproducts.

Forest Surveys of Virginia's Coastal Plain were completed in 1940, 1956, 1966, and 1975. An interim survey was also completed in 1981. The 1975 survey (Cost 1976) showed that the region has 4,003,539 acres of commercial forest land; with 146,237 acres under public control, 768,895 acres under forest industry control, and 3,088,407 acres under NIPF control. The commercial forest area of the study region contains about 8 percent planted pine, 25 percent natural pine, 18 percent pine-hardwood, and 49 percent hardwood. The NIPF commercial forest land contains about 4 percent planted pine, 21 percent natural pine, 19 percent pine-hardwood, and 56 percent hardwood.

Recent trends in Coastal Virginia's timber resource were discussed by Sheffield (1978). These trends illustrate the need for a long-term timber output model for the region. Softwood inventory has declined continuously since 1940 and the softwood removals exceeded net growth by 8 percent between 1966 and 1975. Hardwoods gained in importance over the same period. Commercial forest acreage decreased by about 8 percent between 1940 and 1975. Also, changes in ownership classes have been significant over the same period.

Antecedent Studies

The present study used as background three previous studies that have analyzed the timber supply problem on the Coastal Plain of Virginia (Stebbins 1975, Giauque 1977, Hassler 1978). Stebbins' (1975) presented a plan for investigating timber trends in the study region. He outlined how a three-phase project might analyze timber supply using mensurational, normative, and positive approaches. The present study represents the third phase, the positive approach.

Giauque's Study

Phase one of the normative study, derivation of growth and yield data for the various forest types of Virginia's Coastal Plain, was completed by Giauque (1977). Growth and yield data are the forest's timber production function. A production function physically relates a firm's inputs of resources to an expected output of goods or services per unit time. Investment in timber management, after stand establishment, is mainly the opportunity cost of withholding growing stock from the market. Thus, the main input in a timber production function is time; that is, the production function specifies the additional output (timber yield) expected from an additional unit of input (i.e., adding one additional year to rotation age). The yield tables derived by Giauque are, in a sense, production functions with time as the variable input.

Giauque critiqued and analyzed available growth and yield data and found that regression analysis based growth predictions were of limited value in economic applications; his study was based on normal-yield analysis. Forest stand data was adjusted to account for nonnormality in uneven-aged and partially stocked stands.

Appendix tables 1 through 5 are taken directly from Giauque (1977). They represent a summary, by forest type, of the basis growth and yield data for Virginia's Coastal Plain. Yield per acre is the expected volume per acre of a forest stand at a given age and a given forest type. Mean annual growth is total yield divided by total age. Current annual growth is the increase in yield over a one year period. Current periodic annual growth is the difference in yield between the start and end of a growth period divided by the number of years in the growth period. Appendix tables 1 through 5, then, are the basic timber production functions for each major forest type on Virginia's Coastal Plain.

Hassler's Study

Phase two of the normative study, identification of the key economic variables affecting long-run timber output potential in the study region, was completed by Hassler (1978). Using the biological yield data developed by Giauque, Hassler analyzed the biological potential of the forest resource in economic terms. He identified two key economic variables: prospective changes in commercial forest acreage and the management intensity practiced on the forest acreage. Management intensity was found to be related to the forest owner's alternative rate of return; as a landowner's alternative rate of return decreased, he was more likely to invest in forest management.

Hassler's study was based on Duerr's timber supply model. Thus, Hassler's model assumes that all forest land in the study region is managed as if it were under one central administration, that the land is managed under a regulated-sustained-yield system, and that the model forest is attained during a transition period, during which all commercial forest acreage comes under regulation (See Chapter II, Duerr's Timber Supply Model).

Hassler analyzed each forest type to obtain the rate of return on extra growing stock. The results appear in Appendix tables 6 through 10. The last column of each table (marginal value growth percent) serves as a measure of financial acceptability for any given rotation length to an individual owner with a particular alternative rate of return. For example, in Appendix Table 6, a forest landowner with an alternative rate of return of 2.45 percent would be expected to harvest his timber at rotation age 25 years, the point of financial maturity. Appendix Table 6 is preceded by an explanation of its relation to Duerr's timber supply model.

Appendix Table 11 relates specific alternative rates of return to corresponding economically optimal rotation ages (based on Appendix tables 6 through 10). Note that the zero percent alternative rate of return corresponds to the culmination of mean annual increment for each forest type.

Hassler also projected land use changes on Virginia's Coastal Plain to the year 2020. The procedure for forecasting commercial forest acreage was based upon the observed inverse relationship between population growth and forest acreage: "...that counties with zero or negative population growth experience little change in forest acreage...," but that, "...counties that are showing large increases in population tend to experience simultaneous, significant decreases in commercial forest acreage." Appendix Table 12 gives the results of the commercial forest acreage forecasts by county to the year 2020. The reduction factor in Appendix Table 12 is related to the expected change in population over the projection period.

Using the same past trends, Hassler also provided a projection of commercial forest acreage by forest type and ownership class. Average values of these projections are given in Appendix Table 13.

Data

Data for the study region were obtained from the U.S. Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.[1] The data are from the fourth inventory of Virginia's Forest Survey Unit 1. The inventory was completed in 1975; survey methodology and results are summarized in Cost (1976). The present study used a subset of this inventory data.

The nonindustrial private forest (NIPF) sector was the ownership class under consideration. In general, the forest survey ownership classes are: public, forest industry, farmer, other private-individual, and other private-corporate. Nonindustrial private forest (NIPF) lands are defined here to include farmer-owned lands, miscellaneous

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[1]The data are not reproduced in the dissertation at the request of the Southeastern Forest Experiment Station; the data are available directly from this source.

private lands - individual, and miscellaneous private lands - corporate. Forest Survey Unit 1 includes 2,061 acres of farmer-owned and miscellaneous private lands leased to forest industry. These were classified as forest industry lands. NIPF land, under this definition, includes 3,088,407 acres. By ownership classes, the area consisted of the following acreages:

Farmer-owned	1,650,439
Miscellaneous private lands - individual	1,224,031
Miscellaneous private lands - corporate	213,937
Total NIPF acreage	3,088,407

Based upon this classification of the NIPF acreage, the Southeastern Forest Experiment Station provided data on commercial forest area, timber volumes, net annual growth, annual removals, annual mortality, and size of forest condition. Also obtained was the plot information for the 1,023 sample locations that form the observations for the NIPF sector in the 1975 Forest Survey.

Forest Type

The physical productivity of the region's forest resource must be stratified initially by forest type, the primary physical productivity characteristic of any forest.

Forest type is a classification of forest land based upon the tree species forming a plurality of live-tree stocking (Knight and McClure 1978). The two studies that provided background to the present study (Giauque 1977, Hassler 1978), adopted five generalized forest types: natural pine, planted pine, pine-oak, upland hardwood, and bottomland hardwood. These classifications are used by the Forest Service in their analyses and are "precise enough to portray actual forest conditions, while simultaneously maintaining a reasonable degree of practicality" (Hassler 1978). The present study used these same forest types.

In terms of Forest Service definitions, for this specific study region, natural pine corresponds to the Forest Service definition of the loblolly-shortleaf pine forest type, pine-oak corresponds to the Forest Service oak-pine type, upland hardwood corresponds to the Forest Service oak-hickory type, and bottomland hardwood corresponds to the Forest Service oak-gum-cypress and elm-ash-cottonwood forest types. The relevant forest types are defined in Cost (1976). In general, pine forest type refers to both the natural and planted pine and the hardwood forest type refers to the upland and bottomland hardwood forest types.

By forest type, NIPF acreage in the survey unit is classified as:

Planted Pine	129,996
Natural Pine	658,773
Pine-oak	577,649
Upland Hardwood	1,354,295
Bottomland Hardwood	367,694
Total NIPF Acreage	3,088,407

The stocking measure used in this study is based upon growing stock. Growing stock trees are defined as, "Live trees of commercial species qualifying as desirable or acceptable trees." (Knight and McClure 1978). Stocking levels are defined in Cost (1976).

Size of Forest Condition

Forest Survey inventories in Virginia do not record information on size of forest holding. Legal property ownership boundaries are not usually physically observable by inventory workers. Verification of apparent ownership boundaries would require many days of additional work and, even then, ownership would be subject to errors from owners' misestimates of what they actually own and continuous land transactions. Size of forest holding is not an easily obtainable statistic.

Recent inventories by the Southeastern Forest Experiment Station do record a size of stand statistic. The statistic, "size of forest condition," is based upon the physical attributes of the forest resource, rather than the attributes of the forest owners. Size of forest condition is a physically observable statistic. Knight (1978) describes and defines size of forest condition as:

> In response to concerns over small tracts, the Resource Evaluation Work Unit in the Southeast has attempted to measure and characterize stand size in its recent inventories. Here, a stand is defined as a contiguous forest condition in one forest type of similar origin or age and with similar stocking, without regard to ownership lines. At each sample location, field crews determine and record the size of each unique stand sampled based on their ground observations and interpretations of aerial photographs.

Data obtained from the Southeastern Forest Experiment Station for this study included the size of forest condition statistic, which served as a proxy for the size of forest holding.

Ownership does dictate who will manage a particular forest tract; but, within an ownership class, management intensity was expected to be relatively uniform on equally sized tracts. Management intensity refers mainly to initial forestry investments to establish a forest stand (site preparation and regeneration) and the decision on how much growing stock to hold over time. Size of forest condition denotes a stand that has been under uniform management in the past and, one should be able to presume, a stand likely to receive uniform management in the future.

Size of forest holding has been shown to be an important variable in NIPF timber output studies, and is known to be related to stand age, stocking, volume of timber in a stand, and the value of that timber (See Chapter II, Size of Forest Holding). Since size of forest condition was used as a proxy for size of forest holding in this study, the relationship between these two variables should be established. Hypothesis testing was used to establish this relationship. Size of forest condition was expected to exhibit the same relationship with management intensity that size of forest holding has exhibited with management intensity in past studies.

Relationship Between Size of Forest Condition and Stand Age

Higher levels of management intensity imply lower alternative rates of return; this in turn implies longer rotations, and thus, older stands. If size of forest holding and size of forest condition are similarly related to management intensity, one would expect size of forest condition to be positively correlated with age of stands.

This correlation can be established with the Forest Survey data. The analysis was performed by forest type, since growth relationships and management techniques differ by forest type. The small number of sample locations in the pine plantation and bottomland hardwood types made individual analysis of these types untenable. All pine and all hardwood stands were consolidated for purposes of the analysis. To justify any statement to the effect that there is a relationship between size of forest condition and forest management intensity, the null hypothesis that the correlation coefficient equals zero was tested against the alternative hypothesis that the correlation coefficient does not equal zero. Below are results of a correlation analysis between size of forest condition and stand age for the 1,023 Forest Survey plots:

Forest Type	Correlation Coefficient	Significance Probability
Pine	+0.24566	0.0001
Pine-oak	+0.14496	0.0466
Hardwood	+0.20900	0.0001

For each forest type, size of forest condition was positively correlated with stand age. The relationship was the same one expected for the size of forest holding statistic. The hypothesis cannot be rejected at the 95 percent level of significance. This supports the conclusion that size of forest condition is positively related to forest management intensity.

Relationship Between Size of Forest Condition and Timber Value

Size of forest condition would also be expected to be positively correlated with the volume and value of timber held on a particular tract and stocking. Lower alternative rates of return will allow forest investors to hold higher volumes of timber.

The Forest Survey data does not contain direct information on the value or volume of timber on the individual survey plots. It does, however, identify those forest conditions that contain higher valued sawtimber. A high value stand was defined as a stand with sawtimber quality and a high level of stocking (at least 90 percent stocked). Higher valued stands were represented by a zero-one dummy variable. This dummy variable was given a value of one for high valued stands and a value of zero for low valued stands.

Since such a dummy variable follows a binomial distribution, a nonparametric test procedure was appropriate. The Wilcoxon rank-sum test was used to test the null hypothesis that the median size of forest conditions was equal for both high and low valued stands versus the alternative hypothesis that the median size of forest condition was larger for higher valued stands. The significance level for the test was 0.0551. This indicates that, at the 94 percent level of significance, size of forest condition tends to be larger for higher valued stands.

Thus, size of forest condition is positively related to the volumes and value of timber on the condition. This is precisely the relationship one would expect for the size of forest holding statistic. The hypothesis cannot be rejected at the 94 percent level of significance. This supports the conclusion that size of forest condition is positively correlated with forest management intensity and timber output.

On the basis of these two analyses, the present study was based on the premise that size of forest condition displays the same relationship with timber output that previous studies have attributed to the size of forest holding statistic.

An Incomplete Timber Market Model

In classical economic theory, the quantity of timber supplied is a function of price and the intersection of timber demand and timber supply determines equilibrium timber output and price. Timber demand is a necessary component of a "complete" timber market model. However, the Coastal Plain of Virginia is much too small a region to have a significant effect upon stumpage price. Certainly, timber supply and demand relationships exist within the region but, due to interregional trade, market price will be determined by demand and supply equilibrium over a much larger area. The boundaries of the larger region would be limited by wood transportation costs (truck, rail, and barge) into Virginia's Coastal Plain region.

Regional woodlands are a main source of raw materials for the local forest industries, but timber demand far exceeds regional timber output at current stumpage prices and adjacent regions must supply the balance of the raw material requirements. In 1975, forest industry imported into the region 74 percent of the softwood roundwood and over half of the hardwood roundwood consumed by its mills (Sheffield 1978). Softwood removals have exceeded net growth on Virginia's Coastal Plain since the mid 1950's, making domestic supplies noncompetitive with sources outside the region. Increased imports of both softwood and hardwood roundwood and increased use of hardwood by many mills has reduced the problem, but timber supply is still an "increasing concern among forestry leaders in Virginia" (Sheffield 1978). It is highly unlikely that the excess demand situation will be eliminated during the time frame of this study.

Figure 7 illustrates the excess demand situation in eastern Virginia. As drawn, the timber supply curve for eastern Virginia appears to be almost perfectly inelastic. This is probably a slight exaggeration, but, given the bulk of the region's timber comes from NIPF's, and NIPF timber supply is expected to be insensitive to price, this seems a reasonable simplification.

Current stumpage price does not affect long-run timber output because it has no effect upon the relationship between a landowner's alternative rate of return and the marginal rate of return from a forest investment. Timber output decisions are made on the basis of the rate of return on the marginal growing stock, which equals the value of the extra yield for a longer rotation divided by the value of the extra growing stock needed to produce this extra yield. A change in stumpage price will affect both the value of the extra yield and the value of the extra growing stock in exactly the same proportion, leaving the rate of return on marginal growing stock unchanged. This relationship between long-term timber supply and stumpage price is discussed in detail in Chapter II (Duerr's Timber Supply Model). Two recent studies support the conclusion that long-run timber output is price inelastic. The Division of Forest Economics Research (1963) found price elasticities in the 0.07 to 0.12

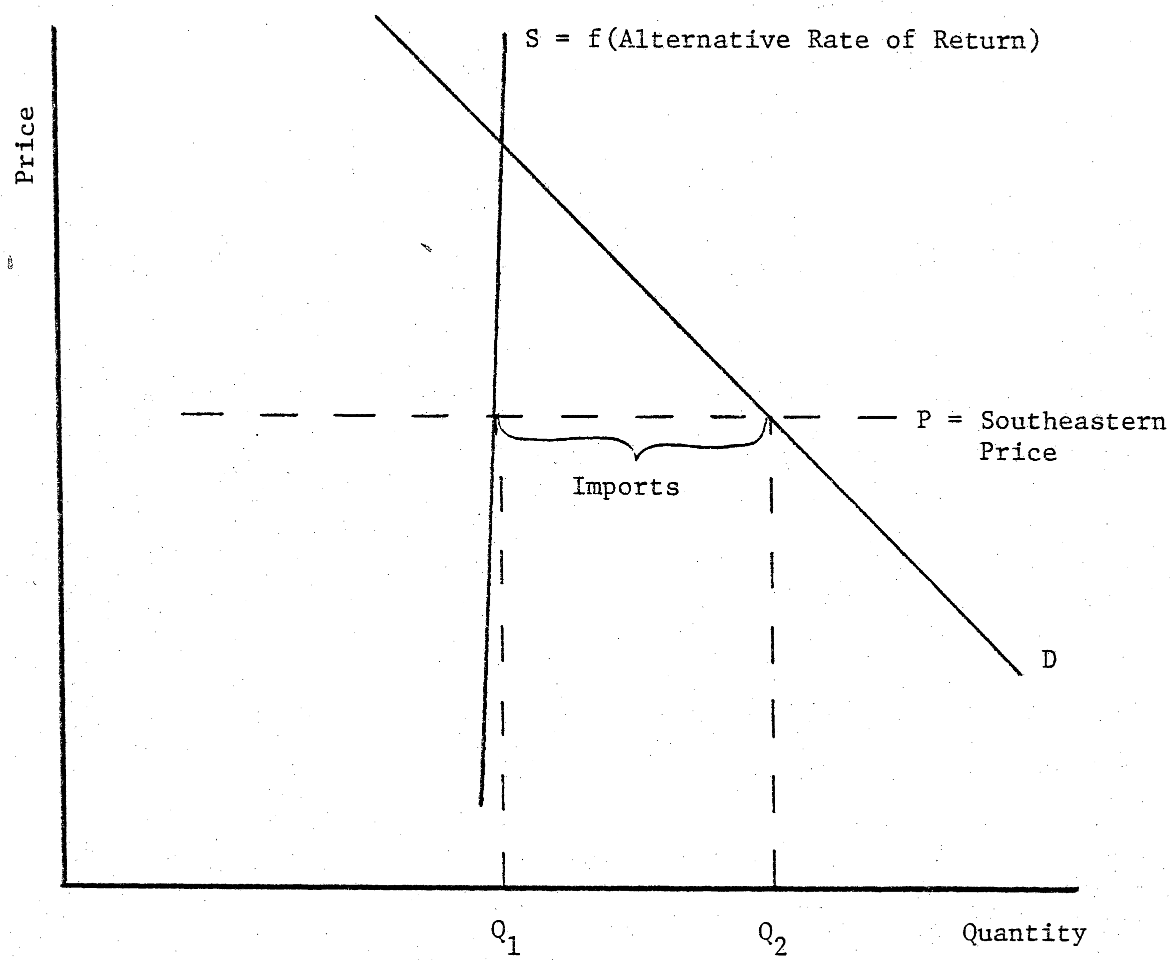

Figure 7. The Coastal Plain of Virginia as a timber importing region.

range. That is, stumpage price has little effect upon long-run timber output. Miville-Deschênes (1974) verified this conclusion.

In practice, short-run responses to price changes are likely to cause departures from Q_1. However, no major difficulties result, since this study is concerned with secular trends, and not specific year-to-year quantities.

Figure 7 represents the timber supply and demand situation in eastern Virginia for the NIPF sector. Eastern Virginia is an excess demand region, importing quantity $Q_1 - Q_2$ from the remainder of the southeastern United States. Eastern Virginia is a small "importer" relative to total Southeastern wood production; thus, it is a price taker. The region can purchase all the timber it needs at the Southeastern market price. The price of stumpage acts only to determine the amount of regional imports. Shifts in the eastern Virginia demand curve affect the amount of imports and shifts in the eastern Virginia supply curve are due mainly to changes in the relationship between the alternative rate of return and the marginal value growth percent of forest stands owned by NIPF landowners.

To summarize, eastern Virginia is an excess demand region, importing the balance of its timber from the remainder of the Southeastern U.S. at market prices.

Regional timber output is determined by nonprice factors. The quantity of imports is determined by regional demand and Southeastern market prices. Under these conditions, the only role of regional demand is to determine the quantity of imports. Thus, this regional study determined timber output without relation to timber demand. Errors may result, but would be reflected mainly in year-to-year fluctuations in timber output and not in the long-term trend.

Developing Subunits within the Study Region

The structure of the data set available for the study region did not allow for the detailed stratification procedures outlined in Chapter III. However, the data were sufficient to verify the viability of the proposed modeling approach.

Lacking the data to obtain a sufficient number of cell values to form a regression relationship, the study region was stratified by its primary physical characteristic (forest type) and its primary economic characteristic (size of forest condition). Within each forest type the study region was divided into subregions, with each subunit representing an observation for the regression analysis.

The key data on volume, net annual growth, and timber removals were available only in stratifications of pine, soft-hardwood, and hard-hardwood. These cannot be directly related to the five forest types used by Giauque (1977) and Hassler (1978). Data now being collected by the Southeastern Forest Experiment Station does relate volume, net annual growth, and timber removals directly to forest type. Thus, while forest type was limitation to the present study, it should not limit future studies.

Since the key timber removals data was only available basically as pine and hardwood removals, it was necessary to consolidate Giauque's and Hassler's data into pine and hardwood tables. Accordingly, Appendix tables 1 to 5 were consolidated using weighted averages, based upon the proportion each type comprised of total forest acreage. For the pine table: planted pine occupied 9.51 percent of the acreage, natural pine occupied 48.21 percent of the acreage, and pine-oak occupied 42.28 percent of the acreage. For the hardwood table: upland hardwood occupied 58.89 percent of the acreage, bottomland hardwood occupied 15.99 percent of the acreage, and pine-oak occupied 25.12 percent of the area. Volumes in the pine-oak forest type were adjusted to reflect the pine-hardwood components of that volume (on the average, Giauque (1977) found that 41.5 percent of the pine-oak volume was pine and 58.5 percent of this volume was hardwood).

To relate current perodic annual growth (which can be determined from Forest Survey data) to the alternative rate of return required consolidating the forest types of Appendix Table 11 in the same manner as above. Together, the consolidated sets of Appendix tables 1 to 5 and Appendix Table 11 formed the basis of deriving an implied alternative rate of return from the current periodic annual growth statistics on Virginia's Coastal Plain. Appendix Table 14 related mean annual growth, current annual growth, and the alternative rate of return, by pine and hardwood forest type, for the study region.

The study region was a forest survey unit with 34 counties. Timber removals, volumes, forest type acreages, net annual growth, size of forest condition distributions, and other relevant statistics were available at the county level. However, the Forest Survey sampling procedure was designed to provide reliable statistics primarily at the survey unit level. County level data, particularly the size of forest condition data, are not statistically precise enough to be used in the present study. This requires that county data be combined into subunit data, where a subunit is a combination of two or more counties. As counties are combined, reliability of data is expected to increase. Cost (1976) in discussing the problems of county data pointed out: "Individual county statistics are presented so that any combination of counties may be added together until the total is large enough to meet the desired degree of reliability."

Combining county data into subunit data means that only a few observations were available for regression analysis; the number of observations being equal to the number of subunits. This led to problems with degrees of freedom and limited the number of independent variables that could be used in the regression equation. The use of the size of forest condition statistic, which is known to be closely correlated with most of the relevant explanatory variables, reduced the number of dependent variables needed in the regression analysis.

The sampling system used in the Forest Survey required that if the subunits are to possess equivalent statistical reliability, each subunit must have approximately equal areas and volumes. Pine output and hardwood output were projected separately. The greater number of sample plot locations on the hardwood acreage allowed the hardwood projection to be based on more subunits than the pine. The pine output projection was based upon six observations and the hardwood projection was based upon nine observations. Subunits were formed using the criteria of equal acreage, equal volume, and geographical proximity.

The six subunits used in the pine projections were combinations of the following counties: I. Caroline, Hanover, King William, and Sussex; II. Accomack, Chesapeake, Greensville, Isle of Wight, New Kent, Prince George, and York; III. Brunswick, Middlesex, Newport News, and Southampton; IV. Chesterfield, Dinwiddie, and Essex; V. Charles City, Gloucester, King George, Lancaster, Northampton, Northumberland, and Suffolk; VI. Hampton, Henrico, James City, King and Queen, Mathews, Richmond, Surry, Virginia Beach, and Westmoreland.

The nine subunits used in the hardwood projections were combinations of the following counties: I. James City and Southampton; II. Brunswick, Caroline, and Greensville; III. New Kent, Sussex, and Virginia Beach; IV. Chesapeake, Surry, Westmoreland, and York; V. Chesterfield and Hanover; VI. Charles City, Dinwiddie, Essex, Hampton, and Middlesex; VII. King George, King William, and Suffolk; VIII. Accomack, Northumberland, Prince George, and Richmond; IX. Gloucester, Henrico, Isle of Wight, King and Queen, Lancaster, Mathews, Newport News, and Northampton.

Estimation of the Pine Regression Relationships

Three basic regression equations were estimated for each of the two forest types. First, the relationship between the alternative rate of return and size of forest condition was established. Second, timber output was estimated as a function of the alternative rate of return and volume per acre. Then, as a basis of inventory adjustment, net annual growth was estimated. The absolute value of the t ratio is shown in parentheses below each regression equation's coefficients. As a general rule, if this ratio is greater than two, the null hypothesis that the coefficient equals zero against the two-tailed alternative can be rejected at the 5 percent level of significance.

The alternative rate of return was expected to be negatively correlated with size of forest condition. Size of forest condition in the study region ranged from 1 acre to over 1000 acres. The size of forest condition statistic used in the regression was the percentage of forest acreage in size of forest conditions containing at least 200 acres (SFH). Both percentages were expressed as mixed numbers between 0 and 100. The estimated regression equation relating alternative rate of return (ARR) to size of forest condition (SFH) for pine was:

$$\underset{}{ARR} = \underset{(19.23)}{3.67523896} - \underset{(7.14)}{0.07647913}SFH \qquad N = 6,\ R^2 = 0.93 \qquad \text{IV.1}$$

Timber removals per acre (TR) or timber output was expected to be positively related to volume per acre (VOLUME) and negatively related to the alternative rate of return (ARR). ARR was obtained from equation IV.1, making this a recursive system. Timber removals per acre and volume per acre were expressed in cubic feet. The estimated regression equation was:

$$TR = \underset{(4.95)}{74.65885705} - \underset{(4.97)}{15.37529191}ARR + \underset{(1.83)}{0.01352978}VOLUME \quad \text{IV.2}$$

$$N = 6$$
$$R^2 = 0.95$$

The inventory adjustment process required a regression equation to project net annual growth for each period. Detailed mensurational data were not available for this study; volume per acre was the only independent variable. Net annual growth per acre (NAG) was expected to be positively related to volume per acre (VOLUME). Net annual growth per acre and volume per acre were expressed in cubic feet. The estimated regression equation was:

$$NAG = \underset{(2.60)}{34.79837915} + \underset{(1.18)}{0.01103314}VOLUME \quad N = 6, \; R^2 = 0.26 \quad \text{IV.3}$$

All three regression equations had the expected coefficient signs. Equations IV.1 and IV.2 provided strong statistical relationships on which to base projections. Equation IV.3 is the least statistically significant regression equation in the pine projection system. The coefficient of volume per acre was not highly significant, but it was the best available independent variable related to net annual growth. The lack of any more detailed mensurational data dictated this equation should also be included in the pine projection system.

Estimation of the Hardwood Regression Relationships

The hardwood projection system equations were based on the same relationships described above for the pine system. The same data problems described above also existed for the hardwood system. The alternative rate of return (ARR) was expected to be negatively related to size of forest condition (SFN). Both percentages were expressed as mixed numbers. The estimated regression equation was:

$$\underset{}{ARR} = \underset{(10.75)}{1.81764862} - \underset{(5.89)}{0.03551048SFN} \qquad N = 9,\; R^2 = 0.83 \qquad \text{IV.4}$$

Timber removals per acre (TR) was expected to be positively related to volume per acre (VOLUME) and negatively related to the alternative rate of return (ARR). Since this is a recursive system, ARR was obtained from equation IV.4. Timber removals per acre and volume per acre were expressed in cubic feet. The estimated regression equation was:

$$TR = \underset{(0.17)}{1.59464341} - \underset{(2.46)}{4.80582341ARR} + \underset{(4.70)}{0.03717812VOLUME} \quad N = 9, \; R^2 = 0.93 \qquad IV.5$$

Detailed mensurational data limited the available independent variables in the hardwood growth equation. Again, only a simple regression was possible, with volume per acre the independent variable. Net annual growth per acre (NAG) was expected to be positively related to volume per acre (VOLUME). Net annual growth per acre and volume per acre were expressed in cubic feet. The estimated regression equation was:

$$NAG = \underset{(7.80)}{60.47941983} - \underset{(1.49)}{0.01135702VOLUME} \quad N = 9, \; R^2 = 0.24 \qquad IV.6$$

Equations IV.4 and IV.5 had the expected coefficient signs. These two equations, while not as statistically significant as their counterparts in the pine projection system, still provided reasonable statistical relationships on which to base projections. Equation IV.6 was the least statistically significant regression equation in the hardwood projection system and its independent variable did not have the expected coefficient sign. This may be due to the less intensive management usually practiced on hardwood lands. Large volumes per acre may indicate older stands with growth rates that have started to decline. An "overmature" stand on Virginia's Coastal Plain is much more likely to be a hardwood stand than a pine stand; thus, the negative coefficient on volume per acre. The lack of any more detailed mensurational data dictated this equation must be included in the hardwood projection system.

Projected Acreage and Size of Forest Condition

Appendix Tables 12 and 13 contain Hasler's (1978) projections of commercial forest acreage by ownership and forest type for eastern Virginia. Acreage changes can be prorated over the projection period (1976-2020) to obtain estimates of NIPF commercial forest area by forest type for the years 1976 to 2000. The results of this process are shown in Appendix Table 15.

Hassler (1978) made no attempt to project changes in the size of forest condition distribution when he compiled the forest acreage changes for eastern Virginia. The Forest Survey has only recently collected size of forest condition data, so trend projections of changes in the size of forest condition distribution were not available from their data.

However, the Census of Agriculture (U.S. Department of Commerce 1972, 1980) does provide data on forest acreage and the number of forest landowners on a county-by-county basis. The information was available for eastern Virginia for the years 1969 and 1978. From this data, the average forest holding size can be determined for eastern Virginia for the years 1969 and 1978. Trend analysis performed over this 9-year period, indicated that the average size of forest holding increased by 1.02 percent annually.

An assumption of the study was that the size of forest condition distribution shifted upward in about the same proportion as the average size of forest holding. Since both statistics are closely related (Chapter IV., Size of Forest Condition), this is a reasonable assumption. To project changes in the size of forest condition beyond 1978, the annual change in size of forest holding must be related to one of the statistics available over the projection period. Size of forest holding is related to forest management intensity and, thus, can also be expected to be related to changes in the acreage of pine plantations (since pine plantations are a form of very intense forest management). For about the same period that size of forest holding increased by 1.02 annually, pine plantation acreage increased by 1.01 percent annually. This is almost identical to the annual change in average size of forest holding. Limited data makes pine plantation acreage the best available proxy variable for estimating expected changes in size of forest condition. Appendix Table 16 gives projections of the percentage of forest acreage expected to be in size of forest condition classes greater than or equal to 200 acres for each year of the projection period, based upon projected changes in pine plantations. These projections were made for both pine and hardwood.

Projection of Long-run Timber Output

The projection technique outlined in Chapter III. was applied to eastern Virginia. Equations IV.1 through IV.6, using Appendix Tables 15 and 16 as input, were used to project timber output, beginning with 1976 values as given in Forest Survey data.

The model was based on six regression equations. These equations defined the relationships among the relevant variables, based upon past experience. The regression relationships were assumed to remain constant for the future. Over time, additional data can be fitted to these equations to account for minor temporal changes. However, the continuity assumption of a positive model does limit the practicality of projecting output more than a few decades into the future. Long-run timber output was projected for the period 1976 to 2000.

Table 1 shows the results of this projection. Growing stock volume and timber output is given for both pine and hardwood. Net annual growth was also calculated for each year and was used to adjust the yearly inventories.

When an econometric model is used to make a temporal projection, the statistical reliability of the forecast can be expected to decrease as the projection period increases. Figure 8 shows the 95 percent confidence band for the long-run timber output projection. Timber output is shown as a linear approximation. Analysts using such projections should be aware of the rapidly increasing confidence limits on projection values as the projection period is increased.

Discussion

Total timber output is expected to increase by about 0.5 percent annually over the projection period. This is mainly due to a 0.9 percent annual increase in hardwood output, but pine output is also expected to increase by about 0.1 percent annually.

In contrast, over the projection period, total NIPF acreage is expected to decrease by about 10 percent. Pine acreage actually increases by 6 percent, due to greater

TABLE 1

Projected pine and hardwood inventory volumes and timber outputs for eastern Virginia, 1976-2000.

Year	Pine Growing Stock Volume	Pine Timber Output	Hardwood Growing Stock Volume	Hardwood Timber Output	Total Timber Output
	Thousand Cubic Feet				
1976	1,706,334	75,731	2,631,284	78,893	154,624
1977	1,698,917	75,339	2,664,833	92,344	167,683
1978	1,691,500	75,367	2,680,303	92,963	168,330
1979	1,683,892	75,537	2,694,088	93,628	169,165
1980	1,675,892	75,764	2,706,160	94,228	169,992
1981	1,667,495	75,776	2,716,606	94,873	170,649
1982	1,658,912	75,994	2,725,399	95,241	171,235
1983	1,649,934	75,996	2,732,834	95,664	171,660
1984	1,640,773	76,204	2,738,872	96,033	172,237
1985	1,631,220	76,404	2,743,583	96,352	172,756
1986	1,621,279	76,392	2,747,031	96,726	173,118
1987	1,611,157	76,376	2,749,177	96,946	173,322
1988	1,600,856	76,563	2,750,189	97,122	173,685
1989	1,590,170	76,744	2,750,125	97,257	174,001
1990	1,579,101	76,918	2,749,037	97,453	174,371
1991	1,567,652	76,881	2,746,876	97,406	174,287
1992	1,556,029	77,045	2,743,897	97,429	174,474
1993	1,544,028	77,203	2,740,039	97,417	174,620
1994	1,531,651	77,355	2,735,348	97,372	174,727
1995	1,518,900	77,296	2,729,867	97,297	174,593
1996	1,505,982	77,439	2,723,633	97,289	174,728
1997	1,492,692	77,575	2,716,589	97,152	174,727
1998	1,479,033	77,704	2,708,873	96,990	174,694
1999	1,465,007	77,625	2,700,518	96,801	174,426
2000	1,450,818	77,947	2,691,558	96,682	174,629

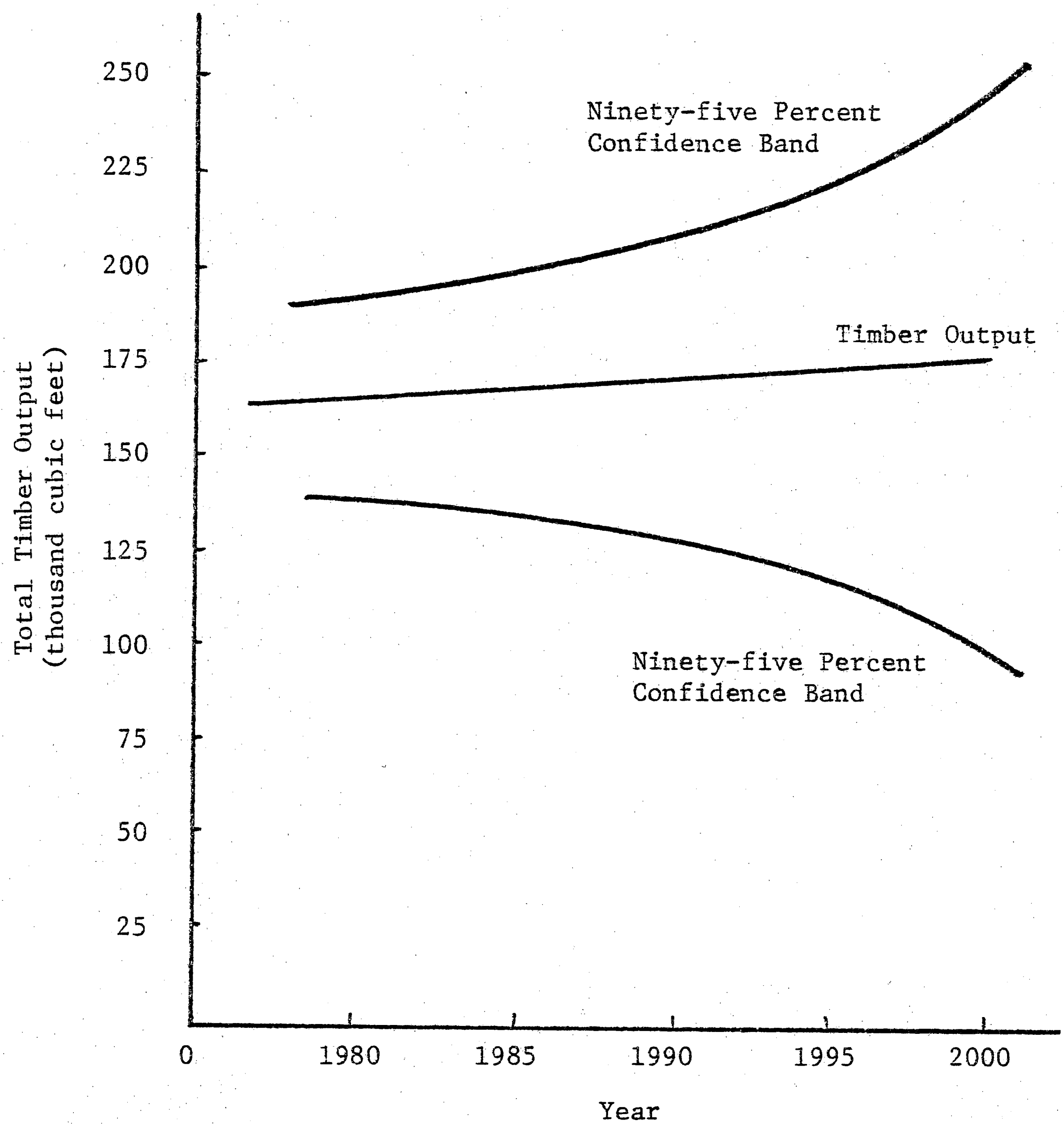

Figure 8. Ninety-five percent confidence band on the timber output projection.

numbers of pine plantations. Pine-oak forest acreage is expected to decrease by 21 percent and the hardwood acreage is expected to decrease by 15 percent.

Pine volume per acre decreased by 12 percent and hardwood volume increased 21 percent over the projection period. The differences in volume per acre partially explain why the hardwood output increased much more rapidly than the pine output.

Pine growing stock volume decreased over the projection period. This indicates that in the inventory adjustment process (change in inventory equals net annual growth minus timber removals), timber output exceeded net annual growth, producing net decreases in pine growing stock volume. Projected hardwood growing stock volume increases until 1988, then gradually decreases. The Forest Survey data exhibited these same general trends between 1966 and 1976. A positive model will tend to duplicate past variable relationships. Projected trends initially followed past trends of declining pine inventory and increasing hardwood inventory, but acreage changes caused a shift in the balance of the growth/output ratio, resulting in slightly declining hardwood inventories after 1988.

Overall, the projection followed the expected trend of slightly increasing timber output. Size of forest condition was expected to exert significant influence over timber output. The gradual increase in the percentage of forest acreage in size of forest conditions greater than 200 acres more than counteracted the significant overall decrease in forest acreage. That is, a shift in the percentage of forest acreage in size of forest conditions greater than 200 acres from 17 to 22 percent for pine and from 24 to 31 percent for hardwood exerted a greater influence on timber output than a 10% reduction in total NIPF acreage. The projection model's results pointed out the important role size of forest condition plays in NIPF timber output modeling.

V. SUMMARY AND CONCLUSIONS

A positive approach for projecting nonindustrial private forest (NIPF) timber output was outlined. An example of the approach was applied to eastern Virginia with satisfactory results. The approach is applicable to any regional timber output study.

Size of forest holding has consistently been shown to be a major determinant of forest management intensity practiced on a particular forest tract. Larger forest holdings tend to be in the hands of forest landowners interested in timber value. Timber volume and timber value, when on a per acre basis, are known to be positively correlated with both forest management intensity and size of forest holding. Explanations for these relationships have centered on economies of tract size and utility theory.

A forest landowner's alternative rate of return is primarily determined by his level of income and asset position. Size of forest holding and the forest landowner's income level and asset position have been shown to be positively correlated. As size of forest holding increases, the income level and asset position of the forest landowner can also be expected to increase. This increase in income level and asset position can be expected to lead to decreasing alternative rates of return. Or, size of forest holding and expected alternative rate of return should be negatively correlated. Lower alternative rates of return will produce more intensive management and greater timber output. Thus, the alternative rate of return provides a framework for analyzing the relationship between size of forest holding and timber output.

The timber output model developed in this study was based upon a cross classification of NIPF land by physical characteristics (e.g., forest type) and economic characteristics (e.g., landowner's alternative rate of return). The study used a Vauxian approach to develop a positive timber output projection model. Such an approach involves (1) development of biological potential growth and yield data for the study region, (2) identification of the economic relationships affecting timber output in the study region, (3) development of homogeneous timber output response cells based on both biological and economic characteristics, (4) estimation of expected changes in commercial forest acreage (land use changes) for each homogeneous timber output response cell over the projection period, (5) estimation of expected timber output levels for each homogeneous timber output response cell over the projection period, and (6) projection of timber output over the relevant planning horizon.

The model used two main stratification dimensions: forest type and size of forest holding. Forest type provides the main stratification dimension for biological potential; size of forest holding provides the main stratification dimension for economic characteristics. Ownership class and geographic class are implicit stratification dimensions. Each forest type/size of forest holding matrix cell possessed an unique relationship between the alternative rate of return and timber output.

The study region was Virginia Forest Survey Unit 1, the Coastal Plain of Virginia. Prior studies on this region supplied necessary background for the present study.

Forest Survey inventories in Virginia did not record information on size of forest holding, a necessary statistic for the study. However, survey crews did record the "size of forest condition." On the basis of correlation analysis, the study was based on the premise that size of forest condition displays the same relationship with timber output that previous studies have attributed to the size of forest holding statistic.

Generalized forest types (pine and hardwood) were the basis of biological stratification and size of forest condition (percent of forest acreage in size of forest conditions greater than or equal to 200 acres) was the economic stratification characteristic. This was a very simple example of stratification, but the strength of these two stratification dimensions allowed for reasonable projections of timber output.

A set of regression equations was developed for each forest type. Economic stratification was obtained by regressing the alternative rate of return against the size of forest condition. Timber output per acre was then obtained using alternative rate of return and volume per acre as independent variables. Lastly, a simple regression equation estimated net annual growth as a function of volume per acre.

Changes in commercial forest acreage were obtained exogenously. Since net annual growth and annual timber removals (output) were obtained via regression, net annual change in inventory (net annual growth - annual timber removals) was known. Per acre inventory values were adjusted to reflect changes in forest acreage. Then, timber output was projected on a year-by-year basis using these simple relationships.

Total timber output on the study region is expected to increase by 0.5 percent annually over the projection period, due mainly to projected increases in the percentage of forest land in size of forest conditions of greater than 200 acres. The effect of increases in the percentage of forest acreage in size of forest conditions greater than 200 acres was more than adequate to counterbalance decreases in forest acreage.

The projection system and its stratification dimensions were necessarily a simple nature. Forest Survey data is intended to provide reliable statistics primarily at the survey unit level. Since this study used data from subunits of a survey unit, independent variables available for the regression equations were very limited. Data limitation should not be a problem in future use of the model, as satisfactory data is available from the Forest Survey for larger areas, and the type of data needed for this projection approach (timber removals by forest type and size of forest condition) is now being collected on a regular basis by survey teams. The approach is most applicable to a series of Forest Survey units (e.g., southeastern U.S. Coastal Plain). A larger study region would easily eliminate most of the data problems.

Homogeneous timber output response cells were shown to be a viable approach in developing a NIPF timber output model. A positive approach must be based on past relationships, both physical and economic. Cross classification by physical productivity and economic characteristics allowed for development of regression equations based upon timber output response stratum. The stratification produced a regression equation with stability over time, but also with the capability to be easily modified if any stratum shows temporal change. Since a positive approach has a key assumption that past relationships will continue over time, regression analysis seems the likely tool for use in a positive timber output model. Homogeneous timber output response cells are a convenient and logical means to obtain the independent variables needed in such analyses.

Size of forest conditions (size of forest holding) was shown to be a major determinant of NIPF timber output. It seems to be an almost mandatory stratification dimension if a homogeneous timber output response cell approach is used to project NIPF timber output. This study showed that even a simple projection system based upon this statistic will give projections that consider the main economic characteristics of NIPF landowners.

The alternative rate of return was found to exhibit a strong positive correlation with size of forest holding. Thus, stratification by size of forest holding constitutes stratification by the alternative rate of return. If the forest resource is also stratified by its physical characteristics, the functional relatiionship between the marginal value growth percent and rotation length will be constant over the stratum's acreage. The relationship between size of forest holding and the alternative rate of return provides an important framework for policy analysis. NIPF landowners can be assigned an expected alternative rate of return based on the size of forest holding, and, since each stratum will have a fixed relationship between long-run timber output and the expected rate of return (marginal value growth percent), projected long-run timber output levels can be determined by the intersection of the alternative rate of return and the expected rate of return. Changes in timber output would result from either a change in the alternative rate of return or a shift in the expected rate of return/timber output function. NIPF timber output policy analysis in this model is centered on the NIPF landowners' alternative rate of return, a primary economic characteristic of the forest sector.

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APPENDIX

Appendix Table 1

Growth and yield data for the natural loblolly pine forest type on the Coastal Plain of Virginia (Giauque 1977).

Stand Age	Yield per acre	Current periodic annual growth per acre	Mean annual growth per acre
Years	Cubic feet		
20	1552		78
		152	
30	3070		102
		121	
40	4283		107
		82	
50	5103		102
		52	
60	5622		94
		36	
70	5986		86
		21	
80	6195		77

Appendix Table 2

Growth and yield data for the planted loblolly pine forest type on the Coastal Plain of Virginia (Giauque 1977).

Stand Age	Yield per acre	Current periodic annual growth per acre	Mean annual growth per acre
Years	Cubic feet		
20	2018		101
		167	
30	3684		123
		124	
40	4925		123
		94	
50	5868		117
		60	
60	6465		108
		42	
70	6884		98
		24	
80	7124		89

Appendix Table 3

Growth and yield data for the pine-oak forest type on the Coastal Plain of Virginia (Giauque 1977).

Stand Age	Yield per acre	Current periodic annual growth per acre	Mean annual growth per acre
Years	Cubic feet		
20	780		39
		98	
30	1760		59
		79	
40	2550		64
		62	
50	3167		63
		46	
60	3624		60
		39	
70	4013		57
		31	
80	4325		54

Appendix Table 4

Growth and yield data for the upland hardwoods forest type on the Coastal Plain of Virginia (Giauque 1977).

Stand Age	Yield per acre	Current periodic annual growth per acre	Mean annual growth per acre
Years	Cubic feet		
20	148		7
		62	
30	772		26
		62	
40	1395		35
		58	
50	1980		40
		52	
60	2500		42
		45	
70	2951		42
		41	
80	3361		42
		37	
90	3729		41
		34	
100	4072		41

Appendix Table 5

Growth and yield data for the bottomland hardwoods forest type on the Coastal Plain of Virginia (Giaugue 1977).

Stand Age	Yield per acre	Current periodic annual growth per acre	Mean annual growth per acre
Years	Cubic feet		
20	539		27
		94	
30	1482		49
		82	
40	2305		58
		76	
50	3064		61
		65	
60	3715		62
		56	
70	4279		61
		53	
80	4811		60
		50	
90	5312		59
		49	
100	5799		58

Appendix Table 6 as an Illustration of Duerr's Timber Supply Model

Appendix Table 6 is based upon the normal yield tables of Giauque (1977) and calculations from Hassler (1978). It assumes a site index 80 (base age 50) natural loblolly pine forest and serves as an illustration of Duerr's timber supply model (Chapter II). The table assumes a production objective of cubic feet of pulpwood and a value of 10 cents per cubic foot.

Columns 1 and 2 show the yields associated with various rotation ages, as derived by Giauque (1977). Since these yields are associated with a regulated, sustained yield forest, an equal acreage is devoted to each 1-year age class and an even annual flow of timber may be expected. Then, yield (Column 2) divided by rotation age (column 1) results in annual yield per acre, or more commonly, mean annual growth (column 3).

Column 3 shows that average annual yield per acre can be increased for rotation lengths up to 40 years. The culmination of mean annual growth at 40 years would present the best rotation length only if there is no cost of holding timber over time (alternative rate of return equals zero percent). Column 4 gives the marginal volume for each additional 5 years of rotation length.

Lengthening the rotation requires the holding of increased levels of growing stock. Hassler (1978) estimated the volume of growing stock necessary to produce each increased output. The volume of required growing stock for each rotation length is given in column 5. Column 6 indicates the volume of the growing stock per acre and is obtained by dividing column 5 by rotation age (column 1). Column 7 shows the marginal volume of growing stock per acre needed to increase rotation length by 5 years. Column 8 gives the rate of return earned by the marginal growing stock needed for each 5-year lengthening of rotation. Column 8 is given by the value of the marginal yield (column 4 times 10 cents per cubic foot) expressed as a percentage of the value of the marginal growing stock needed to produce that yield (column 7 times 10 cents per cubic foot).

The table provides the framework to analyze the expected behavior of rational forest landowners. Consider a landowner who is debating a 20-year versus a 25-year rotation. His alternative rate of return is 6 percent. A 25-year rotation will require tying up $31.93 in growing stock (column 7 at 10 cents per cubic foot); this increases timber output by $1.68 (column 4). The rate of return on this marginal growing stock is 5.25 percent. Since this landowner has a 6 percent alternative rate of return, his best alternative investment would yield 0.75 percent more than the rate of return resulting from a lengthening of rotation. A rational forest landowner, seeking to maximize net revenue, will choose to forgo a 25-year rotation. His best option is to produce 77.55 cubic feet per acre over the next 20 years. The 25-year rotation would increase revenues to $9.43 per acre, but the owner could invest the $31.93 in extra required growing stock at 6 percent and add $1.92 to the $7.76 harvest value, giving a total return of $9.68.

Appendix Table 6 illustrates the relationship between the alternative rate of return and long-run timber output. The higher a forest landowner's alternative rate of return, the more heavily and often he tends to cut timber. That is, the alternative rate of return and long-run timber supply are inversely related.

Appendix Table 6

Rate of return on extra growing stock, for natural loblolly pine on average site in eastern Virginia (Hassler 1978).

Rotation Age (1)	Total Yield Per Acre (2)	Annual Yield Per Acre (3)	Marginal Yield Per Acre (4)	Total Growing Stock (5)	Growing Stock Per Acre (6)	Marginal Growing Stock Per Acre (7)	Return on Extra Growing stock (8)
Years	Cubic Feet						Percent
15	657	43.80		1642.5	109.5		
			33.75			248.63	13.57
20	1551	77.55		7162.5	358.13		
			16.77			319.27	5.25
25	2358	94.32		16935.0	677.40		
			8.35			340.27	2.45
30	3080	102.66		30530.0	1017.67		
			3.48			339.97	1.02
35	3715	106.14		47517.5	1357.64		
			0.46			328.99	0.14
40	4264	106.60		67465.0	1686.63		
			-1.58			312.04	-0.51
45	4726	105.02		89940.0	1998.67		
			-2.96			291.58	-1.02
50	5103	102.06		114512.5	2290.25		
			-4.01			268.89	-1.49
55	5393	98.05		140752.5	2559.14		

Appendix Table 7

Rate of return on extra growing stock, for planted loblolly pine on average site in eastern Virginia (Hassler 1978).

Rotation Age	Total Yield Per Acre	Annual Yield Per Acre	Marginal Yield Per Acre	Total Growing Stock	Growing Stock Per Acre	Marginal Growing Stock Per Acre	Return on Extra Growing Stock
Years		- - - - - - - - - -	Cubic Feet	- - - - - - - - - -			Percent
10	215	21.50		537.5	53.75		
			59.63			220.75	27.01
15	1217	81.13		4117.5	274.50		
			25.62			350.38	7.31
20	2135	106.75		12497.5	624.88		
			11.97			385.32	3.11
25	2968	118.72		25255.0	1010.20		
			5.11			388.55	1.32
30	3715	123.83		41962.5	1398.75		
			1.28			378.32	0.34
35	4379	125.11		62197.5	1777.07		
			-1.16			361.43	-0.32
40	4958	123.95		85540.0	2138.50		
			-2.77			340.78	-0.81
45	5453	121.18		111567.5	2479.28		
			-3.92			317.87	-1.23
50	5863	117.26		139857.5	2797.15		

Appendix Table 8

Rate of return on extra growing stock, for pine-oak on average site in eastern Virginia (Hassler 1978).

Rotation Age	Total Yield Per Acre	Annual Yield Per Acre	Marginal Yield Per Acre	Total Growing Stock	Growing Stock Per Acre	Marginal Growing Stock Per Acre	Return on Extra Growing Stock
Years	Cubic Feet						Percent
15	255	17.00		637.5	42.50		
			22.65			120.38	18.82
20	793	39.65		3257.5	162.88		
			11.99			175.82	6.82
25	1291	51.64		8467.5	338.70		
			6.63			196.80	3.37
30	1748	58.27		16065.0	535.50		
			3.53			202.86	1.74
35	2163	61.80		25842.5	738.36		
			1.65			201.52	0.82
40	2538	63.45		37595.0	939.88		
			0.35			196.06	0.18
45	2871	63.80		51117.5	1135.94		
			-0.54			188.11	-0.29
50	3163	63.26		66202.5	1324.05		
			-1.19			178.59	-0.66
55	3414	62.07		82645.0	1502.64		

Appendix Table 9

Rate of return on extra growing stock, for upland hardwood on average site in eastern Virginia (Hassler 1978).

Rotation Age	Total Yield Per Acre	Annual Yield Per Acre	Marginal Yield Per Acre	Total Growing Stock	Growing Stock Per Acre	Marginal Growing Stock Per Acre	Return on Extra Growing Stock
Years	- - - - - -	- - - - - -	- - - - - -	Cubic Feet	- - - - - -	- - - - - -	Percent
20	148	7.40		370.0	18.50		
			11.72			58.90	19.90
25	478	19.12		1935.0	77.40		
			7.41			93.27	7.95
30	796	26.53		5120.0	170.67		
			5.01			111.33	4.50
35	1104	31.54		9870.0	282.00		
			3.49			121.31	2.87
40	1401	35.03		16132.5	403.31		
			2.46			126.74	1.94
45	1687	37.49		23852.5	530.06		
			1.73			129.39	1.34
50	1961	39.22		32972.5	659.45		
			1.23			130.32	0.95
55	2225	40.45		43437.5	789.77		
			0.85			130.14	0.65
60	2478	41.30		55195.0	919.92		
			0.55			129.16	0.42
65	2720	41.85		68190.0	1049.08		
			0.31			127.60	0.24
70	2951	42.16		82367.5	1176.68		
			0.12			125.62	0.10
75	3171	42.28		97672.5	1302.30		
			-0.03			123.33	-0.02
80	3380	42.25		114050.5	1425.63		

Appendix Table 10

Rate of return on extra growing stock, for bottomland hardwood on average site in eastern Virginia (Hassler 1978).

Rotation Age	Total Yield Per Acre	Annual Yield Per Acre	Marginal Yield Per Acre	Total Growing Stock	Growing Stock Per Acre	Marginal Growing Stock Per Acre	Return on Extra Growing Stock
Years	Cubic Feet						Percent
15	35	2.33		87.5	5.83		
			24.62			70.30	35.02
20	539	26.95		1522.5	76.13		
			13.81			140.57	9.82
25	1019	40.76		5417.5	216.70		
			8.41			171.72	4.90
30	1475	49.17		11652.5	388.42		
			5.34			186.15	2.87
35	1908	54.51		20110.0	574.57		
			3.44			192.31	1.79
40	2318	57.95		30675.0	766.88		
			2.14			193.79	1.10
45	2704	60.09		43230.0	960.67		
			1.23			192.43	0.64
50	3066	61.32		57655.0	1153.10		
			0.57			189.26	0.30
55	3404	61.89		73830.0	1342.36		
			0.11			184.97	0.06
60	3720	62.00		91640.0	1527.33		
			-0.29			179.86	-0.16
65	4011	61.71		110967.5	1707.19		
			-0.58			174.13	-0.33
70	4279	61.13		131692.5	1881.32		

Appendix Table 11

Optimum rotations and yields, by guiding rates of interest and forest type for eastern Virginia (Hassler 1978).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Guiding	Planted Loblolly Pine			Natural Loblolly Pine			Pine-oak		
Rate of Interest	Rotation Age	Yield per Acre		Rotation Age	Yield per Acre		Rotation Age	Yield per Acre	
		Total	Annual		Total	Annual		Total	Annual
Percent	Years	---Cubic Feet---		Years	---Cubic Feet---		Years	---Cubic Feet---	
0	35.0	4379	125.11	38.6	4119	106.71	44.4	2833	63.81
3	23.0	2645	115.00	26.1	2525	96.74	28.5	1615	56.67
4	21.1	2325	110.19	24.2	2235	92.36	26.1	1395	53.45
5	19.7	2082	105.69	22.8	2013	88.29	24.4	1233	50.53
6	18.5	1868	100.97	21.8	1851	84.91	23.2	1117	48.15
7	17.7	1723	97.34	21.0	1719	81.85	22.4	1037	46.29
8	17.1	1612	94.27	20.3	1602	78.92	21.6	957	44.31
9	16.6	1519	91.51	19.6	1482	75.61	21.0	896	42.67
10	16.1	1426	88.57	19.1	1396	73.09	20.5	845	41.22
11	15.7	1350	85.99	18.6	1309	70.38	20.0	793	39.65
12	15.3	1274	83.27	18.3	1257	68.69	19.6	752	38.37

Appendix Table 11

Optimum rotations and yields, by guiding rates of interest and forest type for eastern Virginia (Hassler 1978) (continued).

	(11)	(12)	(13)	(14)	(15)	(16)
Guiding	Upland Hardwood			Bottomland Hardwood		
Rate of Interest	Rotation Age	Yield per Acre Total	Yield per Acre Annual	Rotation Age	Yield per Acre Total	Yield per Acre Annual
Percent	Years	---Cubic Feet---		Years	---Cubic Feet---	
0	76.6	3239	42.28	58.5	3627	62.00
3	37.0	1224	33.08	32.0	1651	51.59
4	33.7	1025	30.42	29.1	1395	47.94
5	31.5	890	28.25	27.3	1232	45.13
6	29.8	784	26.31	25.8	1094	42.40
7	28.5	702	24.63	24.6	981	39.88
8	27.5	638	23.20	23.7	896	37.81
9	26.6	581	21.84	23.0	830	36.09
10	26.0	542	20.85	22.4	772	34.46
11	25.4	503	19.80	21.8	714	32.75
12	24.9	471	18.92	21.4	676	31.59

Appendix Table 12

Projections of commercial forest acreage in eastern Virginia to 2020 (Hassler 1978).

County	1976 Acreage	Average Annual Population Change to 2020	Reduction Factor	2020 Acreage
	Acres	- - - - Percent - - - -		Acres
Accomack	114,092	+.49	3.0	110,669
Brunswick	290,505	+.06	3.0	281,790
Caroline	263,294	+.59	5.0	250,129
Charles City	87,509	+1.68	15.0	74,383
Chesapeake	113,784	+1.01	10.0	102,406
Chesterfield	211,294	+3.08	25.0	158,471
Dinwiddie	246,146	+1.67	15.0	209,224
Essex	107,164	+.56	5.0	101,806
Gloucester	96,044	+1.83	15.0	81,637
Greensville	138,074	-.42	1.0	136,693
Hampton	6,523	+1.38	10.0	5,871
Hanover	198,593	+3.44	25.0	148,945
Henrico	71,760	+1.64	15.0	60,996
Isle of Wight	123,178	+.49	3.0	119,483
James City	62,651	+3.11	25.0	46,988
King and Queen	160,961	+.31	3.0	156,132
King George	69,762	+.66	5.0	66,274
King William	125,112	+.37	3.0	121,359
Lancaster	51,686	+.17	3.0	50,135
Mathews	34,106	+.50	3.0	33,083
Middlesex	53,831	+.56	5.0	51,139
New Kent	101,407	+2.52	25.0	76,055
Newport News	15,442	+.92	5.0	14,670
Northampton	31,586	+.79	5.0	30,007
Northumberland	69,188	-.05	1.0	68,496
Prince George	119,660	+1.54	15.0	101,711
Richmond	79,027	+.33	3.0	76,656
Southampton	263,927	-.09	1.0	261,288
Suffolk	134,912	+.95	5.0	128,166
Surry	133,958	-.23	1.0	132,618
Sussex	248,554	+.05	1.0	246,068
Virginia Beach	57,598	+2.37	20.0	46,078
Westmoreland	86,931	+.85	5.0	82,584
York	35,280	+2.91	25.0	26,460
Totals	4,003,539			3,658,470

Appendix Table 13

Projections of commercial forest acreage for 2020 by forest type and ownership in eastern Virginia (Hassler 1978).

Type of Ownership	Planted Pine	Natural Pine	Pine-oak	Upland Hardwood	Bottomland Hardwood	Total Acreage
	Forest Type					
Public	7,500	45,856	31,523	90,634	10,724	186,237
Forest Industry	402,457	439,377	17,138	37,361	45,501	941,834
NIPF	211,231	666,555	395,446	934,857	322,310	2,530,399
Totals	621,188	1,151,788	444,107	1,062,852	378,535	3,658,470

Appendix Table 14

Current periodic annual growth and mean annual growth related to implied alternative rate of return

PINE

ARR %	Stand Age	Mean Annual Growth Per Acre	Current Periodic Annual Growth Per Acre
0	39	74.54	75
1	35	72.20	87
2	31	69.86	88
3	27	67.52	91
4	25	64.38	93
5	23	61.48	95

HARDWOOD

ARR %	Stand Age	Mean Annual Growth Per Acre	Current Periodic Annual Growth Per Acre
0	65	44.20	44
1	55	41.49	49
2	44	38.77	54
3	34	36.06	58
4	31	33.44	63

Appendix Table 15

Projections of commercial forest acreage in eastern Virginia, by forest type, 1976-2000.

Year	Planted Pine Acreage	Natural Pine Acreage	Pine-oak Acreage	Upland Hardwood Acreage	Bottomland Hardwood Acreage
1976	129,996	658,773	577,649	1,354,295	367,694
1977	131,842	658,950	573,508	1,344,762	366,663
1978	133,689	659,127	569,367	1,335,230	365,631
1979	135,535	659,304	565,226	1,325,670	364,600
1980	137,381	659,481	561,085	1,316,164	363,568
1981	139,227	659,657	556,944	1,306,631	362,537
1982	141,074	659,834	552,803	1,297,099	361,505
1983	142,920	660,011	548,662	1,287,566	360,474
1984	144,766	660,188	544,521	1,278,033	359,442
1985	146,612	660,365	540,380	1,268,500	358,411
1986	148,459	660,542	536,239	1,258,968	357,379
1987	150,305	660,719	532,098	1,249,435	356,348
1988	152,151	660,895	527,957	1,239,902	355,317
1989	153,998	661,072	523,816	1,230,369	354,285
1990	155,844	661,249	519,675	1,220,837	353,254
1991	157,690	661,426	515,534	1,211,304	352,222
1992	159,536	661,603	511,393	1,201,771	351,191
1993	161,382	661,780	507,252	1,192,238	350,159
1994	163,229	661,957	503,111	1,182,706	349,128
1995	165,075	662,133	498,970	1,173,173	348,096
1996	166,921	662,310	494,829	1,163,640	347,065
1997	168,767	662,487	490,688	1,154,107	346,033
1998	170,614	662,664	486,547	1,144,575	345,002
1999	172,459	662,841	482,407	1,135,042	343,971
2000	174,306	663,018	478,265	1,125,509	342,939

Appendix Table 16

Projections of the percentage of forest acreage in size of forest condition classes greater than or equal to 200 acres

Year	Pine Percentage	Hardwood Percentage
1976	17.1	24.1
1977	17.3	24.4
1978	17.5	24.6
1979	17.7	24.9
1980	17.9	25.2
1981	18.1	25.5
1982	18.3	25.7
1983	18.5	26.0
1984	18.7	26.3
1985	18.9	26.6
1986	19.1	26.9
1987	19.3	27.2
1988	19.5	27.5
1989	19.7	27.8
1990	20.0	28.1
1991	20.2	28.4
1992	20.4	28.8
1993	20.6	29.1
1994	20.9	29.4
1995	21.1	29.7
1996	21.3	30.1
1997	21.6	30.4
1998	21.8	30.7
1999	22.0	31.1
2000	22.3	31.4

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A LONG-RUN TIMBER OUTPUT PROJECTION MODEL FOR THE NONINDUSTRIAL PRIVATE FOREST SECTOR

by

Thomas James Straka

(ABSTRACT)

The nonindustrial private forest sector controls 58 percent of the nation's commercial forest area. Timber output from the NIPF has been a major forest policy issue throughout this century.

A long-run regional timber output projection model was developed for the NIPF sector. The model was based upon two key assumptions: (1) forest management intensity and timber output are inversely related to the forest landowner's alternative rate of return, and (2) for the NIPF sector, the alternative rate of return is inversely related to the size of forest holding.

The timber output model was based on a cross classification of NIPF land by its physical characteristics (e.g., forest type) and economic characteristics (e.g., landowner's alternative rate of return). The stratification objective was to create strata with a uniform timber output response to changes in the above characteristics. If the total forest resource is thought of in terms of a matrix, each characteristic serves as a stratification dimension,

creating a matrix composed of "homogeneous timber output response cells." The values of each cell can be used as observations in a regression analysis projecting NIPF timber output.

For the NIPF, the size of forest holding would be a primary stratification dimension. Due to the relationships described above, stratification by size of forest holding constitutes stratification by the landowner's alternative rate of return. Also, since the forest resource is physically uniform, the expected rate of return (marginal value growth percent) of the forest will be uniform within a cell. NIPF landowners base their timber output decision on the relationship between the expected and alternative rates of return, resulting in a convenient forest policy analysis tool.

The model was applied to a study region, Virginia's Coastal Plain, with satisfactory results.