BIBLIOGRAPHIC DATA SHEET

1. CONTROL NUMBER: PN AAK-753

2. SUBJECT CLASSIFICATION (695): AK00-0000-G714

3. TITLE AND SUBTITLE (240)

Investment analyses of fuelwood plantations in Sri Lanka.

4. PERSONAL AUTHORS (100)

Medema, E.L.; Hatch, C.R.; Christophersen, K.A.

5. CORPORATE AUTHORS (101)

Idaho Univ. College of Forestry, Wildlife and Range Sciences

6. DOCUMENT DATE (110): 1981

7. NUMBER OF PAGES (120): 135 p.

8. ARC NUMBER (170)

9. REFERENCE ORGANIZATION (130): Idaho

10. SUPPLEMENTARY NOTES (500)

11. ABSTRACT (950)

12. DESCRIPTORS (920)

Sri Lanka
fuelwood
investments
wooden logs
energy
energy consumption
energy needs

13. PROJECT NUMBER (150)

14. CONTRACT NO.(140): SS-SPIR-1-123

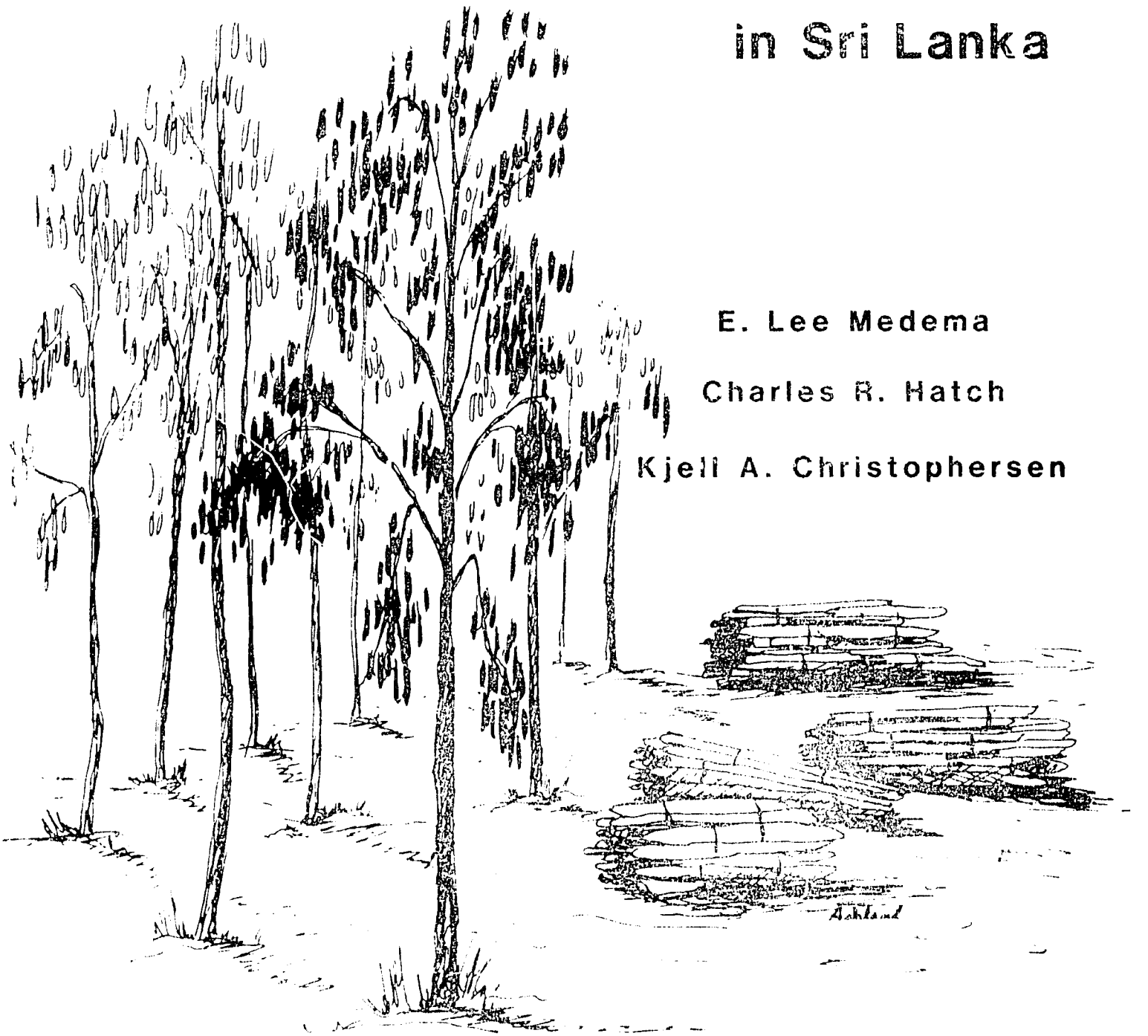
15. CONTRACT TYPE (140): RR

16. TYPE OF DOCUMENT (160)

AID 590-7 (10-79)

PN-MAK-753

Investment Analyses of Fuelwood Plantations in Sri Lanka



E. Lee Medema

Charles R. Hatch

Kjell A. Christophersen

Forest, Wildlife and Range Experiment Station

Contribution No. 221

August 1981

under contract with U.S.D.A., Forest Service

Investment Analyses of Fuelwood Plantations in Sri Lanka

E. Lee Medema,
Charles R. Hatch,
Kjell A. Christophersen

College of Forestry, Wildlife and Range Sciences
University of Idaho

September 1981

Submitted to:

United States Department of Agriculture
Forest Service/Science and Education Administration

Biomass Energy Team
PASA No. AG/05B-5709-6-79
with
USAID Office of Energy
Washington, D.C.

Contract No. 53-319R-1-123

ACKNOWLEDGMENTS

This study has drawn heavily on the insights and guidance of several colleagues. In Colombo, J. Bonner, P. Kumar and R. Thilak of the USAID Mission helped define the issues and problems considered in the study. They also greatly facilitated the collection of information from various sources. Dr. Vivekanandan and Mr. K. Emmanuel of the Sri Lanka Forest Department contributed substantially to our understanding of the technical and economic issues associated with wood production and agro-forestry activities in Sri Lanka. They also arranged two highly informative and useful field trips, on which Mr. Emmanuel accompanied the team.

In Washington, D.C., Gus Wahlgren, PASA core team leader; Jack Fritz, AID Office of Energy Program Officer; Kathleen McNamara and Robert Ichord, Asia Bureau; also helped focus the analyses by refining the scope and direction of the project and providing constant encouragement and support.

These individuals and others who contributed their time to review drafts, discuss issues and clarify ideas are gratefully acknowledged.

TABLE OF CONTENTS

		Page
Executive Summary		
1	Introduction	1
1.1	The Problem	1
1.2	The Objectives	3
1.3	The Scope	3
1.4	The Basic Procedures	6
2	Biological Considerations	12
2.1	Quantification of Biological Productivity	12
2.2	Quantification of Wood Fiber Yields	14
2.2.1	Development of Yield Curves	14
2.2.2	Yield Estimates for Coppice Rotations	20
2.3	Management Regimes	20
3	Investment Assumptions	22
3.1	Base Case Financial Analysis	22
3.1.1	The Discount Rate	22
3.1.2	Stumpage Price	25
3.1.3	Stumpage Price Appreciation Rate	28
3.1.4	Plantation Establishment Costs	31
3.1.5	Plantation Establishment Cost Appreciation Rate	33
3.2	Sensitivity Analysis	33
3.2.1	The Discount Rate	38
3.2.2	Stumpage Price	38
3.2.3	Stumpage Price Appreciation Rate	40
3.2.4	Plantation Establishment Costs	40
3.2.5	Plantation Establishment Cost Appreciation Rates	40
3.3	Base Case Economic Analysis	41
3.3.1	The Discount Rate	41
3.3.2	Plantation Establishment Costs	41
4	Financial Results	44
4.1	Net Present Value	44
4.1.1	Selection of the Preferred Management Regime	44
4.1.2	Comparison of Planting Systems	44
4.1.3	Comparison of Tree Spacing	47
4.1.4	Comparison of Replanting	47
4.2	Soil Expectation Values	48
5	Financial Analysis Sensitivity Results	51
5.1	Net Present Values	51
5.1.1	Effect of Changes in Assumptions on the Base Case Decision	51
5.1.2	Effect of Changes in Assumptions on the Selection of a Planting System	54

5.1.3 Effect of Changes in Assumptions on the Selection of Tree Spacing. 56
5.1.4 Effect of Changes in Assumption on Replanting 56
5.2 Interpolation and Extrapolation from the Sensitivity Analysis Results 59
5.2.1 Graphical Interpolations and Extrapolations. . 59
5.2.2 Mathematical Interpolations and Extrapolations 61
5.3 Break-even Analysis. 61

6 Economic Analysis Results. 65
6.1 Net Present Value. 65
6.2 Selection of the Preferred Management Regime . 65
6.3 Estimating Changes in Base Case Results Associated with Changes in Economic Assumptions. 69

7 Conclusions and Recommendations. 71
7.1 Biological Conclusions 71
7.2 Investment Conclusions - Financial Analysis. . 71
7.3 Investment Conclusions - Economic Analysis . . 72
7.4 Integrating Investment Analyses into the Planning Process 72
7.5 An Investment Analysis Format. 73

Literature Cited 75

Appendices

I *Eucalyptus camaldulensis* Yield Tables
II Mathematical Estimation Equations
III Graphical Presentation of Sensitivity Analyses
IV Glossary of Terms

LIST OF TABLES

		Page
3-1	Summary of Base Case Assumptions for the Financial Analysis	23
3-2	Determination of a Real Discount Rate	24
3-3	Average Annual Fuelwood Prices by District, 1979	26
3-4	Monthly Average Fuelwood Prices, 1979	27
3-5	Determination of the Real Price Appreciation Rate from Quarterly Average Retail Fuelwood Prices, 1979	29
3-6	Determination of the Real Price Appreciation Rate from Monthly Average Fuelwood Prices, 1979	30
3-7	Plantation Establishment Costs	32
3-8	Determination of Plantation Establishment Cost Real Appreciation Rate	34
3-9	Summary of Sensitivity Analysis Assumptions	39
3-10	Summary of Base Case Assumptions for the Economic Analysis	42
4-1	Base Case Results - Financial Analysis	45
4-2	Soil Expectation Values	49
5-1	Sensitivity Analysis Results	52
5-2	Planting System Comparisons - Sensitivity Analysis	55
5-3	Tree Spacing Comparisons - Sensitivity Analysis	57
5-4	Replanting Comparisons - Sensitivity Analysis	58
5-5	Coefficients of the Mathematical Models for Interpolation and Extrapolation from the Sensitivity Analysis Results	62
5-6	Break-Even Analysis Results	64
6-1	Base Case Results -- Economic Analysis	66
6-2	Internal Rate of Return - Economic Analysis	68

LIST OF FIGURES

		Page
1-1	Climatic Zones and Population Centers of Sri Lanka	5
1-2	Graphical Depiction of Financial Harvest Age	9
2-1	Site Index Curves for *Eucalyptus camaldulensis* in Sri Lanka	15
2-2	Yield Curve for *Eucalyptus camaldulensis* by Percent Survival and Tree Spacing - Site Index 9	17
2-3	Yield Curve for *Eucalyptus camaldulensis* by Percent Survival and Tree Spacing - Site Index 11	18
2-4	Yield Curve for *Eucalyptus camaldulensis* by Percent Survival and Tree Spacing - Site Index 13	19
2-5	Management Regimes	21
3-1	Example of Interpolation and Extrapolation for Assumptions with Linear Impact on Net Present Value	36
3-2	Example of Interpolation and Extrapolation for Assumptions with Geometric Impact on Net Present Value	37
4-1	Preferred Regime Decision Tree for Base Case Results - Financial Analysis	46
5-1	Preferred Regime Decision Tree for Sensitivity Analysis Results	53
5-2	Regime: Site Index 13 - 10' x 10' Spacing - 74 Percent Survival - Non-taungya Planting System	60
6-1	Preferred Regime Decision Tree for Base Case Results - Economic Analysis	67

EXECUTIVE SUMMARY

A major problem in Sri Lanka, as in other developing countries, is the heavy dependence on forest resources for domestic energy uses in the face of continuous deforestation. The government of Sri Lanka's response to the fuelwood problem is encouraging, but most of the attention, to date, has been focused on obtaining the maximum biological production of wood fiber from fuelwood plantations with little attention directed towards the costs associated with that production.

The objectives of this report are:

1) to determine the investment feasibility of growing woody biomass for energy in fuelwood plantations under alternative site productivity conditions and management regimes in Sri Lanka, and

2) to identify a procedure decision-makers in developing countries can use to determine the feasibility of establishing fuelwood plantations.

The focus of this report is limited to the investment analysis of fuelwood plantations. This analysis considers only the fuelwood plantation component of the total energy problem and does not directly consider land availability. The results are limited to *Eucalyptus camaldulensis* fuelwood plantations.

The analytical results include both a financial and an economic analysis. In view of the uncertainty associated with analyzing alternative investment schemes in fuelwood plantations, the financial analysis includes a base case scenario of investment assumptions and a sensitivity analysis of these assumptions. The economic analysis provides an estimate of the value of fuelwood plantations to the Sri Lanka society. Both the financial and economic analyses use the maximization of net present value (NPV) as a decision criterion for determining the efficient allocation of resources. In estimating future revenues and costs, the analysis uses real price appreciation rates and real discount rates.

Eucalyptus camaldulensis plantations were established in Sri Lanka just over a decade ago. Site index was selected as the quantitative measure for ranking the biological productivity of these plantations. Curves are developed that can be used by decision-makers to determine a plantation's productivity. Yield tables describing biological production in cubic meters/hectare at a given plantation age by productivity class are constructed. The analysis assumes two coppice crops follow the harvest of the initial plantation. Management regimes considered in the analysis focused on initial tree spacing within the plantation, the planting system used to establish the plantation, and the activities allowed during the maintenance of the plantation.

Base case investment assumptions used in the financial analysis are:

1) a discount rate of 10 percent;

2) a stumpage price for fuelwood of Rs 55/m^3;

3) an annual appreciation rate for fuelwood stumpage prices of 11 percent for five years followed by 5.5 percent through the harvest of the second coppice crop;

4) an average plantation establishment cost of Rs4,629/hectare. This cost varied by management regime;

5) an annual appreciation rate for plantation establishment costs of 10 percent for five years followed by 5.0 percent through the harvest of the second coppice crop.

In addition, procedures are provided for varying each of these investment assumptions in a sensitivity analysis framework so a decision-maker can determine whether a change in an assumption results in a change in the preferred course of action. Base case economic analysis assumptions reflected approximations of "shadow price" estimates for labor costs and lower discount rates.

The findings of the report are summarized in terms of the biological, financial, and economic analysis results. Major conclusions are:

Biological Analysis

- Site productivity as measured by locally derived site index curves ranges in site index from 9 to 14 in north central Sri Lanka.
- On site index 13 lands, plantations established at 6' by 6' spacing with high initial survival rates produce 24.5 m^3/ha/yr at culmination of mean annual increment.
- On site index 9 lands, plantations established at 10' by 10' spacing with high initial survival rates produce 2.0 m^3/ha/yr at culmination of mean annual increment.

Financial Analysis

- Fuelwood plantations on site index 11 and 13 lands generally have positive NPV's and are, therefore, financially desirable investments using a 10 percent discount rate.
- Investment assumptions are critically important for plantations established on lands classified below site index 11 if NPV's greater than zero are desired.
- Fuelwood plantations established on site index class 11 and 13 land produced internal rates of return greater than 11 percent.

Economic Analysis

- Fuelwood plantations on all site index classes have positive NPV's and are, therefore, economically desirable investments from a societal perspective.
- Fuelwood plantations on higher site index classes generally produced internal rates of return greater than 11 percent.

Chapter 7 identifies a procedure resource planners can use to determine the value of land for fuelwood plantations in Sri Lanka.

The Introduction on page 1 of this report identifies the contents of each chapter and suggests which chapters should be read in order to attain stated objectives.

1. INTRODUCTION

This report contains seven chapters. The first chapter defines the problem and identifies the procedures that were used in the analyses. The second chapter develops biological production functions for fuelwood plantations in Sri Lanka. The third chapter develops the investment assumptions that are used in both the financial and economic analyses of fuelwood plantations. The fourth chapter presents the most likely financial analysis results for fuelwood plantations in Sri Lanka. The fifth chapter displays changes in the financial analysis results created by modifying the most likely investment assumptions. The sixth chapter presents an economic analysis result for fuelwood plantations in Sri Lanka. The seventh chapter summarizes conclusions and outlines steps that must be considered when using this report as a tool in Sri Lankan fuelwood plantation decision-making processes. Each of these chapters can serve as a checklist for investment evaluations of fuelwood plantations and represents a step in the analytical process.

To obtain a general overview of the report one should read Chapters 1, 4, 6 and 7. If the biological and/or investment assumptions are of interest to the reader, Chapters 2 and/or 3 should be read. The effect on the results of changes in investment assumptions is addressed in Chapter 5. However, the reader must be familiar with Chapter 3 before reading Chapter 5. Individuals interested in applying this report's methodologies to fuelwood plantation problems in Sri Lanka should read Chapter 7.

For the reader who is unfamiliar with economic and forestry terminology, a glossary of terms is provided in Appendix IV.

1.1 The Problem

A major problem in Sri Lanka, as in other developing countries, is the heavy dependence on forest resources for domestic energy uses in the face of continuous deforestation.

In Sri Lanka, households, which account for about 60 to 70 percent of total energy consumption in this island nation, derive 85 to 90 percent of their energy needs from fuelwood. In rural households, which account for about 80 percent of Sri Lanka's population, the reliance is even greater, with about 98 percent of the cooking energy needs being filled by fuelwood (Eriksson 1979).

Firewood and other fuels associated with the traditional modes of production and the domestic use of the lower income group provide 60 percent of the total energy consumed in the country (Goonatillake 1980). Petroleum products and hydroelectricity associated with the more recent models of production and domestically with the higher income groups provide respectively 28 percent and 12 percent (Goonatillake 1980).

This heavy domestic dependence on fuelwood, coupled with extensive land clearing for slash and burn (chena) agriculture, and both legal and illicit tree harvesting for construction and industrial fuelwood has reduced forest cover in Sri Lanka from an estimated 44 percent (17.8 million hectares) of the total land surface in 1956, to an estimated 22 percent (8.7 million hectares) in 1976 (The People's Bank 1978).

The government of Sri Lanka (GOSL) and donor agencies recognize the importance of this problem as evidenced by (1) the national policy that planting fast-growing firewood species be a major long-term objective of the forestry sector, (2) increases in forestry department budgets for the establishment of fuelwood plantations, and (3) donor agency grants for establishing fuelwood plantations (Perera 1977, Perera 1979).

Although the response to the fuelwood problem is encouraging, to date, most of the attention has been focused on obtaining the maximum biological production of wood fiber from fuelwood plantations with little attention directed towards the costs associated with that production.

This is not to say that fuelwood plantations are not

subjected to financial or economic analyses prior to implementation, but rather, that such analyses are incomplete. Usually a pre-specified management regime is analyzed from a single investment point of view without determining whether or not alternative management regimes are financially superior.

1.2 The Objectives

The objectives of this report are (1) to determine the investment feasibility of growing woody biomass for energy in fuelwood plantations under alternative site productivity conditions and management regimes in Sri Lanka, and (2) to identify a procedure decision-makers in developing countries can use to determine the feasibility of establishing fuelwood plantations.

Although the specific analytical results of the investment analysis depend on the biological and economic conditions prevailing in Sri Lanka and are therefore applicable to only that country, the analytical procedure could be applied to analyses of fuelwood plantations in other developing countries.

1.3 The Scope

The focus of this report is limited to the investment analysis of fuelwood plantations.

Because of this focus, the scope of the results has certain limitations.

This analysis considers only the fuelwood plantation component of the total energy problem.

Although we recognize fuelwood is only a part of the total energy problem in Sri Lanka and other developing countries, this report does not directly address alternative sources of energy. In order to understand and deal with a country's total energy problem, one should first completely understand each of the individual components. This report provides an understanding of the investment consequences of fuelwood plantations, one of the important components. The results associated with fuelwood plantations can be directly compared with results associated with alternative sources of

energy. Such an undertaking, however, is beyond the scope and intent of this report.

This analysis does not consider land availability.

Since the focus of the report is fuelwood plantations, alternative uses of the land associated with these plantations were not considered. A profit-maximizing resource owner would allocate his land to its highest valued use. Existing and potential fuelwood plantation lands in Sri Lanka and other developing countries, could, therefore, be used for non-forestry uses such as grazing or cultivated agriculture, or for alternative forestry uses such as pulpwood or sawlog plantations. Allocation decisions could be determined by comparing the results associated with fuelwood plantations to similar results associated with alternative land uses.

This analysis does not estimate the total plantation acreage needed to meet the demand for fuelwood in Sri Lanka.

The determination of the total plantation acreage needed to satisfy the fuelwood demands in Sri Lanka, if it were to be useful, would go beyond merely dividing the production per acre into an estimate of present fuelwood consumption. Rather, it would necessitate determining future fuelwood demands, alternative fuelwood supplies, the degree of substitutability and availability of alternative energy sources, and the future state and availability of fuelwood energy conversion technology, including stoves and charcoaling processes.

This analysis is limited to Eucalyptus camaldulensis *fuelwood plantations.*

Eucalyptus camaldulensis is the species predominately planted in fuelwood plantations in Sri Lanka. These plantations are located in the dry zone of Sri Lanka (Figure 1-1). This species was selected a number of years ago by the Sri Lankan Forest Department when they first began establishing fuelwood plantations. This species has frequently been selected for fuelwood plantations throughout the world, and

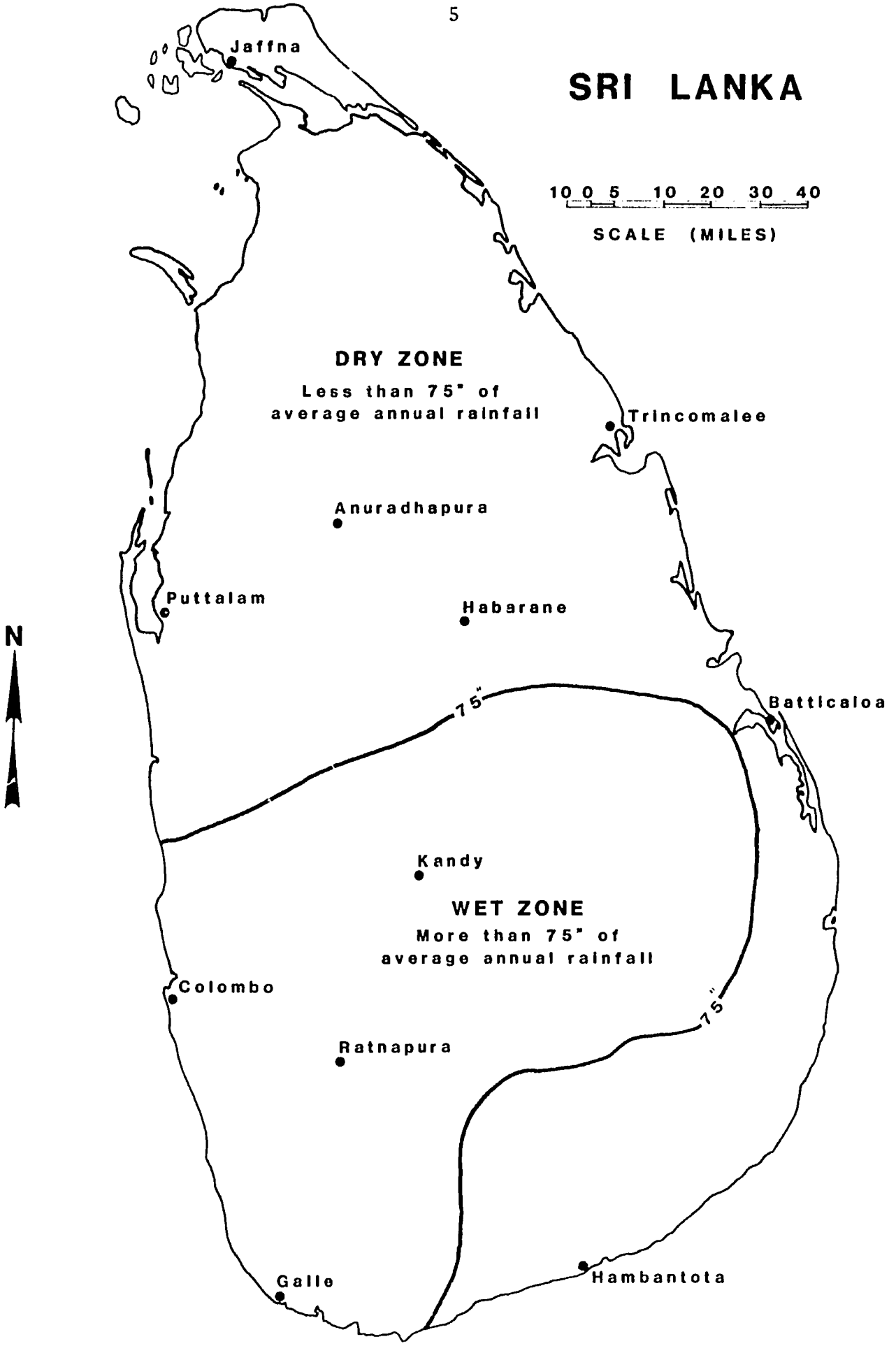


Figure 1-1. Climatic Zones and Population Centers of Sri Lanka.

its environmental requirements and limitations are well documented (Hillis and Brown 1978, Ayensu et al. 1980). Although *Eucalyptus camaldulensis* may not be the optimal species for this purpose, the lack of information on other species in Sri Lanka precluded the consideration of alternatives.

1.4 The Basic Procedures

The analytical results will include both a financial and an economic analysis.

A financial analysis of a project focuses on measuring the returns to an investor based on the costs and revenues actually occurring to the investor. This reflects the perspective of a private enterprise investor who is considering fuelwood projects in Sri Lanka. Therefore, prevailing market prices are used to measure the relative values of revenues and costs.

In an economic analysis, one takes a broader perspective by measuring the returns that accrue to society as a whole. This more likely reflects a government agency's perspective. In this analysis, market prices are replaced with "shadow prices" intended to reflect the "real" values to society of revenues and costs. The "shadow prices" may differ from market prices because of various market distortions resulting from taxes, subsidies, various government controls, income distribution, and economic externalities.

In view of the uncertainty associated with analyzing alternative investment schemes in fuelwood plantations, the financial analysis includes a base case scenario of investment assumptions and a sensitivity analysis of these assumptions.

The decision to invest in fuelwood plantations entails the commitment of resources now in exchange for future volume yields and revenues. In an analytical sense the investment may be viewed as flows of costs and revenues over time. Analyses of these flows of costs and revenues over time are based on predictions about future market conditions that determine the relevant values and costs. Since markets

are subject to unanticipated fluctuations, however, such predictions and corresponding analytical results must be interpreted with caution. Such is the case in developed countries and perhaps to an even greater extent in developing countries.

In view of the uncertainties, this report presents a base case financial analysis which reflects our most likely estimate of future market conditions in Sri Lanka and a sensitivity analysis which reflects the result of fluctuations around the base case assumptions. Since potential investors in fuelwood plantations will have alternative expectations of future market conditions, the base case assumptions and results will not reflect all expectations nor are they intended to do so. However, alternative economic expectations are considered and displayed in the sensitivity analysis.

The sensitivity analysis also reflects the extent to which assumptions concerning future market conditions are critical. If, for example, the sensitivity analysis indicates that a relatively small change in a base case assumption results in a small change in the analytical results, the precision with which that assumption is estimated is not as critical as when a relatively small change in a base case assumption results in a large change in the analytical results.

A base case economic analysis provides an estimate of the value of fuelwood plantations to the Sri Lankan society.

Ideally the base case market value assumptions used in the economic analysis would be documentable "shadow prices." The empirical estimation of "shadow prices" for an economic analysis is a complicated process which has been done in only a few countries--Sri Lanka not being one of them. The differences between the values associated with market prices and "shadow prices," however, is merely one of magnitude. Although these magnitudes are not known or documented in Sri Lanka, a range of market prices and economic assumptions are

defined in this study. A set of the economic assumptions that reflect the results that might be obtained with the use of "shadow prices" is presented as a base case economic analysis.

Both the financial and economic analyses use the maximization of net present value (NPV) as a decision criterion for determining the efficient allocation of resources.

In analyzing investments in fuelwood plantations, alternatives are considered and a selection is made from among the alternatives. The alternatives include the plantation's management regimes (tree spacing and planting methods), and the plantation's harvest ages (the selection of ages at which to harvest the original plantation and subsequent coppice crops). Presumably, an investor selects the alternative that yields the greatest return, i.e., the largest NPV. If the alternative with the largest NPV is greater than zero, that alternative is preferred and financially desirable. If the alternative with the largest NPV is less than zero, then, it is the preferred alternative, but it is not financially desirable.

The harvest age of fuelwood plantations in Sri Lanka has been determined by establishing an arbitrarily selected target diameter or age for the plantation (Bollinger 1979, The World Bank 1980, USAID 1980). When the plantation reaches the target diameter or age, the plantation is harvested. In this analysis, the harvest age is not predetermined but is instead identified as the age when the harvest of the plantation and the subsequent coppice crops maximizes the NPV of the revenues and costs.

The determination of an optimal harvest age (r) is depicted in Figure 1-2. Given a management regime, the NPV generally increases[1/] as the plantation reaches maturity.

[1/] The NPV of a plantation may indeed decrease over time or if it increases may not become greater than zero. In those cases, the optimal harvest age would be zero and one would not undertake the investment.

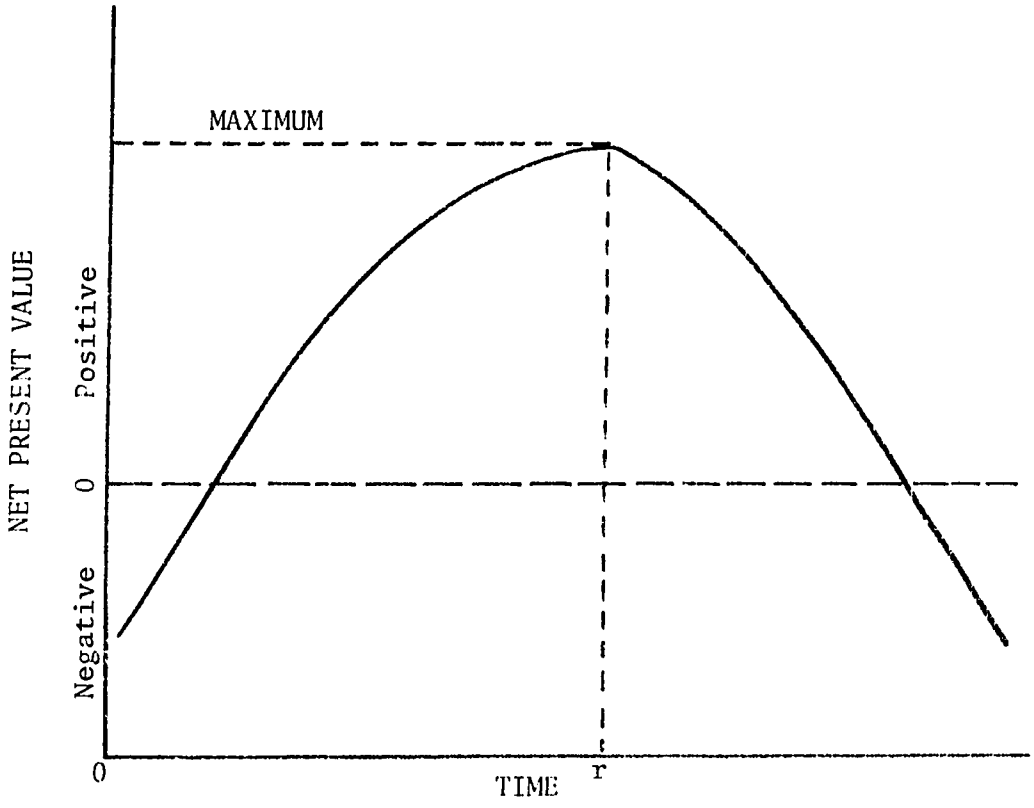


Figure 1-2. Graphical Depiction of Financial Harvest Age (r).

In both the financial and economic analysis, the optimal harvest age (r) occurs at the time of maximum NPV. Establishment of a harvest age by means of a diameter target, unless by coincidence, will not be consistent with the financial or economic harvest age and, hence, will not result in as efficient an allocation of resources. Furthermore, financial and economic optimal harvests depend on the management regime, the productivity of the land, and the investment assumptions used in the analysis. Therefore, a change in any of these conditions may change the optimal harvest age.

In estimating future revenues and costs, the analysis uses real price appreciation rates and real discount rates.

Real appreciation rates and discount rates are simply the nominal rates corrected for inflation. Consistent use of real or nominal rates of price appreciation and discounting will yield the same analytical results since the "effective" rate is the same in either case. However, by using real instead of nominal rates, one does not have to predict the rate of inflation.

This procedure yields real internal rates of return. The use of nominal appreciation and discount rates would result in larger internal rates of return.

Soil expectation value (SEV) will be determined for the base case financial analysis.

A SEV analysis is a special case of a NPV analysis. The SEV is the NPV of an infinite series of plantings and coppicings on a particular parcel of land. The NPV reflects the discounted benefits and costs of the first plantation and subsequent coppice crops. SEV is derived from the rationale that the value of a parcel of land for fuelwood use is equal to the net value of the fuelwood crops the land can produce *ad infinitum.*

SEV is useful in determining how one might allocate land among alternative uses. When considering an investment in fuelwood plantations, the investor could compare the

value (SEV) of a parcel of land used as a fuelwood plantation with the value (SEV) of the same parcel of land under an alternative use. The alternative use could include various agricultural crops or alternative forestry crops such as pulpwood plantations or sawlog plantations. The use producing the largest SEV would be the preferred and financially desirable use.

2. BIOLOGICAL CONSIDERATIONS

The Eucalyptus camaldulensis *plantations were established in Sri Lanka just over a decade ago.*

All of the plantations were placed in the monsoon forest and shrub lands located in the dry zone, which averages less than 75 inches of rainfall annually. Since the soil types in Sri Lanka coincide with the major climatic zones, the soils of the dry zone are predominantly Red Earths. Red Earths are characterized by a generally loamy texture, a humus content of 2-percent or less, partial leaching, a pH of 7-8, good depth, and a low silica and high iron oxide content; have a low waterholding capacity so they tend to dry up soon after the rains cease; and are a relatively fertile tropical soil (Library of Congress 1978).

Until 1979, plantation trees were planted at 10' by 10' spacings. Recently plantations with 6' by 6' spacing between trees have been established for fuelwood production.[2/] To date, none of the plantations have been harvested.

2.1 Quantification of Biological Productivity

Site index was selected as the quantitative measure for ranking biological productivity of Eucalyptus camaldulensis *plantations.*

Individual *Eucalyptus camaldulensis* plantations in Sri Lanka were not ranked in order of biological productivity. In assessing the biological and economical potential of fuelwood plantations it was necessary that we rank the plantations by their productive capacity.

The Red Earths soil type does not occur uniformly throughout the dry zone but varies in productivity depending on factors such as local rainfall and water-holding capacity. Therefore, in this study, site index was the quantitative

---

[2/] The Sri Lankan Forest Department used tree spacing based on distances measured in feet instead of metric units. Although all other plantation measurements in this report are in metric units, tree spacing is described in feet to be consistent with Forest Department practices.

measure selected to assign plantations to biological productivity classes. Site index relates the height of the tallest trees in a plantation to the age of the plantation. The taller the trees for a given age, the more productive the plantation. It was selected because it provides a relatively easy procedure for indexing biological productivity and can be related to climatic and edaphic factors.

Site index curves are developed for Eucalyptus camaldulensis *in Sri Lanka.*

Several *Eucalyptus camaldulensis* plantations near the Puttalam and Habarane areas of Sri Lanka were visited. Diameter at breast height and total height were measured on individual sample trees within each plantation. In addition, plantation age and initial and current spacing between trees were recorded.

The data for each of the sampled plantations were used to develop a height-diameter curve. The height associated with the mean diameter of the 250 largest trees per hectare in a plantation was estimated from the height-diameter curve. Site index curves were then constructed using these estimated height-plantation age data. A base age of six years was used in constructing the site index curves because of the age of the sampled plantations and to simplify comparisons with similar site index studies in India (Sharma 1978, Sharma 1979).

Nonlinear regression was used to estimate the site index curve coefficients from the sampled plantation data. The following height-age relationship was obtained for each site index:

$$H_S = S(1.4478 - 1.2789e^{-0.1748A})$$

where: H_S is mean total height of the largest 250 trees/hectare in meters

S is site index in meters at base age of 6 years

A is plantation age in years

e is base of the natural logarithms

Figure 2-1 illustrates the height-age relationship for site indices 9, 11 and 13. *Eucalyptus camaldulensis* plantations in the Puttalam and Habarane areas of Sri Lanka had site indices ranging between 9 and 14. The results are similar to site index curves developed for *Eucalyptus tereticornis* in India (Sharma 1978, Sharma 1979).

Plantations with the higher site indices are associated with Red Earths soils that have greater than average water-holding capacity and in dry zone areas that receive the greatest annual rainfall. In the absence of existing *Eucalyptus camaldulensis* plantations, these edaphic and climatic factors can be used to estimate the biological productivity of the land.

2.2 Quantification of Wood Fiber Yields

Yield curves are used to quantify biological production within each productivity class.

The biological production through time of individual *Eucalyptus camaldulensis* plantations in Sri Lanka is not documented. This information is needed by land productivity class before the investment potential of fuelwood plantations can be assessed. Yield curves relate the biological production of a plantation at a given age to a specified productivity class and are used as the basis for the investment analysis.

2.2.1 Development of Yield Curves

The sampled plantation data and the site index curves were used to estimate the diameter and height of the average-sized tree in a plantation of a given age. The volume of this average-sized tree multiplied by the number of trees per hectare in the plantation provided an estimate of the volume/hectare at that given age. By repeating this process for each year, the plantation yields through time were developed. The specific procedures and assumptions associated with this process are described in the following paragraphs.

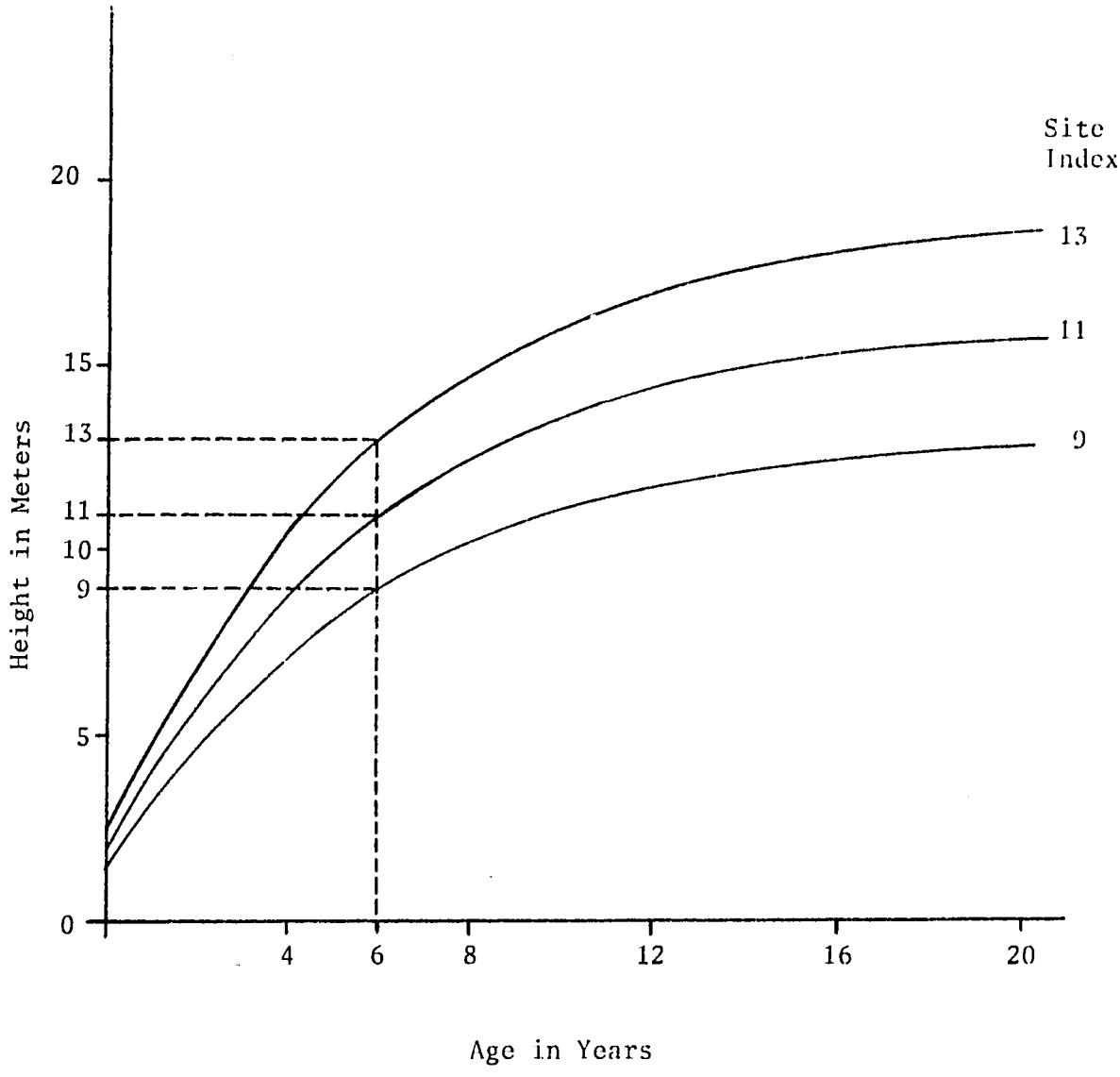


Figure 2-1. Site Index Curves for Eucalyptus camaldulensis in Sri Lanka

From a selected site index curve the height of the largest 250 trees/hectare was estimated for a given age. The sampled plantation data defined the following relationship between the mean plantation height and the height of the largest 250 trees/hectare:

$$H_m = 0.83H_s$$

where: H_s is mean total height of the largest 250 trees/hectare in meters

H_m is mean total height of the plantation in meters

Using the previously constructed height-diameter curves and the estimated value of H_m, a diameter for the tree of average height was obtained. The estimated tree diameter and height values were used to compute volume/tree in cubic meters inside bark (Veiga and Carvalho 1972).

Yield curves were developed for plantations where trees were initially planted at 6' by 6' and 10' by 10' spacings. Sampled plantation data and Sri Lanka Forest Department data (Vivekanandan 1979) were used to estimate the expected tree survival in plantations. Observed rates ranged from 65 to 100 percent survival with mortality generally occurring in the plantation during the first two years. Improved nursery and planting procedures have resulted in the more recent plantations exhibiting higher survival rates. As a result of this analysis, yield curves were developed using approximately 74 and 94 percent survival rates. The combination of percent survival and tree spacing resulted in established plantations with 800, 1000, 2200, and 2800 stems/hectare.

Figures 2-2, 2-3, and 2-4 illustrate yields by percent survival and tree spacing for three site index classes, respectively. Appendix 1 provides a tabular representation of these figures. Since the data used to develop these yield curves were solely based on 10' by 10' spacings, it was necessary to reflect the impact of increased competition on the yield curves by reducing the estimated average diameter and height of trees in dense plantations. These yield

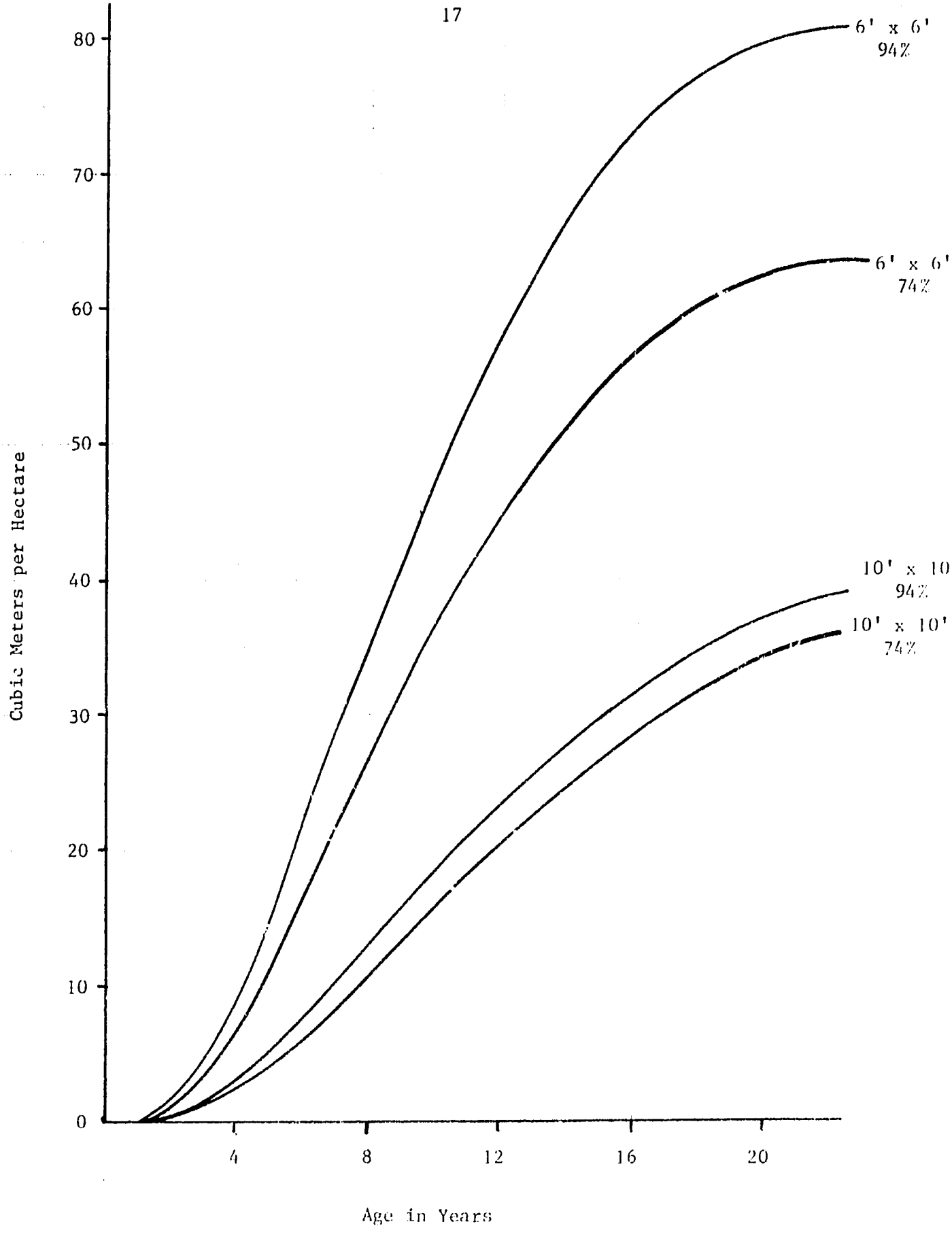


Figure 2-2. Yield Curve for Eucalyptus camaldulensis by Percent Survival and Tree Spacing - Site Index 9

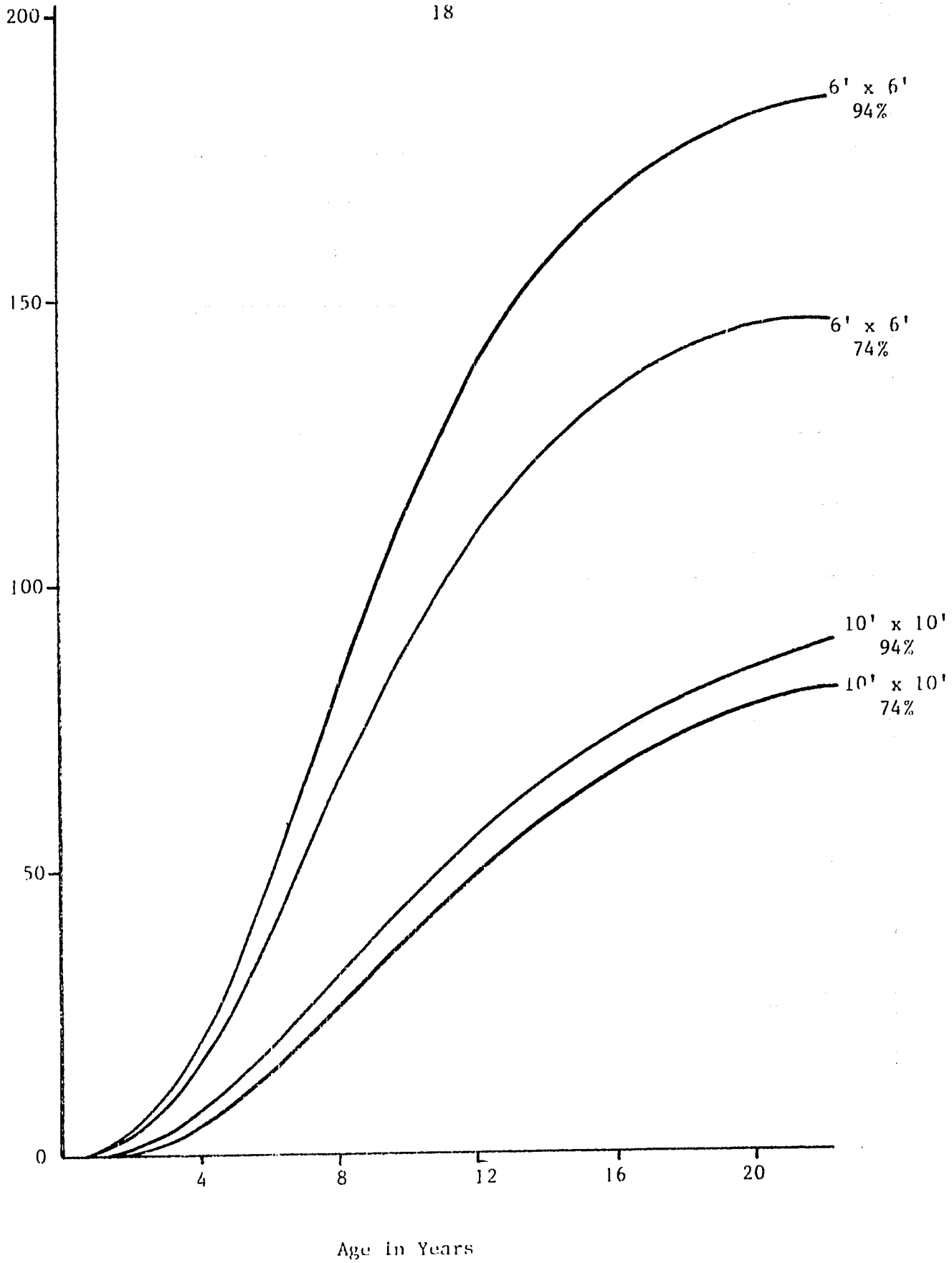


Figure 2-3. Yield Curve for Eucalyptus camaldulensis by Percent Survival and Tree Spacing - Site Index 11

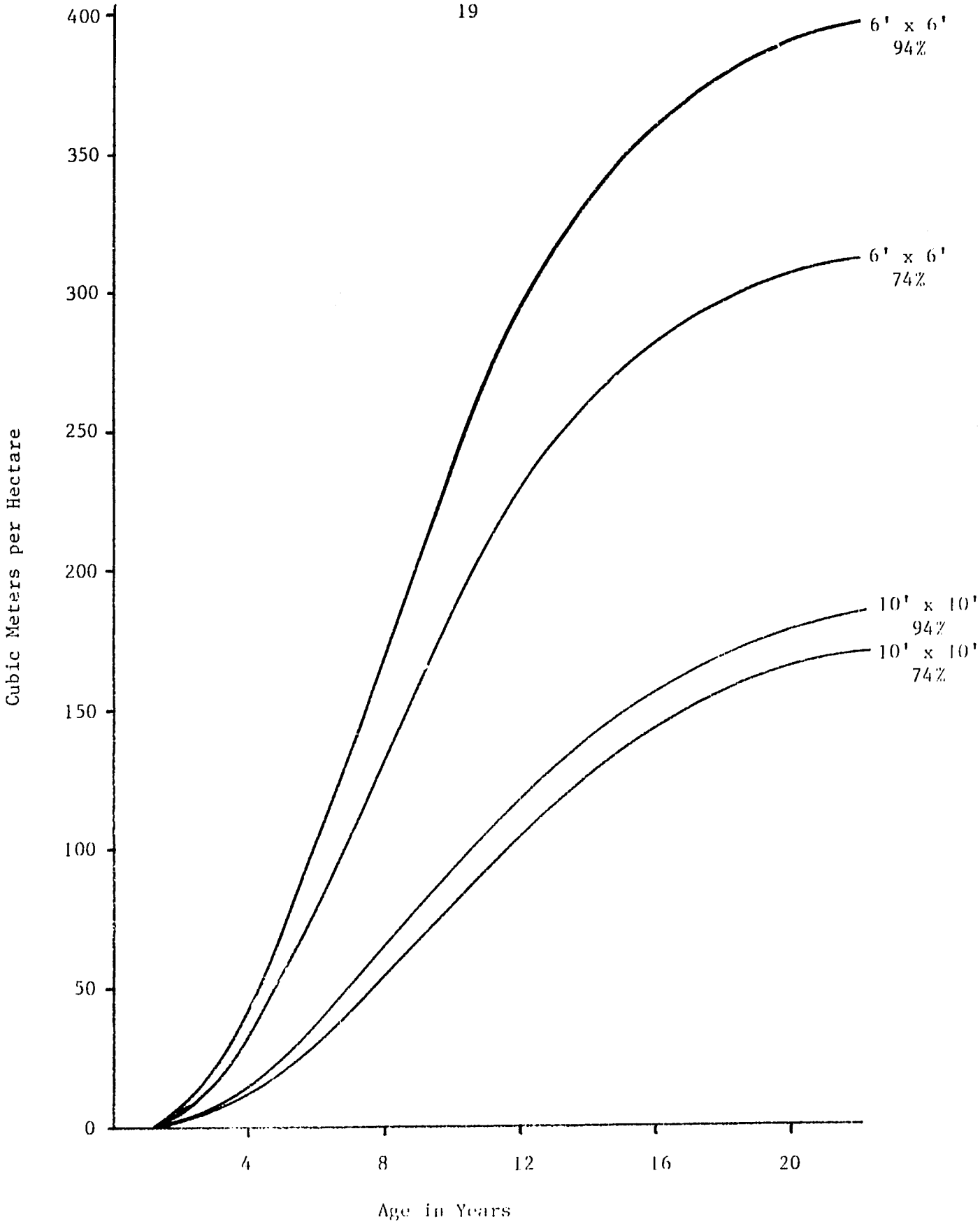


Figure 2-4. Yield Curve for Eucalyptus camaldulensis by Percent Survival and Tree Spacing - Site Index 13

curves compare favorably to values reported on similar sites by Sharma (1978) for *Eucalyptus tereticornis* in India.

2.2.2 Yield estimates for Coppice Rotations

Since none of the *Eucalyptus camaldulensis* plantations have been harvested in Sri Lanka, there is no information on yields associated with coppice crops. The literature indicates yields associated with the first coppice can vary from 120 to 80 percent of the original plantation yield (Myburgh 1967, Hillis and Brown 1978). These same studies also indicate subsequent coppices always yield less than the original plantation by 10 to 40 percent, depending on the coppice. Based on this literature and the assumption of two coppices, yield for the first and second coppice crops was 95 and 85 percent of the original plantation yield, respectively.

2.3 Management Regimes

Figure 2-5 illustrates the management regimes considered in each site class. All trees in a plantation were initially planted and the first harvest was followed by two coppice crops. In plantations with 10' by 10' spacing, both taungya and non-taungya planting systems were evaluated. Under the taungya planting system, a farmer is hired to clear a site, plant the trees and maintain the site in exchange for a fee and the right to intercrop the land. Since intercropping is not possible in plantations with 6' x 6' spacing, the taungya planting system was not analyzed. Replanting occurred one year after the original planting when the initial survival was less than 94 percent. Replanting increased survival to 94 percent. Weedings were conducted during the first, second, and third years of the initial plantation and of each coppice. No intermediate removals were considered. The same yield curves were used for both the taungya and non-taungya planting systems. When continued yields were desired following the harvest of the second coppice crop, it was necessary to replant the plantation.

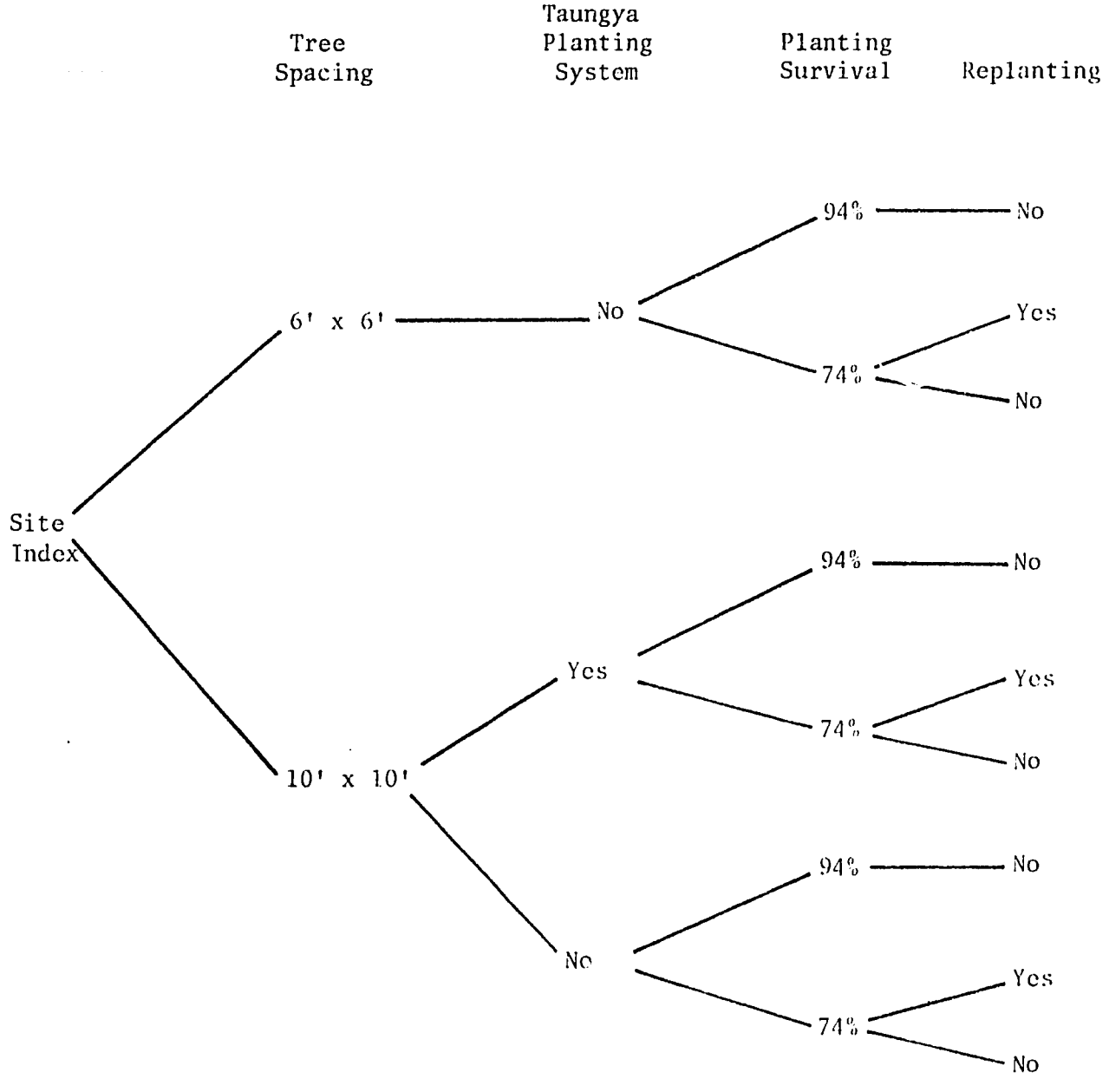


Figure 2-5. Management Regimes

3. INVESTMENT ASSUMPTIONS

This chapter presents the assumptions used in the base case financial analysis, documents the variation about the base case assumptions and identifies the base case assumptions used in the economic analysis. The derivation of each assumption is briefly discussed.

3.1 Base Case Financial Analysis

The assumptions necessary to undertake an investment analysis include the discount rate, current values of revenue, and cost items explicit in the management of fuelwood plantations and the duration and rate of value changes of these revenue and cost values during the life of the investment. Table 3-1 summarizes the base case assumptions for the financial analysis.

3.1.1 The Discount Rate

The base case discount rate is 10 percent in real terms.

The determination of an appropriate discount rate is, at best, a difficult undertaking. Economic theory suggests that the discount rate used in analyzing investments should represent the investor's opportunity cost of capital, which is measured by returns on possible alternative investments. Since returns on alternative investments are often difficult to determine and are not homogeneous between investments or investors, the selection of an appropriate discount rate is often an arbitrary and controversial undertaking.

The empirical determination of a discount rate for this analysis was based on a comparison between a measure of the annual rate of inflation, the Colombo Consumer's Price Index, and the annual rates used by major lending and savings institutions in Sri Lanka for the period 1976-1979 (Table 3-2).

As measured by the price index, the average rate of inflation for this period was 6.33 percent. However, the

Table 3-1. Summary of Base Case Assumptions for the Financial Analysis.

Assumption	Base Case
A. Discount Rate	10.0%
B. Stumpage Price	Rs 54.75/m^3
C. Stumpage Price Appreciation Rate	11% for 5 years; 5.5% through the harvest of the second coppice crop
D. Plantation Establishment Costs	
1. 10' x 10' spacing	
a. Non-taungya System	
i. Site Preparation	Rs 1,668/Hectare
ii. Planting	Rs 1,489/Hectare
iii. Weeding	
First year	Rs 247/Hectare
Second year	Rs 680/Hectare
Third year	Rs 445/Hectare
iv. Protection	Rs 45/Hectare/year
v. Replanting	Rs 308/Hectare
b. Taungya System	
i. Site Preparation	Rs 48/Hectare
ii. Planting	Rs 1228/Hectare
iii. Weeding	
First year	Rs 110/Hectare
Second year	Rs 139/Hectare
Third year	Rs 445/Hectare
iv. Protection	Rs 45/Hectare/year
v. Replanting	Rs 140/Hectare
2. 6' x 6' spacing	
a. Non-taungya System	
i. Site Preparation	Rs 1,668/Hectare
ii. Planting	Rs 3,781/Hectare
iii. Weeding	
First year	Rs 247/Hectare
Second year	Rs 680/Hectare
Third year	Rs 445/Hectare
iv. Protection	Rs 45/Hectare/year
v. Replanting	Rs 855/Hectare
E. Plantation Establishment Cost Appreciation Rate	10% for 5 years; 5% through the harvest of the second coppice crop.

Table 3-2. Determination of a Real Discount Rate.

Year	Colombo Consumer's Price Index-All Commodities* (1952=100) Index	Annual Percent Change	Annual Lending Rate of The State Mortgage And Investment Bank**	Annual Rate Paid on Long Term Accounts by the National Savings Bank**
1976	200.7	1.21	12.00	7.50
1977	203.2	1.25	12.00	18.00
1978	227.8	12.11	15.00	18.00
1979	252.3	10.76	15.00	18.00
Average		6.33	13.50	15.38

* Central Bank of Ceylon. 1979. Review of the economy. Control Bank of Ceylon, Columbo, Sri Lanka. Appendix table 60.

** Central Bank of Ceylon. 1980. Central Bank Bulletin 30(R). Appendix table 10.

lending rate charged and savings rate paid were 13.50 and 15.38 percent, respectively. Since the lending and saving rates are the actual rates used, they include inflation and are therefore nominal rates. The lending and saving rates in the absence of inflation (real rates) are 6.74 and 8.51, respectively.[3/]

Second, the annual rate paid by the National Savings Bank and the annual rate charged by the State Mortgage and Investment Bank are relatively low in risk compared to investments in fuelwood plantations. For example, the rate paid by the National Savings Bank is a guaranteed rate on 12-month deposits. However, there are certain risks involved in fuelwood plantation investments. One faces potential natural disasters, such as insect and disease damage which may increase because of monoculture practices, elephant damage, and the widespread problem of illicit tree felling that can result in the loss of a portion or all of a plantation. These risks translate into a need for a higher return on investment in order to entice investors. Therefore, the real discount rate used in this analysis is 10 percent. This reflects an 8-percent institutional discount rate plus a 2-percent risk factor.

3.1.2 Stumpage Price

The base case stumpage price for fuelwood is Rs 54.75/m^3.

A retail fuelwood price was derived by averaging reported 1979 retail fuelwood prices from two sources--the reported retail fuelwood prices in Sri Lanka by district (Table 3-3) and the reported retail fuelwood prices in 1979 by month for all districts (Table 3-4). The average of the retail prices from both tables is Rs 136.88/m^3. However, in this analysis we are concerned with the amount paid for standing timber (stumpage prices) and not with retail prices. Stumpage price is obtained by deducting the costs of harvesting and

---

[3/] $\text{Real Rate} = \left(\frac{1+\text{ nominal rate}}{1+\text{ inflation rate}} - 1.0\right) \times 100$

Table 3-3. Annual Average Fuelwood Prices by District, 1979. *

District	(Rs/Cwt)	Rs/m^3 1/
Colombo	12.19	169.47
Kalutara	9.02	125.40
Galle	7.89	109.69
Matara	9.41	130.82
Ratnapura	10.31	143.34
Kegalla	9.01	125.26
Kurunegala	8.46	117.62
Puttalam	12.05	167.53
Kandy	12.26	170.45
Matale	9.06	125.96
Nuwara Eliya	14.94	207.71
Badulla	10.69	148.62
Moneragala	7.30	101.49
Jaffna	14.39	200.06
Vavuniya	8.95	124.43
Mannar	7.36	102.32
Anuradhapura	6.75	93.84
Polonnaruwa	6.00	83.42
Trincomalee	7.68	106.77
Batticaloa	14.65	203.67
Amparai	5.94	82.58
Hambantota	10.10	140.42
Average		135.49
St. Dev.		37.45

* Central Bank of Ceylon. 1979. Price and wage statistics: Recent trends in retail, producer, and input prices and wages. Vol. 1, No. 2. Colombo, Sri Lanka. pp. 1-88.

1/ Conversion from Rs/cwt to Rs/m^3 assumes 13.902 cwt/m^3 of fuelwood.

Table 3-4 Monthly Average Fuelwood Prices, 1979. *

Month	Rs/Cwt	Rs/m^3 1/
January	8.55	118.87
February	8.86	123.18
March	8.85	123.04
April	9.26	128.74
May	9.30	129.29
June	9.51	132.21
July	9.86	137.08
August	9.36	130.13
September	10.64	147.92
October	11.52	160.16
November	11.61	161.41
December	12.02	167.11
Average		138.26
St. Dev.		16.66

* Central Bank of Ceylon. 1979. Economic and Social Statistics of Sri Lanka. Vol. II, No. 2. Colombo, Sri Lanka. p. 76.

1/ Conversion from Rs/cwt to Rs/m^3 assumes 13.902 cwt/m^3 of fuelwood.

transporting the fuelwood to retail outlets from the retail price.

The retail prices shown in Tables 3-3 and 3-4 are those charged for fuelwood at urban wood depots, including the GOSL's State Timber Corporation (STC) depots. The STC prices are determined on a cost of production plus profit basis. Thus, the retail price includes the costs of harvesting, transporting, loading and unloading the fuelwood plus a 40-percent profit margin to the GOSL.

Since the difference between retail price and production costs determines the stumpage value, the 40-percent profit margin can be viewed as a residual stumpage value if the landowner is the GOSL. Because the fuelwood market is competitive, private fuelwood depot prices in Sri Lanka should be similar to STC depot prices. Since the private dealers face the same costs of production, their profit margins should be similar. For these reasons, stumpage values in the base case analysis are 40 percent of the average retail fuelwood price.

3.1.3 Stumpage Price Appreciation Rate

The annual appreciation rate for fuelwood stumpage prices is 11 percent in real terms for five years followed by 5.5 percent in real terms through the harvest of the second coppice crop.

An annual price appreciation rate for fuelwood stumpage was derived from two sources--the reported quarterly fuelwood prices in Sri Lanka by district and the average quarterly prices in 1979 for all districts (Table 3-5) and the reported monthly retail prices in 1979 for all districts (Table 3-6). These prices, expressed in nominal terms, were converted to real prices by using the wholesale price index for Sri Lanka.[4/]

Annual price appreciation rates were determined from these real prices by first calculating the quarterly and

---

[4/] Retail price in real terms =

$$\frac{\text{retail price in nominal terms}}{\text{wholesale price index}} \times 100.$$

Table 3-5. Determination of the Real Price Appreciation Rate from Quarterly Average Retail Fuelwood Prices, 1979.

DISTRICT	Nominal Retail Prices (Rs/Cwt)*				Real Retail Prices (Rs/Cwt) 1/				Quarterly Percentage Change (%)	Coefficient of Determination (r^2)	Annual 2/ Percentage Change (%)
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	First Quarter	Second Quarter	Third Quarter	Fourth Quarter			
Colombo	9.61	10.08	11.83	13.93	5.89	6.63	6.71	7.39	7.3	0.99	32.6
Kalutara	9.70	8.10	8.77	9.61	5.95	5.11	4.98	5.10	-4.9	0.60	-21.1
Galle	7.20	8.02	6.46	8.88	5.29	5.06	3.66	4.71	-6.7	0.28	-29.6
Matara	8.32	8.29	9.49	11.00	5.10	5.23	5.38	5.84	4.3	0.91	18.3
Ratnapura	9.32	9.44	9.86	11.17	5.72	5.96	5.59	5.93	0.4	0.04	1.[illegible]
Kegalla	8.14	8.32	8.60	10.33	4.99	5.25	4.88	5.48	2.1	0.27	8.7
Kurunegala	8.24	8.18	9.02	9.63	5.05	5.16	5.12	5.11	0.3	0.16	1.2
Puttalam	9.20	10.54	10.91	15.67	5.64	6.65	6.19	8.31	10.9	0.73	51.3
Kandy	9.15	13.50	13.30	13.19	5.61	8.52	7.55	7.00	5.4	0.16	23.4
Matale	9.05	9.00	9.00	9.19	5.55	5.68	5.11	4.88	-4.9	0.80	-21.1
Nuwara Eliya	13.30	13.35	16.87	21.29	8.16	8.42	9.57	11.30	11.0	0.93	51.8
Badulla	9.76	11.69	10.39	10.92	5.99	7.38	5.89	5.79	-3.3	0.14	-13.9
Monaragala	6.98	7.42	7.50	N.A.	4.28	4.68	4.25	N.A.	-0.4	0.01	-1.6
Jaffna	13.80	13.19	13.49	16.64	8.46	8.32	7.65	8.83	0.4	0.01	1.6
Vavunia	9.89	8.22	8.61	9.08	6.07	5.19	4.88	4.82	-7.5	0.84	-33.5
Mannar	7.10	7.13	7.67	7.64	4.35	4.50	4.35	4.05	-2.5	0.52	-10.4
Anuradhapura	7.30	7.43	5.75	6.59	4.48	4.69	3.26	3.50	-11.0	0.63	-51.8
Polonnaruwa	6.00	6.00	6.00	6.00	3.68	3.79	3.40	3.18	-5.5	0.79	-23.9
Trincomalee	7.01	7.71	8.18	5.00	4.30	4.86	4.64	2.65	-15.0	0.48	-74.9
Batticoloa	14.56	15.69	13.77	14.53	8.93	9.90	7.81	7.71	-6.8	0.54	-30.1
Amparai	5.45	5.47	7.00	N.A.	3.34	3.45	3.97	N.A.	8.6	0.89	39.1
Hambantota	9.72	9.35	9.82	12.12	5.96	5.90	5.57	6.43	1.7	0.14	7.0
Average					5.37	5.91	5.47	5.90	2.1	0.28	8.7

* Central Bank of Ceylon. 1979. Price and wage statistics: Recent trends in retail, producer, and input prices and wages. Vol. 1, No. 2. Colombo, Sri Lanka. pp. 1-88.

1/ Nominal Prices converted to real prices by the Wholesale Price Index - All Commodities (1974=100). The indexes are: first quarter 1.631, second quarter 1.585, third quarter 1.763, and fourth quarter 1.885. Central Bank of Ceylon. 1979. Review of the economy. Central Bank of Ceylon, Colombo, Sri Lanka. Appendix table 62.

2/ Annual appreciation percentage = $([1.0 + \text{quarterly rate}]^4 - 1.0) \times 100$.

Table 3-6. Determination of the Real Price Appreciation Rate from Monthly Average Fuelwood Prices, 1979.

Month	Nominal Monthly Average Fuelwood Prices* (Rs/m^3)	Wholesale Price Index-All Commodities** (1974=100)	Real Monthly Average Fuelwood Prices (Rs/m^3)
January	131.94	165.6	79.67
February	136.73	161.9	84.45
March	136.57	161.7	84.46
April	142.90	160.1	89.26
May	143.52	158.9	90.32
June	146.76	156.5	93.78
July	152.16	169.9	89.56
August	144.44	175.3	82.40
September	164.20	183.6	89.43
October	177.78	184.0	96.62
November	179.16	189.6	94.49
December	185.49	191.8	96.71
Monthly Percentage Change			1%
Coefficient of Determination (r^2)			0.57
Annual Percentage 1/			12.7%

* Central Bank of Ceylon. 1979. Economic and Social Statistics of Sri Lanka. Vol. II, No. 2. Colombo, Sri Lanka. p 76.

** Central Bank of Ceylon. 1979. Review of the economy. Central Bank of Ceylon, Colombo, Sri Lanka. Appendix table 62.

1/ Annual appreciation percentage = $([1.0 + \text{monthly rate}]^{12} - 1.0) \times 100$.

monthly appreciation rates and then converting them to an annual rate. Quarterly and monthly appreciation rates were determined by an exponential curve-fitting technique.[5] Annual rates of 8.7 and 12.7 percent were calculated from the quarterly and monthly rates, respectively (Tables 3-5 and 3-6).

The two annual rate estimates were averaged to determine the base case annual appreciation rate for fuelwood stumpage prices of 11 percent.

The duration of the real stumpage price appreciation rate is extremely difficult to estimate empirically. In this analysis, prices were appreciated at 11 percent for the first five years followed by a 5.5-percent appreciation rate through the harvest of the second coppice crop.

3.1.4 Plantation Establishment Costs

The plantation establishment costs for the base case financial analyses are given in Table 3-7.

Plantation establishment costs vary with each management regime and depend on the type of planting system (taungya vs. non-taungya), tree spacings (6' by 6' vs. 10' by 10') and tree survival (replanting vs. no replanting). These costs are based on estimates supplied by the Sri Lanka Forest Department.

Under the taungya planting system, a farmer is hired to clear a site, plant the trees and maintain the site in exchange for a fee and the right to intercrop the land. Therefore, the site preparation and planting costs are substantially reduced since the site preparation costs include only a boundary survey and the planting costs include only the planting stock and the preparation of the planting tract. In this analysis, intercropping occurs for two years, so the first two-year weeding costs are different from the non-taungya system.

Because of the difference in number of trees/hectare, the planting costs for stands planted at 6' by 6' spacing

---

[5] See Appendix II for the formulation of this mathematical procedure.

Table 3-7. Plantation Establishment Costs. *

Cost Item	Non Taungya 10'x10' Spacing	Non Taungya 10'x10' Spacing (replanted)	Non Taungya 6'x6' Spacing	Non Taungya 6'x6' Spacing (replanted)	Taungya 10'x10' Spacing	Taungya 10'x10' Spacing (replanted)
Site Preparation	1,668	1,668	1,668	1,668	48	48
Planting						
Planting Stock	539	539	1,495	1,495	539	539
Track Preparation	305	305	494	494	305	305
Hole Digging	645	645	1,792	1,792	384	384
	1,489	1,489	3,781	3,781	1228	1228
Weeding						
First year	247	247	247	247	110	110
Second year	680	680	680	680	139	139
Third year	445	445	445	445	445	445
Protection	45	45	45	45	45	45
Replanting	0	308	0	855	0	140

* Based on plantation establishment costs estimated by the Sri Lanka Forest Department.

are greater. This difference results from increased costs of planting stock, tract preparation and hole digging.

Replanting costs for the 74-percent survival alternative was 26 percent of the initial planting stock and/or hole-digging costs. Preparation of planting tracts for replanting was unnecessary.

3.1.5 Plantation Establishment Cost Appreciation Rate

The plantation establishment cost appreciation rate is 10.0 percent in real terms for five years followed by 5.0 percent in real terms through the harvest of the second coppice crop.

Plantation establishment costs in Sri Lanka, for both the non-taungya and taungya planting systems, is extremely labor intensive (The World Bank 1980). Therefore, the real appreciation rate of these costs was estimated from available information on wage rates for unskilled agricultural workers.

Table 3-3 depicts a wage index for workers in agriculture in nominal terms for the period 1975 to 1979. This nominal wage index was converted to a real wage index and an exponential curve-fitting technique was used to determine the annual percentage rate of change.[6/]

The duration of the plantation establishment cost appreciation rate is extremely difficult to estimate empirically. In this analysis, costs were appreciated at 10 percent for the first five years followed by a 5-percent appreciation rate through the harvest of the second coppice crop. This is a conservative estimate, but one consistent with our estimates for price appreciation rates.

3.2 Sensitivity Analysis

A sensitivity analysis estimates the magnitude of change from the base case result attributable to a given change in the base case assumption. The magnitude of this

---

[6/] See Appendix II for the formulation of this mathematical procedure.

Table 3-8. Determination of Plantation Establishment Cost Real Appreciation Rate.

Year	Nominal Wage Index*	Wholesale Price** Index-All Commodities 1974=100	Real Wage 1/ Index
1975	241.2	103.4	233.3
1976	246.4	111.9	220.2
1977	310.2	135.3	229.3
1978	451.0	156.7	287.8
1979	578.5	171.6	337.1
Annual Percentage Change			10%
Coefficient of Determination (r^2)			0.76

* Central Bank of Ceylon. 1979. Review of the economy. Central Bank of Ceylon, Colombo, Sri Lanka. Appendix table 64.

** Central Bank of Ceylon. 1979. Review of the economy. Central Bank of Ceylon, Colombo, Sri Lanka. Appendix table 62.

1/ Real wage index = $\frac{\text{Nominal wage index}}{\text{Wholesale price index}} \times 100.$

change, *per se*, is not the critical factor. One knows from the mathematics of capital theory that changes in assumptions affecting the value of revenue and cost items have a linear impact on base case NPV's, and changes in assumptions affecting the discount rate and cost and price appreciation rates have a geometric impact on base case results (Christophersen et al. 1978, Medema and Moore 1980, Mills et al. 1976, Schweitzer 1970).

What is critical in the sensitivity analysis is whether a change in an assumption changes the preferred course of action. If a change in the preferred course of action occurs, the sensitivity analysis has identified an assumption that should be closely evaluated by the decision-maker.

A second major use of sensitivity analysis is to interpolate or extrapolate results associated with alternative assumptions, as demonstrated in the following examples. The NPV's based on a sensitivity analysis of three different price assumptions (Rs 50/m^3, Rs 100/m^3 and Rs 200/m^3) are shown in Figure 3-1. The linear relationship between NPV and price can then be used to interpolate or extrapolate the NPV associated with other price assumptions.[7/]

The NPV's based on a sensitivity analysis of three different discount rate assumptions (2, 6 and 12 percent) are shown in Figure 3-2. The geometric relationship between NPV and discount rate can then be used to interpolate or extrapolate the NPV associated with other discount rate assumptions.[8/] The selection of appropriate values of the assumptions used in the sensitivity analyses should encompass a realistic range of values around the base case assumptions. In this report, two alternative values were selected for each assumption. One value represents an optimistic assumption (one more favorable to investments than the base case) and the other a pessimistic assumption

---

[7/] See Appendix II for the formulation of this mathematical procedure.

[8/] See Appendix II for the formulation of this mathematical procedure.

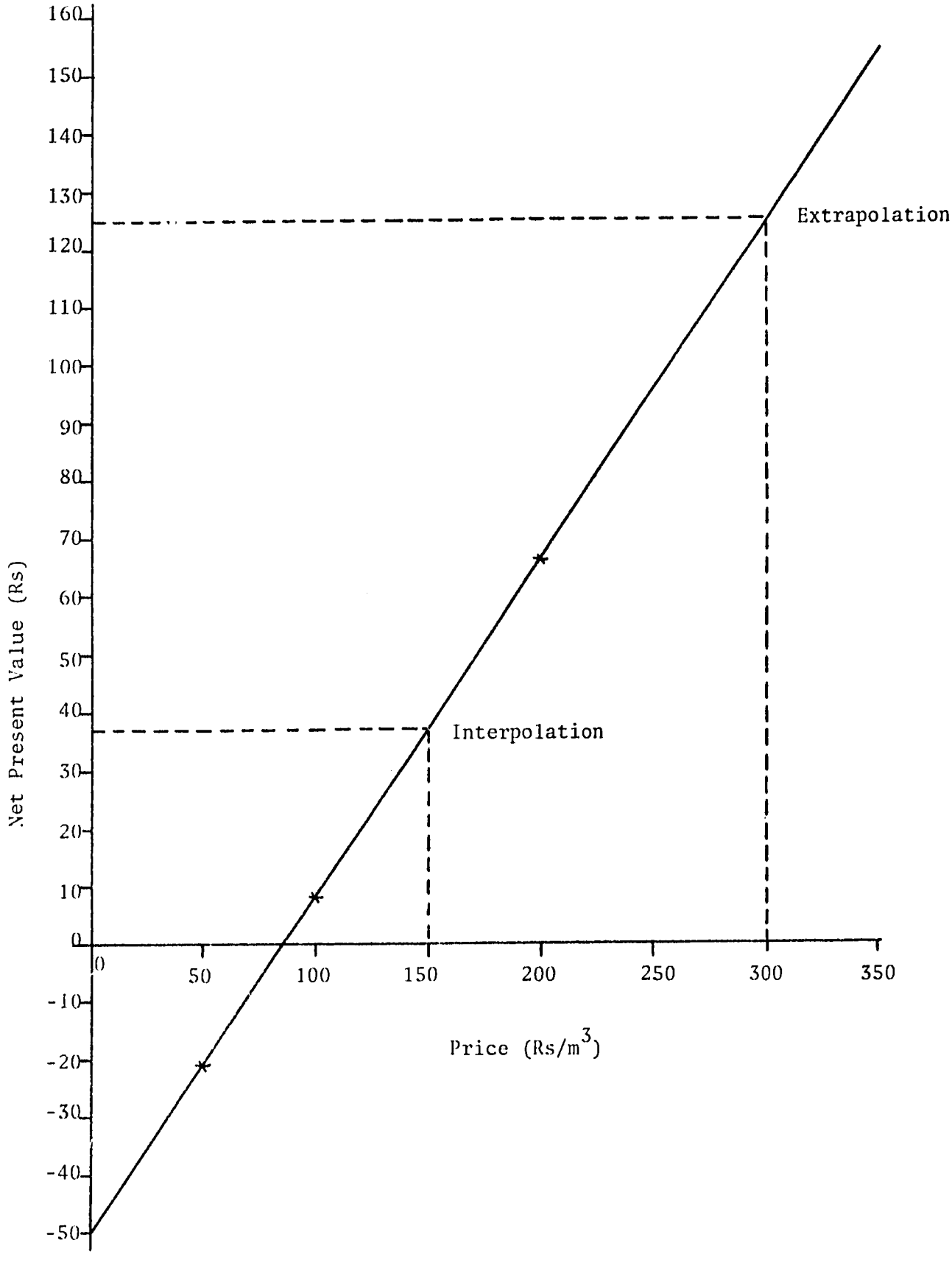


Figure 3-1. Example of Interpolation and Extrapolation for Assumptions with Linear Impact on Net Present Value.

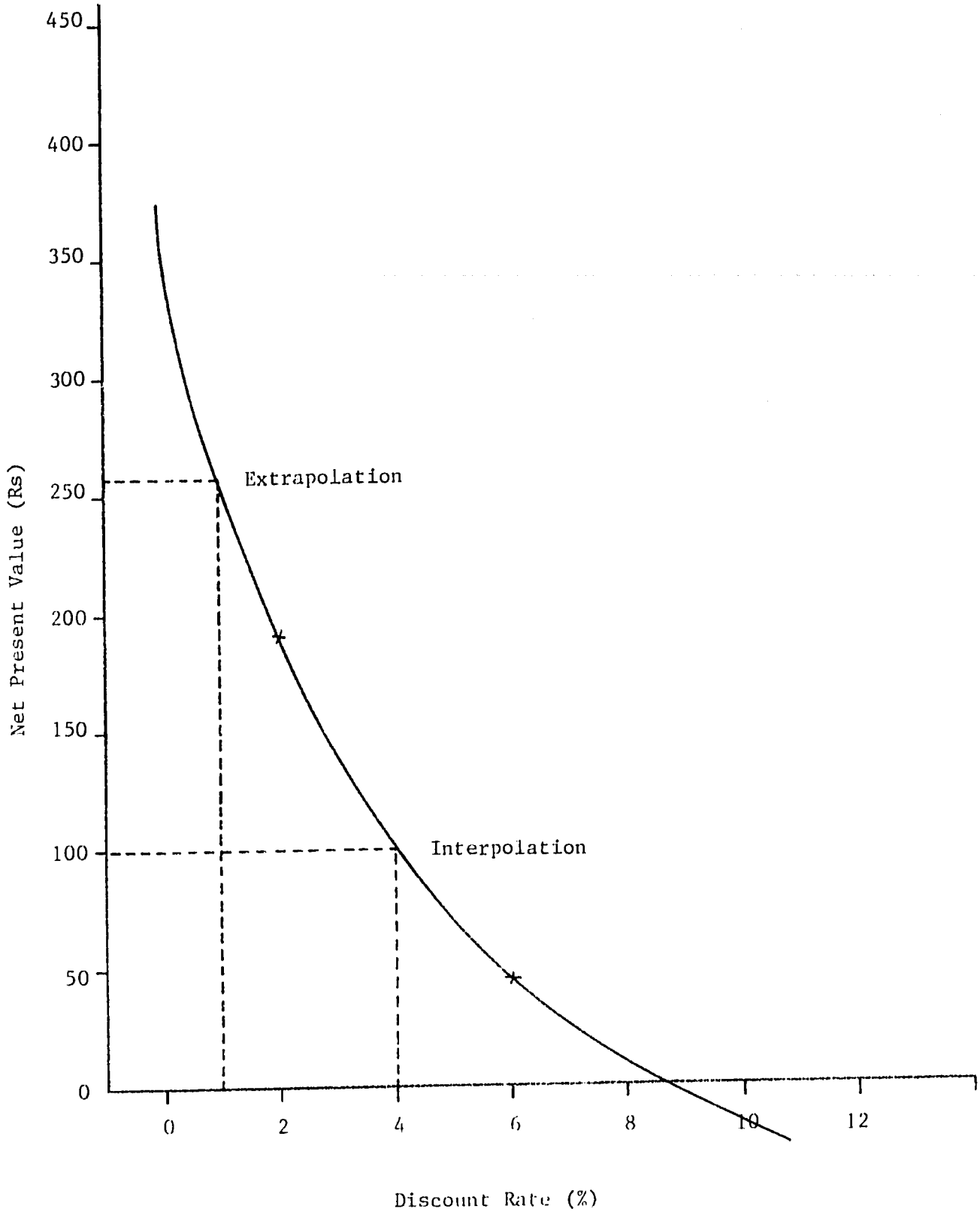


Figure 3-2. Example of Interpolation and Extrapolation for Assumptions with Geometric Impact on Net Present Value.

(one less favorable to investments than the base case). A summary of these sensitivity analysis assumptions are given in Table 3-9.

3.2.1 The Discount Rate

The discount rates used in the sensitivity analyses were 6 percent and 14 percent in real terms.

Real discount rates ranging from 8 to 12 percent are frequently used in investment analyses (Meta Systems, Inc. 1980). For this analysis, given the often volatile economic conditions prevailing in developing countries, we extended the range of discount rates.

3.2.2 Stumpage Price

The stumpage prices used in the sensitivity analyses were Rs 36.67/m^3 and Rs 92.23/m^3.

The range of stumpage prices used in the sensitivity analysis was derived from the fuelwood prices given in Table 3-3. The lowest reported price (Amparai District) and the highest reported price (Nuwara Eliya District) were used in conjunction with a more conservative conversion factor, 15.43 cwt/m^3, and the procedures in Section 3.1.2 to estimate a pessimistic and an optimistic stumpage price assumption.

The stumpage price used in analyzing a plantation investment is location specific and reflects the retail price at the time of harvest in the market area where the fuelwood will be consumed. The distance between the plantation and the markets is an important factor since transportation costs comprise a relatively large portion of the fuelwood price in Sri Lanka. This cost becomes more significant as petroleum prices increase. Since transportation of wood products in Sri Lanka costs approximately Rs 2.68/m^3/mile (Bollinger 1979, USAID 1980) on a round-trip basis, the retail price is increased by that amount for each mile between the stand and the market. Detailed considerations of transportation costs are beyond the scope of this presentation. However, given the linear relationship of NPV

Table 3-9. Summary of Sensitivity Analysis Assumptions.

Assumption	Base Case	Optimistic	Pessimistic
A. Discount Rate	10.0%	6.0%	14.0%
B. Stumpage Price	Rs 54.75/m^3	Rs 36.67/m^3	Rs 92.23/m^3
C. Stumpage Price Appreciation Rate	11% - 5 years; 5.5% - end of 2nd harvest of the second coppice crop	11% - 10 years; 5.5% - end of 2nd harvest of the second coppice crop	7% - 5 years; 3.5% - end of 2nd harvest of the second coppice crop
D. Plantation Establishment Costs	1.00 x Base Case 1/	.75 x Base Case 1/	1.25 x Base Case 1/
E. Plantation Establishment Cost Appreciation Rate	10% - 5 years 5% - end of 2nd harvest of the second coppice crop	6% - 5 years 3% - end of 2nd harvest of the second coppice crop	10% - 10 years 5% - end of 2nd harvest of the second coppice crop

1/ See Table 3-7.

to cost, the results associated with changes in the stumpage price assumption created by transportation can be estimated.

3.2.3 Stumpage Price Appreciation Rate

The stumpage price appreciation rates used in the sensitivity analyses were:

1) *11.0 percent for 10 years followed by 5.5 percent through the harvest of the second coppice crop and*
2) *7 percent for 5 years followed by 3.5 percent through the harvest of the second coppice crop.*

These changes in base case assumptions were selected to demonstrate the impact of alternative appreciation rate assumptions on the base case results.

3.2.4 Plantation Establishment Costs

The plantation establishment costs for the sensitivity analyses are 75 percent and 125 percent of the base case costs.

Data on Sri Lankan unemployment are incomplete. According to periodic assessments (Central Bank of Ceylon 1979), the unemployment rate has dropped from a high of 24 percent in 1973 to 15 percent in 1979. However, no data are available on seasonal employment. Labor availability for plantation establishment may coincide with the rice planting and harvesting seasons. A 25-percent fluctuation in base case costs reflects the impact of alternative plantation cost assumption on the base case results.

3.2.5 Plantation Establishment Cost Appreciation Rates

The plantation establishment cost appreciation rates used in the sensitivity analyses were:

1) *6.0 percent for 5 years followed by 3.0 percent through the harvest of the second coppice crop and*
2) *10.0 percent for 10 years followed by 5.0 percent through the harvest of the second coppice crop.*

These changes in base case assumptions were selected to demonstrate the impact of alternative appreciation rate assumptions on the base case results.

3.3 Base Case Economic Analysis

The base case economic analysis assumptions are given in Table 3-10. These base case assumptions represent an approximation of "shadow price" estimates for labor costs and the discount rate. In an economic analysis, one may also consider the non-market benefits of an investment decision such as reduced soil erosion and watershed protection. However, due to the difficulty in quantifying these benefits for a specific plantation they were not included in the analysis.

3.3.1 The Discount Rate

The base discount rate for the economic analysis is 6 percent in real terms.

A 6-percent discount rate is substantially lower than the financial base case analysis discount rate of 10 percent. This lower discount rate results in higher NPV's and therefore makes investments in fuelwood plantations more attractive. The lower discount rate can reflect the GOSL's relatively high priority on reforestation and, perhaps, a lower risk premium on these investments because of the diversification and magnitude of the government's total investment profile.

3.3.2 Plantation Establishment Costs

The plantation establishment costs for the base case economic analysis are 75 percent of the plantation establishment costs used in the base case financial analysis.

The reduced cost assumption used in the economic analysis reflects the labor intensity of plantation establishment costs and the shadow pricing of labor. The GOSL currently attempts to schedule its planting activities when labor is available--that is, before or after peak planting or harvesting seasons associated with agricultural crops. Tree planting, like other agricultural crops, is closely tied to the monsoon season. To the extent that the GOSL is successful in its scheduling efforts, a shadow price for

Table 3-10. Summary of Base Case Assumptions for the Economic Analysis.

Assumption	Base Case
A. Discount Rate	6.0%
B. Stumpage Price	Rs 54.75/m^3
C. Stumpage Price Appreciation Rate	11% - 5 years; 5.5% - end of 2nd harvest of the second coppice crop.
D. Plantation Establishment Costs	0.75 x Base Case 1/
E. Plantation Establishment Cost Appreciation Rate	10% - 5 years 5% - end of 2nd harvest of the second coppice crop.

1/ See table 3-7.

labor less than the market price used in the financial analysis is warranted.

4. FINANCIAL RESULTS

Fuelwood plantations on site index 11 and 13 lands have positive NPV's and are, therefore, financially desirable investments.

4.1 Net Present Value

The base case results for all the alternative management regimes by site index class are given in Table 4-1. This table compares NPV's of taungya versus non-taungya planting systems, 6' by 6' versus 10' by 10' tree spacing and the effect of replanting plantations with poor initial survival rates by site index classes.

4.1.1 Selection of the Preferred Management Regime

From the comparisons of management regimes within a given site index class, one can determine the preferred alternative. A decision tree (Figure 4-1) is useful in identifying that alternative.

The preferred regime within each site index class is that which yields the largest NPV. This regime is denoted by an asterisk in Figure 4-1. On site index 13, the preferred regime has 6' by 6' spacing. In these plantations an investor can afford to spend an additional Rs 4,922/hectare in establishment costs (13,924 - 9002) to ensure a 94-percent initial survival rate. Site index 11 has the same preferred regime. However, in these plantations an additional expenditure of Rs 2,232/hectare could be spent to ensure a 94-percent initial survival rate.

On site index 9, none of the alternative regimes have positive NPV's. An investor could minimize the investment loss on these sites by selecting a 10' by 10' spacing taungya planting system regime.

4.1.2 Comparison of Planting Systems

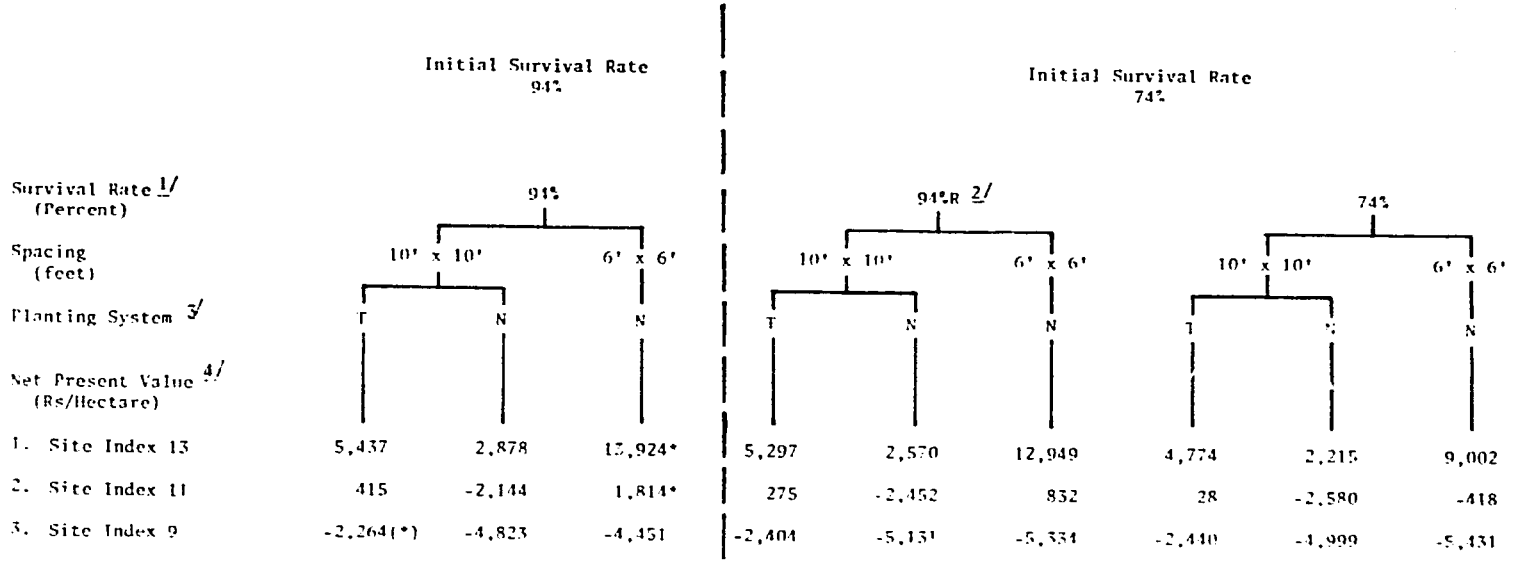
Plantations established by the taungya planting system always produced a greater NPV than those established by a non-taungya system. On site index classes 11 and 13, the

Table 4-1. Base Case Results - Financial Analysis.

Site Index Class	Tree Spacing (feet)	Survival Rate 1/ (%)	Planting System 2/	Net Present Value and Stand Age at Harvest: Initial Plantation (Rs/ha.)	Initial Plantation (years)	First Coppice (Rs/ha.)	First Coppice (years)	Second Coppice (Rs/ha.)	Second Coppice (years)	Total Net Present Value (Rs/ha.)
13	10	74	N	34	16	1,496	16	685	16	2,215
13	10	74	T	2,593	16	1,496	16	685	16	4,774
13	10	94R	N	112	16	1,683	16	755	16	2,570
13	10	94R	T	2,839	16	1,683	16	755	16	5,297
13	10	94	N	420	16	1,683	16	755	16	2,878
13	10	94	T	2,979	16	1,683	16	755	10	5,437
11	10	74	N	-2,741	16	145	16	65	16	-2,580
11	10	74	T	-182	16	145	16	65	16	28
11	10	94R	N	-2,822	16	255	16	115	16	-2,452
11	10	94R	T	-95	16	255	16	115	16	275
11	10	94	N	-2,514	16	255	16	115	16	-2,144
11	10	94	T	45	16	255	16	115	16	415
9	10	74	N	-4,150	15	-570	16	-279	15	-4,999
9	10	74	T	-1,591	15	-579	16	-279	15	-2,440
9	10	94R	N	-4,349	15	-515	15	-267	15	-5,131
9	10	94R	T	-1,622	15	-515	15	-267	15	-2,404
9	10	94	N	-4,041	15	-515	15	-267	15	-4,823
9	10	94	T	-1,482	15	-515	15	-267	15	-2,264
13	6	74	N	2,874	15	4,160	15	1,968	15	9,002
13	6	94R	N	4,711	15	5,587	15	2,650	15	12,949
13	6	94	N	5,686	15	5,588	15	2,650	15	13,924
11	6	74	N	-2,567	14	1,451	14	698	14	-418
11	6	94R	N	-2,183	15	2,028	14	987	14	832
11	6	94	N	-1,323	14	2,110	14	1,027	14	1,814
9	6	74	N	-5,371	15	-27	15	-33	15	-5,431
9	6	94R	N	-5,692	15	255	14	103	14	-5,334
9	6	94	N	-4,816	14	261	14	101	14	-4,451

1/ R denotes the plantation was replanted.

2/ T denotes a taungya and N denotes a non-taungya planting system.



	Initial Survival Rate 94%			Initial Survival Rate 74%					
	10' x 10'		6' x 6'	10' x 10'		6' x 6'	10' x 10'		6' x 6'
	T	N	N	T	N	N	T	N	N
1. Site Index 13	5,437	2,878	13,924*	5,297	2,570	12,949	4,774	2,215	9,002
2. Site Index 11	415	-2,144	1,814*	275	-2,452	832	28	-2,580	-418
3. Site Index 9	-2,264(*)	-4,823	-4,451	-2,404	-5,131	-5,334	-2,440	-4,999	-5,431

1/ It may be unclear that the investor has control over the survival rate and, therefore, choice between the 74 and 94 percent initial survival rates. However, the difference between the NPV of the management regime with a 94 percent initial survival rate and a 74 percent initial survival rate is a measure of the additional amount an investor could spend on establishment costs to insure the higher survival rate.

2/ R denotes the stand was replanted.

3/ T denotes a taungya and N denotes a non-taungya planting system.

4/ An asterisk denotes the preferred and financially desirable regime. An asterisk in brackets denotes the regime is preferred but not financially desirable.

Figure 4-1. Preferred Regime Decision Tree for Base Case Results - Financial Analysis.

NPV's under the taungya system were positive, indicating the regimes are financially desirable. The non-taungya planting system is financially desirable on site index class 13, but is not preferred since the NPV's are greater under the taungya system. Although the taungya planting system is preferred on site index class 9, it is not a financially desirable alternative since the NPV is negative.

These results are expected since the establishment costs for the non-taungya planting system are greater, but the volume yields are the same as the taungya system.

4.1.3 Comparison of Tree Spacing

On site index class 13, 6' by 6' spacing is always associated with the largest NPV. The productivity associated with this site index class offsets the increased stand establishment costs of the non-taungya planting system. On site index class 11, 6' by 6' spacing is preferred only under the replanted and the 94 percent survival regimes. In the poor survival and non-replanted regime, 6' by 6' spacing is not preferred, and it also has a negative NPV. On site index class 9, the 10' by 10' taungya regime is always preferred, but always has a negative NPV. Neither spacing produces revenues sufficient to offset the stand establishment and maintenance costs on this site.

An interaction between productivity and spacing was expected. In more productive plantations, increased production resulting from narrower spacings can offset the increased costs associated with the narrower spacings. This interaction was observed in this study.

4.1.4 Comparison of Replanting

In nearly every situation, replanting plantations with poor initial survival is preferred to not replanting them. The exception is the 10' by 10' spacing, non-taungya planting regime on site index class 9 land. On site index class 11, replanted plantations at 10' by 10' spacing have only a positive NPV under the taungya planting system. On site

index class 9, none of the replanting management regimes have positive NPV's.

An interaction between productivity and replanting was expected. In more productive plantations, increased production resulting from greater numbers of trees can offset the increased cost of replanting. This interaction was observed in this study.

4.2 Soil Expectation Values

A resource decision-maker confronted with the issue of land use may wish to know the values associated with alternative land uses. The results of this report can be used by that resource decision-maker to estimate the value of land for fuelwood production. Since land derives value from the goods it produces, the value of land is simply the NPV associated with the flow of revenues generated from it. This NPV associated with the highest valued land use is referred to as the soil expectation value (SEV). In this analysis the SEV is the NPV for the first harvest and subsequent two coppice crops plus the NPV's of all subsequent harvests and coppice crops *ad infinitum* for the highest valued fuelwood plantation use within a site index class.

The comparison of alternative land uses is beyond the scope and intent of this analysis. The value of land for use as fuelwood plantations is given in Table 4-2. However, SEV's derived for alternative uses of the land can be directly compared with SEV's in Table 4-2 to determine if fuelwood plantations represent the land use of greatest value. Only the preferred and financially desirable management regime is given by site index class in Table 4-2, since SEV reflects the highest valued fuelwood plantation use. Since none of the management regimes in site index 9 plantations had positive NPV's, the value of that land for fuelwood plantation use is zero.

Table 4-2. Soil Expectation Values

Site Index Class	Initial Survival Rate %	Spacing (feet)	Planting System	Net Present Value of First Harvest and First Two Coppice Crops (Rs/hectare)	Net Present Value of Subsequent Harvests and Coppice Crops (Rs/hectare)	Soil Expectation Value (Rs/hectare)
13	94	6	Non-taungya	13,924	299	14,223
11	94	6	Non-taungya	1,814	-616	1,198
9	-	-	-	-	-	0

The contribution to SEV of all subsequent harvests and coppice crops is small relative to the NPV of the first harvest and first two coppice crops. On site index 11 this additional contribution is actually negative. This is caused by two factors. First, the revenues from subsequent harvests and coppice crops are discounted over long periods of time. Second, the original plantation establishment costs are predicted to be substantial when the plantation must be reestablished, since these costs are appreciated in real terms for the duration of the first harvest and first two coppice crops.

5. FINANCIAL ANALYSIS SENSITIVITY RESULTS

Investment assumptions are critically important for plantations on land classified as site index 11 or less if NPV's greater than zero are desired.

5.1 Net Present Values

The sensitivity analysis results for all the alternative management regimes by site index class are given in Table 5-1. This table compares NPV's of taungya versus non-taungya planting systems, 6' by 6' versus 10' by 10' tree spacing and the effect of replanting plantations with poor initial survival rates by site index classes for alternative base case discount rate, price, cost and appreciate rate assumptions.

5.1.1 Effect of Changes in Assumptions on the Base Case Decision

By comparing the NPV of the preferred management regime under the base case assumptions to the NPV's associated with sensitivity analysis assumptions within the same management regimes and site index class, one can determine the effect of an alternative assumption on the base case decision. A decision tree (Figure 5-1) is useful in identifying assumptions that result in different decisions. For each management regime, Figure 5-1 gives the NPV associated with the base case investment assumptions, the NPV associated with the assumption in Table 5-1 that resulted in the largest NPV (the most optimistic investment assumption) and the NPV associated with the assumption in Table 5-1 that resulted in the smallest NPV (the most pessimistic investment assumption).

The preferred regime within each set of site index classes-investment assumptions is that which yields the largest NPV. This regime is denoted by an asterisk in Figure 5-1. On site index 13, the base case preferred regime is not altered by the most optimistic and pessimistic investment assumptions. Although the actual NPV's are substantially different, the NPV's are always greater than

Table 5-1. Sensitivity Analysis Results.

Site Index Class	Spacing (feet)	Survival Rate (%) 1/	Planting System 2/	Net Present Value Associated with: Base Case	Discount Rate 6%	Discount Rate 14%	Stumpage Price (Rs/m³) 36.67	Stumpage Price (Rs/m³) 92.23	Costs (Rs/Hectare) .75xBase Case	Costs (Rs/Hectare) 1.25xBase Case	Stumpage Price Appreciation 11%-10yrs	Stumpage Price Appreciation 7%-5yrs	Cost Appreciation 10%-10yrs	Cost Appreciation 6%-5yrs
				(Rs/Hectare)										
13	10	74	N	2,215	17,857	-1,401	-729	8,316	3,883	546	4,792	-1,374	1,739	3,055
13	10	74	T	4,774	20,448	1,129	1,830	10,875	5,772	3,745	7,352	1,185	4,298	5,584
13	10	94R	N	2,550	19,638	-1,156	-551	9,103	4,309	801	5,320	-1,064	2,148	3,438
13	10	94R	T	5,271	22,303	1,536	2,176	11,830	6,354	4,210	8,047	1,663	4,875	6,129
13	10	94	N	2,858	19,958	-859	-243	9,411	4,540	1,186	5,628	-756	2,456	3,735
13	10	94	T	5,437	22,567	1,671	3,129	11,970	6,429	4,385	8,187	1,803	5,015	6,264
11	10	74	N	-2,580	3,201	-3,707	-3,907	322	-863	-4,199	-1,325	-4,308	-3,006	-1,660
11	10	74	T	28	5,792	-1,177	-1,348	2,881	1,026	-1,000	1,234	-1,749	-447	773
11	10	94R	N	-2,452	3,994	-3,767	-3,971	667	-706	-4,208	-1,134	-4,326	-2,938	-1,569
11	10	94R	T	275	6,759	-1,075	-1,244	3,394	1,309	-799	1,593	-1,599	-211	1,122
11	10	94	N	-2,144	4,313	-3,470	-3,663	975	-475	-3,823	-826	-4,018	-2,630	-1,272
11	10	94	T	415	6,905	-940	-1,104	3,534	1,414	-624	1,733	-1,459	-71	1,257
9	10	74	N	-4,999	-4,099	-5,030	-5,723	-3,703	-3,247	-6,868	-4,411	-5,879	-5,677	-4,033
9	10	74	T	-2,440	-1,508	-2,500	-3,164	-1,144	-1,358	-3,669	-1,852	-3,320	-3,118	-1,503
9	10	94R	N	-5,131	-4,015	-5,200	-5,980	-3,856	-3,340	-6,971	-4,529	-6,122	-5,767	-4,195
9	10	94R	T	-2,444	-1,250	-2,508	-3,253	-1,129	-1,295	-3,562	-1,802	-3,395	-3,040	-1,503
9	10	94	N	-4,823	-3,696	-4,903	-5,672	-3,475	-3,109	-6,586	-4,221	-5,814	-5,459	-3,898
9	10	94	T	-2,264	-1,105	-2,372	-3,113	-898	-1,220	-3,387	-1,662	-3,255	-2,900	-1,368
13	6	74	N	9,002	38,257	1,576	3,244	21,365	11,260	7,064	14,227	2,464	8,829	9,881
13	6	94R	N	12,949	50,974	3,255	5,706	28,628	15,420	10,910	19,563	4,648	12,888	13,859
13	6	94	N	13,924	51,934	4,252	6,647	29,687	16,183	12,100	20,573	5,634	13,865	14,803
11	6	74	N	-418	11,624	-3,572	-3,288	5,291	1,854	-2,690	2,097	-3,686	-924	431
11	6	94R	N	832	16,819	-3,262	-2,657	8,117	3,262	-1,539	3,887	-3,168	440	1,700
11	6	94	N	1,814	17,706	-2,404	-1,794	8,972	3,904	-458	4,742	-2,292	1,308	2,524
9	6	74	N	-5,431	-1,772	-6,278	-6,658	-2,949	-3,173	-7,721	-4,382	-6,941	-5,955	-4,553
9	6	94R	N	-5,334	114	-6,592	-6,847	-2,224	-2,868	-7,807	-4,016	-7,165	-5,827	-4,434
9	6	94	N	-4,451	1,016	-5,737	-5,989	-1,399	-2,210	-6,722	-3,141	-6,281	-4,957	-3,614

1/ R denotes the stand was replanted.

2/ T denotes a Taungya and N denotes a non-taungya planting system.

	Initial Survival Rate 94%			Initial Survival Rate 74%					
Survival Rate * (Percent)	94			94R 2/			74		
Spacing (Feet)	10' x 10'		6' x 6'	10' x 10'		6' x 6'	10' x 10'		6' x 6'
Planting System 3/	T	N	N	T	N	N	T	N	N
Net Present Value 4/ (RS/Hectare)									
1. Site Index 13									
a. Base Case	5,437	2,858	13,924*	5,271	2,550	12,949	4,774	2,215	9,002
b. Optimistic assumption	22,567	19,958	51,934*	22,303	19,638	50,974	20,448	17,857	38,257
c. Pessimistic assumption	1,671	-859	4,252*	1,536	-1,156	3,255	1,129	-1,401	1,576
2. Site Index 11									
a. Base Case	415	-2,144	1,814*	275	-2,452	832	28	-2,580	-418
b. Optimistic assumption	6,905	4,313	17,706*	6,759	3,994	16,819	5,792	3,201	11,624
c. Pessimistic assumption	-1,459(*)	-4,018	-2,404	-1,599	-4,326	-3,262	-1,749	-4,308	-3,686
3. Site Index 9									
a. Base Case	-2,264(*)	-4,823	-4,451	-2,444	-5,131	-5,334	-2,440	-4,999	-5,431
b. Optimistic assumption	-898	-3,109	1,016	-1,129	-3,540	114	-1,144	-3,247	-1,772
c. Pessimistic assumption	-3,387(*)	-6,586	-6,722	-3,562	-6,971	-7,807	-3,669	-6,868	-7,721

1/ It may be unclear that the investor has control over the survival rate and, therefore, choice between the 74 and 94 percent initial survival rates. However, the difference between the NPV of the management regime with a 94 percent initial survival rate and a 74 percent initial survival rate is a measure of the additional amount an investor could spend on establishment costs to insure the higher survival rate.

2/ R denotes the stand was replanted.

3/ T denotes a taungya planting system and N denotes a non-taungya planting system.

4/ An asterisk denotes the regime is preferred and financially desirable.
An asterisk in brackets denotes the regime is preferred but not financially desirable.

Figure 5-1. Preferred Regime Decision Tree for Sensitivity Analysis Results.

zero.

On site index 11, however, the most pessimistic investment assumption changes both the preferred regime and its financial desirability. The base case regime was associated with a plantation established under a non-taungya planting system at 6' by 6' spacing. The preferred regime under the most pessimistic investment assumption was a plantation established under a taungya planting system at 10' by 10' spacing. In the first case, the plantation is financially desirable and in the second case it is not. In this situation, the investment assumptions associated with the most pessimistic results should be carefully evaluated in terms of the assumptions associated with the base case results because the management regime changes with changes in the investment assumptions.

Similarly, on site index 9 lands, the most optimistic investment assumption changes the preferred regime to a non-taungya planting system at 6' by 6' spacing and results in the investment being financially desirable.

5.1.2 Effect of Changes in Assumptions on the Selection of a Planting System

Table 5-2 shows the preferred planting systems associated with the base case and alternative investment assumptions. Plantations established at 10' by 10' spacing always produce a greater NPV under the taungya planting system. Regardless of the management regime and investment assumptions, the NPV's associated with plantations on site index 13 land were always greater than zero. On site index 11 land, although the taungya planting system was always the preferred alternative, the results are financially desirable for the base case and optimistic investment assumptions and financially undesirable under the pessimistic investment assumptions. Therefore, investment assumptions associated with the establishment of plantations on site index 11 land should be carefully evaluated.

Table 5-2. Planting System Comparisons - Sensitivity Analysis.[2/]

Site Index Class	Spacing* (feet)	Survival Rate 1/ (%)	Base Case	Discount Rate (6%)	Discount Rate (14%)	Stumpage Price (Rs/m^3) (36.67)	Stumpage Price (Rs/m^3) (92.23)	Costs (Rs/Hectare) .75xBase Case	Costs (Rs/Hectare) 1.25xBase Case	Stumpage Price Appreciation 11%-10 yrs.	Stumpage Price Appreciation 7%-5 yrs.	Cost Appreciation 10%-10 yrs.	Cost Appreciation 6%-5 yrs.
13	10	74	T	T	T	T	T	T	T	T	T	T	T
13	10	94R	T	T	T	T	T	T	T	T	T	T	T
13	10	94	T	T	T	T	T	T	T	T	T	T	T
11	10	74	T	T	(T)	(T)	T	T	(T)	T	(T)	(T)	T
11	10	94R	T	T	(T)	(T)	T	T	(T)	T	(T)	(T)	T
11	10	94	T	T	(T)	(T)	T	T	(T)	T	(T)	(T)	T
9	10	74	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)
9	10	94R	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)
9	10	94	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)	(T)

1/ R denotes the stand was replanted.

2/ T denotes that the taungya planting system is preferred and financially desirable.
N denotes that the non-taungya system is preferred and financially desirable.
If T or N are in brackets, the alternative is preferred but is not financially desirable.

* The taungya planting system is not used at 6' by 6' spacings.

5.1.3 Effect of Changes in Assumptions on the Selection of Tree Spacing

Table 5-3 shows the preferred tree spacing associated with the base case and alternative investment assumptions. On site index 13 land, 6' by 6' spacing is always preferred and financially desirable regardless of the management regime and investment assumptions.

On site index 9 land, 10' by 10' spacing is almost always preferred but is never financially desirable. The exception occurs under a 6-percent discount rate assumption when 6' by 6' spacing is both preferred and desirable. On site index 11 land, 6' by 6' spacing is generally preferred and financially desirable under base case and optimistic investment assumptions, and 10' by 10' spacing is generally preferred but seldom financially desirable under pessimistic investment assumptions. Therefore, investment assumptions associated with the establishment of plantations on site index 9 and 11 land should be carefully evaluated.

5.1.4 Effect of Changes in Assumption on Replanting

Table 5-4 shows when the added cost of replanting is preferred for base case and alternative investment assumptions. On site index 13 land, the added cost of replanting is always preferred and is financially desirable except under the most pessimistic investment assumptions. Under the pessimistic assumptions replanting is preferred, but the NPV is less than zero. On site index 11 land associated with 6' by 6' non-taungya and 10' by 10' taungya management regimes, the added cost of replanting is again always preferred and financially desirable except under certain pessimistic investment assumptions where replanting is preferred but it is financially undesirable.

Regardless of the management regime on site index 9 land and for the 10' by 10' non-taungya regime on site index 11 lands, the added cost of replanting and its financial desirability varies from the base case result depending on

Table 5-3. Tree Spacing Comparisons - Sensitivity Analysis. 2/

Site Index Class	Survival Rate 1/ (%)	Base Case	Discount Rate		Stumpage Price (Rs/m^3)		Costs (Rs/Hectare)		Stumpage Price Appreciation		Cost Appreciation	
			6%	14%	36.67	92.23	.75xBase Case	1.25xBase Case	11%-10 yrs.	7%-5 yrs.	10%-10 yrs.	6%-5 yrs.
13	74	6N	6N	6N	6N	6N	6N	6N	6N	6N	6N	6N
13	94R	6N	6N	6N	6N	6N	6N	6N	6N	6N	6N	6N
13	94	6N	6N	6N	6N	6N	6N	6N	6N	6N	6N	6N
11	74	10T	6N	(10T)	(10T)	6N	6N	(10T)	6N	(10T)	(10T)	10T
11	94R	6N	6N	(10T)	(10T)	6N	6N	(10T)	6N	(10T)	6N	6N
11	94	6N	6N	(10T)	(10T)	6N	6N	(6N)	6N	(10T)	6N	6N
9	74	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)
9	94R	(10T)	6N	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)
9	94	(10T)	6N	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)	(10T)

1/ R denotes the stand was replanted.

2/ 6N denotes the 6' by 6' spacing established under a non-taungya planting system is preferred and financially desirable.
10T denotes the 10' by 10' spacing established under a taungya system is preferred and financially desirable.
If 6N or 10T are in brackets, the alternative is preferred, but is not financially desirable.

Table 5-4. Replanting Comparisons - Sensitivity Analysis. [2]

Site Index Class	Spacing (feet)	Planting System [1]	Base Case	Discount Rate		Stumpage Price (Rs/m^3)		Costs (Rs/Hectare)		Stumpage Price Appreciation		Cost Appreciation	
				6%	14%	(36.67)	92.23	.75xBase Case	1.25xBase Case	11%-10 yrs.	7%-5 yrs.	10%-10 yrs.	6%-5 yrs
13	10	N	R	R	(R)	(R)	R	R	R	R	(R)	R	R
13	10	T	R	R	R	R	R	R	R	R	R	R	R
11	10	N	(R)	R	(NR)	(NR)	R	(R)	(NR)	(R)	(NR)	(R)	(R)
11	10	T	R	R	(R)	(R)	R	R	(R)	R	(R)	(R)	R
9	10	N	(NR)	(R)	(NR)	(NR)	(NR)	(NR)	(NR)	(NR)	(NR)	(NR)	(NR)
9	10	T	(R)	(R)	(NR)	(NR)	(R)	(R)	(R)	(R)	(NR)	(R)	(R)
13	6	N	R	R	R	R	R	R	R	R	R	R	R
11	6	N	R	R	(R)	(R)	R	R	(R)	R	(R)	R	R
9	6	N	(R)	R	(NR)	(NR)	(R)	(R)	(NR)	(R)	(NR)	(R)	(R)

[1] T denotes taungya and N denotes non-taungya planting system.

[2] R denotes replanting is the preferred and financially desirable option.
NR denotes not replanting is the preferred and financially desirable option.
If R or NR are in brackets, the alternative is preferred but is not financially desirable.

the specific alternative investment assumption. Therefore, investment assumptions associated with the establishment of plantations on the less productive lands should be carefully evaluated.

5.2 Interpolation and Extrapolation from the Sensitivity Analysis Results

Interpretations associated with the sensitivity analysis are not limited to the assumptions and results presented in Section 5.1. Interpolations between the assumptions used and extrapolations beyond the assumptions used can be done graphically and mathematically.

5.2.1 Graphical Interpolations and Extrapolations

An example of the graphical mechanism for interpolating and extrapolating results associated with the sensitivity analysis results is given in Figure 5-2. The graphical results associated with the sensitivity analyses for all the management regimes within each site index class are given in Appendix III.

Figure 5-2 displays the relationship between NPV and alternative stumpage price, establishment costs and discount rate assumptions. The horizontal axis is calibrated so the three curves on the graph coincide at the base case assumption.

The NPV resulting from a change in an assumption can be determined by first selecting the appropriate value for the desired assumption on the horizontal axis. The point on the vertical axis associated with the intersection of the horizontal axis and the curve associated with the assumption is the NPV for the desired assumption. For example, in Figure 5-2 the NPV associated with a stumpage price of 40 Rs/m^3 is approximately zero. Using this procedure, an infinite number of economic assumptions can be tested and the analytical results obtained.

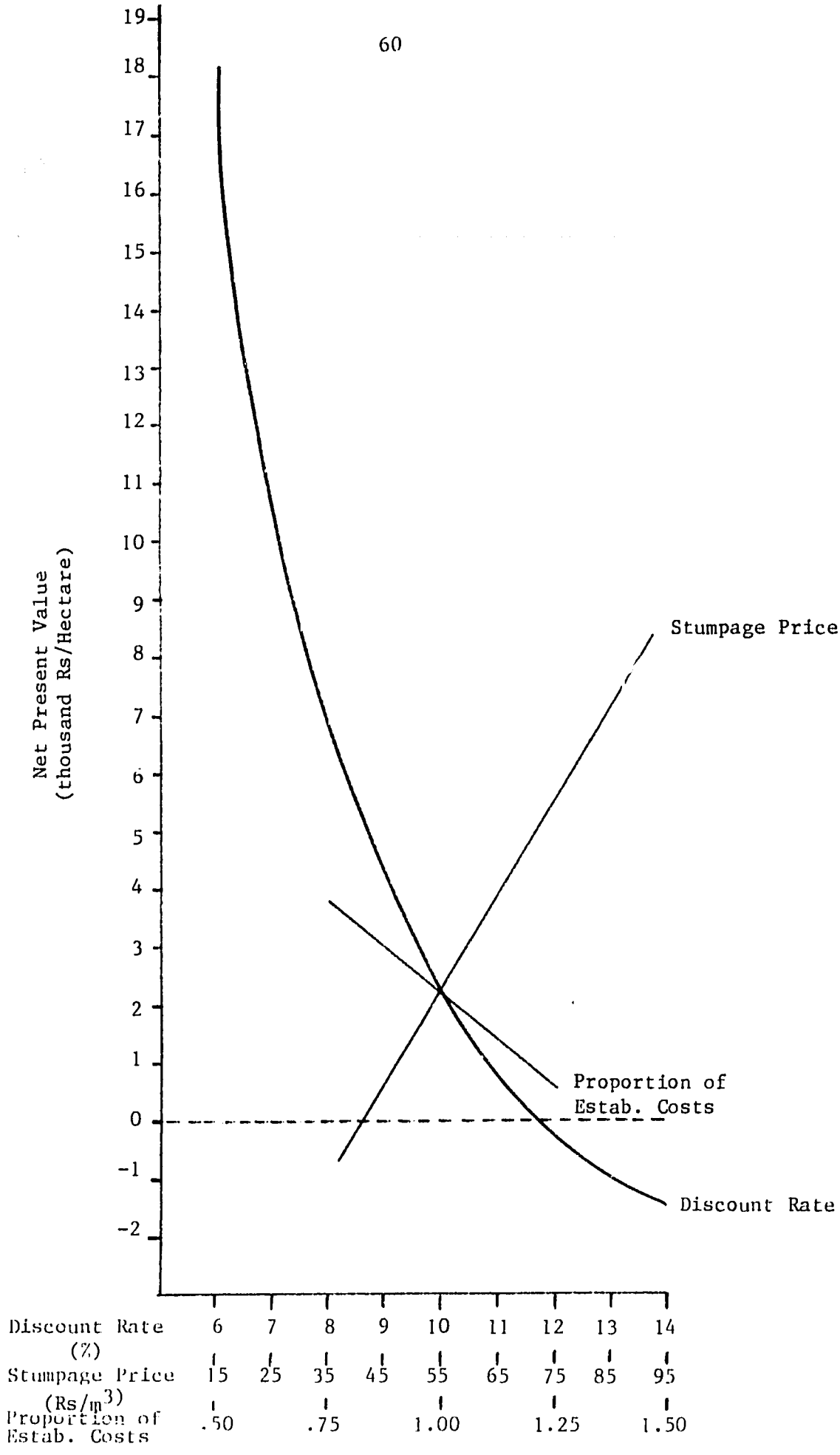


Figure 5-2. Regime: Site Index 13 - 10' x 10' Spacing - 74% Survival - Non-taungya Planting System

5.2.2 Mathematical Interpolations and Extrapolations

Assumptions that are linearly related to NPV are approximated by the linear model:

$NPV = a_o + a_1 x$; where NPV is net present value, x is stumpage price or proportion of establishment cost, and a_o, a_1 are model coefficients.

Assumptions described by this model include stumpage price and plantation establishment costs. The discount rate assumption is geometrically related to NPV and is approximated by the model

$NPV = b_o + b_1 D + b_2 D^2$; where NPV is net present value, D is the discount rate in percent b_o, b_1, b_2 are model coefficients.

The coefficients for both models have been determined analytically and the results for all the management regimes within each site index class are given in Table 5-5. To determine the NPV for a desired assumption, select the appropriate coefficients from Table 5-5, substitute the value of the assumption for x or D in the appropriate equation and solve for NPV. For example, using the mathematical procedure the NPV associated with a stumpage price of 40 Rs/m^3 for the management regime shown in Figure 5-2 is:

$$- 6{,}698\ 40 + (162.79) \cdot (40) = - 186.80 \text{ Rs/hectare}$$

The equations in this section approximate the NPV for alternative assumptions. Extrapolating discount rate equation estimates of NPV for discount rates greater than 14 percent may result in overestimating the NPV.

5.3 Break-even Analysis

Using the graphical or mathematical interpolation and extrapolation procedures described in the previous sections, it is possible to do a break-even analysis. In a break-even analysis, the value of assumption that makes the NPV of the investment equal to zero is determined. This provides

Table 5-5. Coefficients of the Mathematical Models for Interpolation and Extrapolation from the Sensitivity Analysis Results.

Site Index Class	Spacing (feet)	Survival Rate 1/ (percent)	Planting System 2/	Mathematical Model Coefficients: Stumpage Price 3/ a_0	Stumpage Price 3/ a_1	Plantation Establishment Costs 3/ a_0	Plantation Establishment Costs 3/ a_1	Discount Rate 4/ b_0	Discount Rate 4/ b_1	Discount Rate 4/ b_2
13	10	74	N	-6,698.40	162.79	8,888.67	-6,674.00	63868.75	-9923.50	375.81
13	10	74	T	-4,313.34	164.00	8,817.67	-4,054.00	66513.37	-9933.00	375.91
13	10	94R	N	-6,946.22	173.92	9,569.33	-7,016.00	70361.25	-10963.00	418.19
13	10	94R	T	-4,219.22	173.92	9,568.33	-4,288.00	72782.87	-10906.50	415.53
13	10	94	N	-6,638.22	173.92	9,569.33	-6,708.00	70701.12	-10966.50	418.22
13	10	94	T	-3,055.70	161.59	9,497.33	-4,088.00	73319.50	-10964.50	417.62
11	10	74	N	-6,726.68	76.31	4,124.67	-6,672.00	20598.75	-3772.25	145.44
11	10	74	T	-4,139.27	76.12	4,070.00	-4,052.00	22986.12	-3720.50	142.47
11	10	94R	N	-7,026.47	83.44	4,548.67	-7,004.00	23283.62	-4177.00	160.34
11	10	94R	T	-3,601.59	75.03	4,477.67	-4,216.00	26111.25	-4188.00	160.41
11	10	94	N	-6,718.47	83.44	4,548.67	-6,696.00	23619.12	-4179.75	160.34
11	10	94	T	-4,159.47	83.44	4,477.67	-4,076.00	26268.12	-4190.00	160.47
9	10	74	N	-7,017.56	36.09	2,204.00	-7,242.00	-1119.62	-659.50	27.16
9	10	74	T	-4,458.56	36.09	2,133.00	-4,622.00	1525.00	-669.00	27.25
9	10	94R	N	-7,290.55	37.59	2,114.67	-7,262.00	-377.87	-802.50	32.72
9	10	94R	T	-4,586.54	37.75	2,100.33	-4,534.00	2659.75	-863.50	35.31
9	10	94	N	-6,982.35	37.59	2,114.67	-6,954.00	-42.38	-805.25	32.72
9	10	94	T	-4,500.58	39.35	2,043.67	-4,334.00	2604.12	-815.25	32.84
13	6	74	N	-8,796.48	326.71	17,500.67	-8,392.00	123068.87	-18228.25	682.16
13	6	94R	N	-9,548.00	413.43	22,113.00	-9,020.00	161132.12	-23671.75	885.34
13	6	94	N	-8,687.43	415.57	22,235.00	-8,166.00	162082.75	-23671.50	885.56
11	6	74	N	-8,294.82	154.09	8,670.00	-9,088.00	46352.00	-7454.50	277.75
11	6	94R	N	-9,777.78	193.98	10,453.67	-9,602.00	63098.87	-9943.25	371.66
11	6	94	N	-8,838.99	193.35	10,477.33	-8,724.00	63432.75	-9810.00	364.81
9	6	74	N	-9,094.35	66.68	3,654.33	-9,096.00	8989.00	-2320.75	87.88
9	6	94R	N	-9,893.22	83.17	4,545.00	-9,882.00	16112.25	-3457.00	130.94
9	6	94	N	-8,992.72	82.43	4,563.00	-9,074.00	17055.87	-3457.25	130.66

1/ R denotes the stand was replanted.

2/ T denotes a taungya and N denotes a non-taungya planting system.

3/ The mathematical model is $y = NPV = a_0 + a_1 x$; where NPV = net present value, x = the stumpage price or plantation establishment cost assumption.

4/ The mathematical model is $NPV = b_0 + b_1 D + b_2 D^2$; where NPV = net present value, D = the discount rate assumption.

potential investors an estimate of the minimum values for each assumption that will result in the investment yielding financially desirable results.

Break-even values for stumpage price, establishment cost and discount rate assumptions are given in Table 5-6 for all of the management regimes within each site index class. The establishment cost and stumpage price values were determined using the mathematical models in Table 5-5. In this analysis, the break-even value of the assumption in question is computed with the value of all other assumptions equal to the base case values.

The break-even discount rates shown in Table 5-6 can be interpreted as internal rates of returns for each of the management regimes. Plantations established on site index class 11 and 13 land would generally result in investments with internal rates of return greater than 11 percent, given the base case assumptions.

Table 5-6. Break Even Analysis Results.

Site Index Class	Spacing (feet)	Survival Rate 1/ (%)	Planting System 2/	Discount Rate 3/ (%)	Stumpage Price 3/ (Rs/ha.)	Proportion of Estab. Cost 3/
13	10	74	N	11.1	41.15	1.33
13	10	74	T	16.1	25.43	2.17
13	10	94R	N	11.2	39.94	1.36
13	10	94R	T	14.3	24.26	2.24
13	10	94	N	12.2	38.17	1.43
13	10	94	T	14.2	19.11	2.32
11	10	74	N	7.8	88.14	0.62
11	10	74	T	10.0	54.38	1.00
11	10	94R	N	8.1	84.21	0.65
11	10	94R	T	10.3	48.12	0.94
11	10	94	N	8.3	80.52	0.68
11	10	94	T	10.7	49.85	1.10
9	10	74	N	0.0	194.27	0.30
9	10	74	T	0.0	123.46	0.46
9	10	94R	N	0.0	193.00	0.29
9	10	94R	T	0.0	121.25	0.46
9	10	94	N	0.0	184.86	0.30
9	10	94	T	0.0	114.15	0.47
13	6	74	N	14.3	26.93	1.31
13	6	94R	N	15.3	23.10	2.45
13	6	94	N	15.5	20.91	2.72
11	6	74	N	9.7	57.64	0.95
11	6	94R	N	10.5	50.40	1.09
11	6	94	N	11.1	45.72	1.20
9	6	74	N	4.7	136.39	0.40
9	6	94R	N	5.6	118.95	0.46
9	6	94	N	5.9	109.08	0.51

1/ R denotes the stand was replanted.

2/ T denotes a taungya and N denotes a non-taungya planting systems.

3/ Determined from mathematical models in Table 5-5.

6. ECONOMIC ANALYSIS RESULTS

Fuelwood plantations on all site index classes have positive NPV's and are, therefore, economically desirable investments from a societal perspective.

6.1 Net Present Value

The base case results for all the alternative management regimes by site index class are given in Table 6-1. This table compares NPV's of taungya versus non-taungya planting systems, 6' by 6' versus 10' by 10' tree spacing and the effect of replanting plantations with poor initial survival rates by site index classes.

Harvest ages associated with the management regimes are substantially greater than the ages associated with similar regimes in the financial analysis (Table 4-1). Harvests were delayed because of the relationship between the price appreciation assumption and the discount rate.

6.2 Selection of the Preferred Management Regime

The preferred regime within each site index class is the one which yields the largest NPV. This regime is identified by an asterisk in the decision tree shown in Figure 6-1. On all site indexes, the preferred regime is established at 6' by 6' spacing. All preferred management regimes have NPV's greater than zero. Comparisons among planting systems, tree spacing and replanting display the same relationships that occurred in the financial analysis (Chapter 4).

The lower discount rate and "shadow price" labor costs associated with plantation establishment result in substantially larger NPV's than those observed in the financial analysis. If the results associated with these "shadow prices" can be attributed to model distortions caused by taxes, subsidies, various government controls, income distribution and/or economic externalities, they may better estimate the return to Sri Lanka of fuelwood plantation investments. Under this assumption, Table 6-2 shows the

Table 6-1. Base Case Results - Economic Analysis.

Site Index Class	Tree Spacing (feet)	Survival Rate 1/ (%)	Planting System 2/	Initial Plantation (Rs/ha.)	Initial Plantation (Years)	First Coppice (Rs/ha.)	First Coppice (Years)	Second Coppice (Rs/ha.)	Second Coppice (Years)	Total Net Present Value (Rs/ha.)
13	10	74	N	6,692	26	7,623	26	6,050	26	20,365
13	10	74	T	8,635	26	7,623	26	6,050	26	22,308
13	10	94R	N	7,193	24	8,303	24	6,637	24	22,133
13	10	94R	T	9,269	24	8,303	24	6,637	24	24,209
13	10	94	N	7,432	24	8,304	24	6,637	24	22,373
13	10	94	T	9,376	24	8,303	24	6,637	24	24,316
11	10	74	N	811	23	2,692	23	2,157	23	5,660
11	10	74	T	2,754	23	2,692	23	2,157	23	7,603
11	10	94R	N	1,021	26	3,061	26	2,440	26	6,522
11	10	94R	T	3,097	26	3,061	26	2,440	26	8,598
11	10	94	N	1,261	26	3,061	26	2,439	26	6,761
11	10	94	T	3,204	26	3,061	26	2,439	26	8,704
9	10	74	N	-2,056	22	240	22	183	22	-1,633
9	10	74	T	-113	22	240	22	184	22	311
9	10	94R	N	-2,135	21	369	21	284	21	-1,482
9	10	94R	T	-59	21	369	21	284	21	594
9	10	94	N	-1,895	21	369	21	283	21	-1,243
9	10	94	T	48	21	369	21	283	21	700
13	6	74	N	13,624	21	15,198	21	12,296	21	41,118
13	6	94R	N	18,286	21	19,844	21	16,060	21	54,190
13	6	94	N	19,025	21	19,844	21	16,060	21	54,929
11	6	74	N	3,247	20	6,291	20	5,098	20	14,636
11	6	94R	N	4,949	20	8,338	20	6,765	20	20,052
11	6	94	N	5,615	20	8,338	20	6,765	20	20,718
9	6	74	N	-1,976	19	1,777	19	1,424	19	1,225
9	6	94R	N	-1,574	20	2,711	20	2,184	20	3,321
9	6	94	N	-894	19	2,716	20	2,188	20	4,010

1/ R denotes the stand was replanted.

2/ T denotes a taungya and N denotes a non-taungya planting system.

	Initial Survival Rate 94%			Initial Survival Rate 74%					
Survival Rate[1/] (Percent)	94%			94%R[2/]			74%		
Spacing (feet)	10' x 10'		6' x 6'	10' x 10'		6' x 6'	10' x 10'		6' x 6'
Planting System[3/]	T	N	N	T	N	N	T	N	N
Net Present Value[4/] (Rs/Hectare)									
1. Site Index 13	24,316	22,373	54,929*	24,209	22,133	54,190	22,308	20,365	41,118
2. Site Index 11	8,704	6,761	20,718*	8,598	6,522	20,052	7,603	5,660	14,636
3. Site Index 9	700	-1,243	4,010*	594	-1,482	3,321	311	-1,633	1,225

1/ It may be unclear that the investor has control over the survival rate and, therefore, choice between the 74 and 94 percent initial survival rates. However, the difference between the NPV of the management regime with a 94 percent initial survival rate and a 74 percent initial survival rate is a measure of the additional amount an investor could spend on establishment costs to insure the higher survival rate.

2/ R denotes the stand was replanted.

3/ T denotes a taungya and N denotes a non-taungya planting system.

4/ An asterisk denotes the preferred and financially desirable regime. An asterisk in brackets denotes the regime is preferred but not financially desirable.

Figure 6-1. Preferred Regime Decision Tree for Base Case Results - Economic Analysis.

Table 6-2. Internal Rate of Return-Economic Analysis

Site Index Class	Tree Spacing (feet)	Survival Rate 1/ (%)	Planting System 2/	Internal Rate of Return (%)
13	10	74	N	10.9
13	10	74	T	13.6
13	10	94R	N	11.5
13	10	94R	T	14.5
13	10	94	N	11.7
13	10	94	T	14.7
11	10	74	N	8.4
11	10	74	T	10.7
11	10	94R	N	8.2
11	10	94R	T	10.3
11	10	94	N	8.4
11	10	94	T	10.4
9	10	74	N	4.9
9	10	74	T	6.3
9	10	94R	N	5.0
9	10	94R	T	6.6
9	10	94	N	5.2
9	10	94	T	6.7
13	6	74	N	13.4
13	6	94R	N	14.1
13	6	94	N	14.7
11	6	74	N	10.2
11	6	94R	N	10.9
11	6	94	N	11.3
9	6	74	N	6.6
9	6	94R	N	7.2
9	6	94	N	7.6

1/ R denotes the stand was replanted

2/ T denotes a taungya and N denotes a non-taungya planting system.

internal rate of return on the investment for each management regime by site index class.

6.3 Estimating Changes in Base Case Results Associated with Changes in Economic Assumptions

The base case assumptions in the economic analysis represent an approximation of "shadow price" estimates for labor costs and a lowered discount rate. Since empirically estimated "shadow prices" do not exist for Sri Lanka, a resource planner may wish to deviate from the economic assumptions used in this report.

Chapter 5 demonstrated the use of mathematical equations to interpolate or extrapolate results associated with a change in a single economic assumption. In this section, the resource planner needs to interpret the effect on the base case result of simultaneously changing two economic assumptions: establishment costs and discount rate.

The coefficients associated with the mathematical models for all the management regimes within each site index class given in Table 5-5 can be used to estimate the NPV for simultaneous changes in proportion of establishment costs and discount rate. To determine the NPV associated with a desired set of assumptions:

1) select the appropriate coefficients from Table 5-5 for the management regime in question,

2) substitute the value of the proportion of establishment cost assumption for x into the appropriate equation,

3) solve for the NPV using step 2 (NPV_E),

4) substitute the value of the discount rate assumption for D into the appropriate equation,

5) solve for the NPV using step 4 (NPV_D),

6) determine the NPV (NPV_B) associated with the base case financial analysis (Table 4-1) for the management regime in question, and

7) estimate the NPV associated with the simultaneous change in the two assumptions:

$$NPV = NPV_D + (NPV_E - NPV_B)$$

Using the first management regime given in Table 6-1 as an example, the NPV associated with a 7 percent discount rate and establishment costs that are 80 percent of the base case financial analysis establishment costs is:

$$NPV_E = 8888.67 - (6674.00)(0.80) = 3,549$$
$$NPV_D = 63868.75 - (9923.50)(7) + (375.81)(7^2) = 12,819$$
$$NPV_B = 2,215$$
$$NPV = 12,819 + (3,549 - 2,215) = 14,153$$

The equations only approximate the NPV for alternative economic assumptions. The approximation is sufficiently accurate to evaluate changes in base case economic results attributable to alternative "shadow price" estimates.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Biological Conclusions

- Site productivity as measured by locally derived site index curves ranges in site index from 9 to 14 in north central Sri Lanka.
- On site index 13 lands, plantations established at 6' by 6' spacing with high initial survival rates produce 24.5 m^3/ha/yr at culmination of mean annual increment.
- On site index 9 lands, plantations established at 10' by 10' spacing with high initial survival rates produce 2.0 m^3/ha/yr at culmination of mean annual increment.
- Following harvest of the initial plantation, subsequent coppice crops produce 95 and 85 percent of the initial plantation yields, respectively.
- Plantations with a low initial survival rate can be replanted one year after establishment.

7.2 Investment Conclusions - Financial Analysis

- Fuelwood plantations on site index 11 and 13 lands generally have positive NPV's and are, therefore, financially desirable investments using a 10 percent discount rate.
- Investment assumptions are critically important for plantations established on lands classified below site index 11 if NPV's greater than zero are desired.
- Fuelwood plantations established on site index class 11 and 13 land produced internal rates of return greater than 11 percent.
- On site index 13, the preferred management regime is a 6' by 6' spaced plantation established by the non-taungya planting system. When necessary, replanting is financially justifiable to obtain a high plantation survival rate. Using a 10-percent rate, this management regime is financially desirable for a range of investment assumptions.
- On site index 11, the preferred management regime is a 6' by 6' spaced plantation established by the non-taungya system. When necessary, replanting is financially justifiable to obtain a high plantation survival rate. This management regime is financially desirable under base case and optimistic investment assumptions. However, under pessimistic investment assumptions, none of the management regimes are financially desirable at a 10-percent discount rate.
- On site index 9, the preferred management regime is a 10' by 10' spaced plantation established by the taungya

planting system. When necessary, replanting is financially justifiable to obtain a high plantation survival rate. A subsidy of 2,264 Rs/hectare is required for this investment to have a positive NPV using a 10-percent discount rate.

- The taungya planting system was preferred to the non-taungya planting system for all management regimes and investment assumptions.
- The preferred spacing is 6' by 6' except for plantations established on site index 9 lands. In these plantations 10' by 10' spacing is preferred.
- Replanting to achieve high survival rates is generally justified except for site index 9 plantations under pessimistic investment assumptions.

7.3 Investment Conclusions - Economic Analysis

- Fuelwood plantations on all site index classes have positive NPV's and are, therefore, economically desirable investments from a societal perspective.
- Only plantations established at 10' by 10' spacing under the non-taungya planting system on site index 9 land have NPV's less than zero.
- Fuelwood plantations on all site index classes generally produced internal rates of return greater than 11 percent.
- Harvest ages were substantially greater than those generally observed under financial investment assumptions.

7.4 Integrating Investment Analyses into the Planning Process

Resource planners in Sri Lanka must determine how much land should be placed in fuelwood plantations in order to satisfy the domestic demand for energy. This determination requires that alternative energy sources and land availability issues be considered. Using this report, the resource planner can estimate the value of land for fuelwood production. The estimate can then be contrasted with estimates for the value of land under alternative uses to determine land availability. Biomass energy production per unit of available land in conjunction with land availability and alternative energy sources provides an estimate of the energy that can be supplied from fuelwood plantations.

To determine land availability the resource planner would:

1) Identify potential fuelwood plantation locations.

2) Collect *Eucalyptus camaldulensis* plantation site index data in the vicinity of each potential fuelwood plantation location by measuring the height of the largest 250 trees/hectare and compute the average height of the measured trees in the plantation. In the absence of *Eucalyptus camaldulensis* plantations, determine the edaphic and climatic factors in the vicinity of each potential fuelwood plantation location.

3) Use Figure 2-1, the average height and plantation age or edaphic and climatic factors, to estimate the productivity of the land for fuelwood production.

4) Use Chapter 4 to determine the value of the potential fuelwood plantation location for fuelwood production.

5) Use Chapter 5 to modify the initial results if changes in base case investment assumptions are warranted.

6) Determine the desired use of the land by comparing the value of the land in a fuelwood plantation to its value in alternative uses.

7) Use the tables in Appendix I to estimate biomass yields from lands designated as fuelwood plantations.

7.5 An Investment Analysis Format

Resource planners in other developing countries can use this report as a pattern for analyzing fuelwood plantations. The chapter on biological considerations outlines a procedure for estimating the productivity of land for fuelwood production and for determining the biomass fuelwood plantations can produce. Although these methodologies may not be possible in every situation, they do provide a framework for addressing important biological factors.

The chapter on investment assumptions identifies financial and economic constraints and relationships that must be considered in an investment analysis, develops a methodology for quantifying the identified relationships and provides a

framework for incorporating the relationship in an investment analysis of fuelwood plantations. Chapters 4, 5 and 6 present methodologies for analyzing and interpreting the results of a fuelwood plantation investment analysis. Importantly, Chapter 5 demonstrates how sensitivity analysis is used to extend the base case interpretations.

LITERATURE CITED

Ayensu, E.S., et al. 1980. Firewood crops--shrub and tree species for energy production. National Academy of Sciences, Washington, D.C. 237 pp.

Bollinger, W.H., et al. 1979. Watershed reforestation and fuelwood development design for Sri Lanka. Rep. to U.S. Agency for Internat. Development. Internat. Sci. and Tech. Inst., Inc., Washington, D.C. 166 pp.

Central Bank of Ceylon. 1979. Review of the economy. Central Bank of Ceylon, Colombo, Sri Lanka. 231 pp.

_____. 1979. Economic and social statistics of Sri Lanka. Vol. II, No. 2. Colombo, Sri Lanka. 113 pp.

_____. 1979. Price and wage statistics: Recent trends in retail, producer, and input prices and wages. Vol. I, No. 2. Colombo, Sri Lanka. 189 pp.

_____. 1980. Central Bank of Ceylon Bulletin 30 (12).

Christophersen, K.A., et al. 1978. Idaho forest productivity study-economic analysis. Forest, Wildlife and Range Exp. Sta. Bull. No. 26, Moscow, Idaho. 84 pp.

Eriksson, J.R. 1979. Energy, environment and forestry in Sri Lanka: Some major issues. AID Asia Bureau Conference on Energy, Environment and Forestry. Manila, November 12-16, 1979, 15 p.

Goonatillake, S. 1980. Social factors and production modes in energy use. Economic Review 6(2):4-5. The People's Bank, Colombo, Sri Lanka.

Hillis, W.E. and A.G. Brown, eds. 1978. Eucalyptus for wood production. Commonwealth Scientific and Industrial Research Organization, Australia, Griffin Press Limited. 434 p.

Library of Congress. 1978. Draft Environmental Report on Sri Lanka. Science and Technology Division, Washington, D.C. 70 pp.

Medema, E.L. and J.A. Moore. 1980. Investment analysis of forest management alternatives on Department of Lands commercial forest acreage in north Idaho. Report to the Idaho Department of Lands, Boise, ID. 127 pp.

Meta Systems, Inc. 1980. State-of-the-art review of economic evaluation of nonconventional energy alternatives. Report to USDA, Forest Service Bioresources for Energy Project, Washington, D.C.

Mills, T.J., et al. 1976. Sensitivity of estimated financial returns on timber investments to data errors. USDA Forest Serv. Res. Pap. WO-31, Washington, D.C. 23 pp.

Myburgh, H.H. 1967. Kraft pulping of eucalyptus in South Africa. Appita 21(2):49-53.

Perera, W.R.H. 1977. Guidelines for Sri Lanka's forest policy. The Sri Lanka Forester (The Ceylon Forester) 13(1,2):3-4.

_____. 1979. Administration report of the Conservator of Forests for the year 1978. Office of the Conservator of Forests, Colombo, Sri Lanka. 16 pp.

Schweitzer, D.L. 1970. The impact of estimation errors on evaluation of timber production opportunities. USDA Forest Serv. Res. Pap. NC-43, North Central Forest Exp. Sta., St. Paul, MN 18 pp.

Sharma, R.P. 1978. Yield tables for *Eucalyptus hybrid* (Plantation) for various levels of stocking. Indian Forester 104(6):387-397.

Sharma, R.P. 1979. Production potential and other crop characters of the first generation coppice of *Eucalyptus hybrid*. Indian Forester 105(2):89-100.

The People's Bank. 1978. Forest Resources Economic Review 3(11):3-15. The People's Bank, Colombo, Sri Lanka.

The World Bank. 1980. Sri Lanka forestry sector review, Sept. 8, 1980. South Asia Projects Dept., Agri., Div. B. Internat. Document. 57 pp.

USAID. 1980. Sri Lanka: Reforestation and watershed management. Project paper. Agency for Internat. Development, Washington, D.C. 197 pp.

Veiga, R.A.A. and C.M. Carvalho. 1972. Volume equations for *Eucalyptus saligna*. Proceedings of the Seventh World Forestry Congress, Buenos Aires, Argentina, 4-18 October 1972, Vol. II: 2388-2390.

Vivekanandan, K. 1979. Performance of provenances of Eucalyptus in the dry zone. Sri Lanka Forester (The Ceylon Forester) 14(1 and 2):49-57.

Appendix I

Eucalyptus camaldulensis Yield Tables

Table I-1. Eucalyptus camaldulensis Yield Tables by Site Index Class - 10' by 10' Spacing, 74 Percent Initial Survival.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.08	0.08	0.01	0.21	0.21	0.02	0.46	0.46	0.03
2	0.48	0.24	0.03	1.17	0.58	0.04	2.38	1.19	0.05
3	1.35	0.45	0.04	3.16	1.05	0.06	6.37	2.12	0.07
4	2.69	0.67	0.05	6.23	1.56	0.07	12.66	3.16	0.09
5	4.41	0.88	0.06	10.32	2.06	0.08	21.06	4.21	0.11
6	6.50	1.08	0.07	15.21	2.53	0.10	31.23	5.21	0.12
7	8.81	1.26	0.08	20.65	2.95	0.11	42.70	6.10	0.14
8	11.23	1.40	0.09	26.40	3.30	0.12	54.99	6.87	0.15
9	13.69	1.52	0.09	32.27	3.59	0.12	67.68	7.52	0.16
10	16.12	1.61	0.10	38.08	3.81	0.13	80.38	8.04	0.17
11	18.46	1.68	0.10	43.71	3.97	0.14	92.82	8.44	0.18
12	20.69	1.72	0.11	49.08	4.09	0.14	104.77	8.73	0.19
13	22.78	1.75	0.11	54.13	4.16	0.15	116.09	8.93	0.19
14	24.63	1.76	0.11	58.54	4.18	0.15	126.69	9.05	0.20
15	26.53	1.77	0.12	62.98	4.20	0.16	136.55	9.10	0.21
16	28.40	1.77	0.12	67.35	4.21	0.16	144.04	9.00	0.21
17	30.31	1.78	0.12	70.56	4.15	0.16	150.61	8.86	0.21
18	31.93	1.77	0.12	73.24	4.07	0.16	156.35	8.69	0.22
19	33.05	1.74	0.12	75.61	3.98	0.17	161.32	8.49	0.22
20	34.02	1.70	0.12	77.59	3.88	0.17	165.60	8.28	0.22
21	35.00	1.67	0.13	79.00	3.76	0.17	168.00	8.00	0.22
22	36.00	1.64	0.13	81.00	3.68	0.17	171.00	7.77	0.22
23	36.50	1.59	0.13	82.00	3.57	0.17	173.00	7.52	0.22
24	36.70	1.53	0.13	82.50	3.44	0.17	175.00	7.29	0.23
25	36.90	1.48	0.13	82.75	3.31	0.17	177.00	7.08	0.23
26	37.00	1.42	0.13	83.00	3.19	0.17	179.00	6.88	0.23

Table I-2. *Eucalyptus camaldulensis* Yield Tables by Site Index Class - 10' by 10' Spacing, 74 Percent Initial Survival, Replanted to 94 Percent Survival in Year 1.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.08	0.08	0.01	0.21	0.21	0.02	0.46	0.46	0.03
2	0.50	0.25	0.03	1.22	0.61	0.04	2.50	1.25	0.05
3	1.47	0.49	0.04	3.31	1.10	0.06	6.97	2.32	0.07
4	3.03	0.76	0.05	7.02	1.75	0.07	14.25	3.56	0.09
5	5.08	1.02	0.06	11.88	2.38	0.08	24.19	4.84	0.11
6	7.60	1.27	0.07	17.76	2.96	0.09	36.39	6.06	0.12
7	10.41	1.49	0.08	24.36	3.48	0.10	50.27	7.18	0.14
8	13.37	1.67	0.08	31.38	3.92	0.11	65.24	8.15	0.15
9	16.17	1.80	0.09	38.00	4.22	0.12	79.40	8.82	0.16
10	18.77	1.88	0.10	44.29	4.43	0.13	93.24	9.32	0.17
11	21.19	1.93	0.10	50.21	4.56	0.13	106.41	9.67	0.18
12	23.29	1.94	0.10	55.67	4.64	0.14	118.81	9.90	0.19
13	25.34	1.95	0.11	60.43	4.65	0.14	130.15	10.01	0.19
14	27.37	1.95	0.11	65.25	4.66	0.15	139.28	9.95	0.20
15	29.41	1.96	0.11	69.75	4.65	0.15	147.47	9.83	0.21
16	31.25	1.95	0.11	73.61	4.60	0.15	154.70	9.67	0.21
17	33.00	1.94	0.11	77.00	4.53	0.15	161.00	9.47	0.21
18	34.57	1.92	0.11	79.94	4.44	0.16	166.66	9.26	0.21
19	35.74	1.88	0.12	82.44	4.34	0.16	171.40	9.02	0.21
20	36.81	1.84	0.12	84.62	4.23	0.16	175.42	8.77	0.21
21	37.80	1.80	0.12	86.00	4.10	0.16	180.00	8.57	0.21
22	38.30	1.73	0.12	87.50	3.98	0.16	184.00	8.36	0.21
23	39.00	1.70	0.12	89.00	3.87	0.16	186.50	8.11	0.21
24	39.50	1.65	0.12	90.00	3.75	0.17	188.00	7.83	0.22
25	39.75	1.59	0.12	91.00	3.64	0.17	189.00	7.56	0.22
26	40.00	1.54	0.12	92.00	3.54	0.17	190.00	7.31	0.22

Table I-3. Eucalyptus camaldulensis Yield Tables by Site Index Class - 10' by 10' Spacing, 94 Percent Initial Survival.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.10	0.10	0.01	0.26	0.26	0.02	0.58	0.58	0.03
2	0.60	0.30	0.03	1.46	0.73	0.04	2.98	1.49	0.05
3	1.69	0.56	0.04	3.96	1.32	0.06	7.96	2.65	0.07
4	3.36	0.34	0.05	7.78	1.95	0.07	15.66	3.92	0.09
5	5.51	1.10	0.06	12.75	2.55	0.08	25.81	5.16	0.11
6	8.01	1.33	0.07	18.57	3.10	0.09	37.87	6.31	0.12
7	10.70	1.53	0.08	24.91	3.56	0.10	51.23	7.32	0.13
8	13.46	1.68	0.08	31.47	3.93	0.11	65.25	8.16	0.15
9	16.17	1.80	0.09	38.00	4.22	0.12	79.40	8.82	0.16
10	18.77	[illegible]	0.10	44.29	4.43	0.13	93.24	9.32	0.17
11	21.19	[illegible]	0.10	50.21	4.56	0.13	106.41	9.67	0.17
12	23.29	[illegible]	0.10	55.67	4.64	0.14	118.81	9.90	0.18
13	25.34	1.95	0.11	60.43	4.65	0.14	130.15	10.01	0.19
14	27.37	1.95	0.11	65.25	4.66	0.15	139.28	9.95	0.19
15	29.41	1.96	0.11	69.75	4.65	0.15	147.47	9.83	0.20
16	31.25	1.95	0.11	73.61	4.60	0.15	154.70	9.67	0.20
17	33.00	1.94	0.11	77.00	4.53	0.15	161.00	9.47	0.20
18	34.57	1.92	0.11	79.94	4.44	0.16	166.66	9.26	0.21
19	35.74	1.88	0.12	82.44	4.34	0.16	171.40	9.02	0.21
20	36.81	1.84	0.12	84.62	4.23	0.16	175.42	8.77	0.21
21	37.80	1.80	0.12	86.00	4.10	0.16	180.00	8.57	0.21
22	38.50	1.75	0.12	87.50	3.98	0.16	184.00	8.36	0.21
23	39.00	1.70	0.12	89.00	3.87	0.16	186.50	8.11	0.21
24	39.50	1.65	0.12	90.00	3.75	0.17	188.00	7.83	0.22
25	39.75	1.59	0.12	91.00	3.64	0.17	189.00	7.56	0.22
26	40.00	1.54	0.12	92.00	3.54	0.17	190.00	7.31	0.22

Table I-4. *Eucalyptus camaldulensis* Yield Tables by Site Index Class - 10' by 10' Spacing, 74 Percent Survival, First Coppice Crop.

	Site Index Class								
	9			11			13		
Age (yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.08	0.08	0.01	0.20	0.20	0.02	0.44	0.44	0.03
2	0.46	0.23	0.03	1.11	0.56	0.04	2.26	1.13	0.05
3	1.28	0.43	0.04	3.00	1.00	0.06	6.05	2.02	0.07
4	2.56	0.64	0.05	5.92	1.48	0.07	12.03	3.007	0.09
5	4.19	0.84	0.06	9.80	1.96	0.08	20.01	4.00	0.10
6	6.17	1.03	0.07	14.45	2.41	0.09	29.67	4.94	0.11
7	8.37	1.20	0.08	19.62	2.80	0.10	40.57	5.80	0.13
8	10.67	1.33	0.09	25.08	3.13	0.11	52.24	6.53	0.14
9	13.01	1.45	0.09	30.66	3.41	0.11	64.30	7.14	0.15
10	15.31	1.53	0.09	36.18	3.62	0.12	76.36	7.64	0.16
11	17.54	1.59	0.09	41.52	3.77	0.13	88.18	8.02	0.17
12	19.66	1.64	0.10	46.63	3.89	0.13	99.53	8.29	0.18
13	21.64	1.66	0.10	51.42	3.96	0.14	110.29	8.48	0.18
14	23.40	1.67	0.10	55.61	3.97	0.14	120.36	8.60	0.19
15	25.20	1.68	0.11	59.83	3.99	0.15	129.72	8.65	0.20
16	26.98	1.69	0.11	63.98	4.00	0.15	136.84	8.55	0.20
17	28.79	1.69	0.11	67.03	3.94	0.15	143.08	8.42	0.20
18	30.53	1.69	0.11	69.58	3.87	0.15	148.53	8.25	0.21
19	31.40	1.65	0.11	71.83	3.78	0.16	153.25	8.07	0.21
20	32.32	1.62	0.11	73.71	3.69	0.16	157.32	7.87	0.21
21	33.23	1.58	0.12	75.05	3.57	0.16	159.60	7.60	0.21
22	34.20	1.55	0.12	76.93	3.50	0.16	162.45	7.38	0.21
23	34.67	1.51	0.12	77.90	3.39	0.16	164.33	7.15	0.21
24	34.86	1.45	0.12	78.37	3.27	0.16	166.25	6.93	0.22
25	35.06	1.40	0.12	78.61	3.14	0.16	168.15	6.73	0.22
26	35.15	1.35	0.12	78.85	3.03	0.16	170.05	6.54	0.22

Table I-5. *Eucalyptus camaldulensis* Yield Tables by Site Index Class - 10' by 10' Spacing, 74 Percent Survival, Second Coppice Crop.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.07	0.07	0.01	0.18	0.18	0.02	0.39	0.39	0.03
2	0.41	0.20	0.03	0.99	0.50	0.03	2.02	1.01	0.04
3	1.15	0.38	0.03	2.69	0.90	0.05	5.41	1.80	0.06
4	2.29	0.57	0.04	5.30	1.32	0.06	10.76	2.69	0.08
5	3.75	0.75	0.05	8.77	1.75	0.07	17.90	3.58	0.09
6	5.53	0.92	0.06	12.93	2.15	0.08	26.55	4.42	0.10
7	7.49	1.07	0.07	17.55	2.51	0.09	36.29	5.18	0.12
8	9.55	1.19	0.08	22.44	2.80	0.10	46.74	5.84	0.13
9	11.64	1.29	0.08	27.43	3.05	0.10	57.53	6.39	0.14
10	13.70	1.37	0.08	32.37	3.24	0.11	68.32	6.83	0.14
11	15.69	1.43	0.08	37.15	3.38	0.12	78.90	7.17	0.15
12	17.59	1.47	0.09	41.72	3.48	0.12	89.05	7.42	0.16
13	19.36	1.49	0.09	46.01	3.54	0.13	98.68	7.59	0.16
14	20.94	1.50	0.09	49.76	3.55	0.13	107.69	7.69	0.17
15	22.55	1.50	0.10	53.53	3.57	0.14	116.07	7.74	0.18
16	24.14	1.51	0.10	57.25	3.58	0.14	122.43	7.65	0.18
17	25.76	1.52	0.10	59.98	3.53	0.14	128.02	7.53	0.18
18	27.14	1.51	0.10	62.25	3.46	0.14	132.90	7.38	0.19
19	28.09	1.48	0.10	64.27	3.38	0.14	137.12	7.22	0.19
20	28.92	1.45	0.10	65.95	3.30	0.14	140.76	7.04	0.19
21	29.75	1.42	0.11	67.15	3.20	0.14	142.80	6.80	0.19
22	30.60	1.39	0.11	68.85	3.13	0.14	145.35	6.61	0.19
23	31.02	1.35	0.11	69.70	3.03	0.14	147.05	6.39	0.19
24	31.19	1.30	0.11	70.12	2.92	0.14	148.75	6.20	0.20
25	31.36	1.25	0.11	70.34	2.81	0.14	150.45	6.02	0.20
26	31.45	1.21	0.11	70.55	2.71	0.14	152.15	5.85	0.20

Table I-6. *Eucalyptus camaldulensis* Yield Tables by Site Index Class - 10' by 10' Spacing, 94 Percent Survivals, First Coppice Crop.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.09	0.09	0.01	0.25	0.25	0.02	0.55	0.55	0.03
2	0.57	0.28	0.03	1.39	0.69	0.04	2.83	1.41	0.05
3	1.61	0.54	0.04	3.76	1.25	0.06	7.56	2.52	0.07
4	3.19	0.80	0.05	7.39	1.85	0.07	14.88	3.72	0.09
5	5.23	1.05	0.06	12.11	2.42	0.08	24.52	4.90	0.10
6	7.61	1.27	0.07	17.64	2.94	0.09	35.98	6.00	0.11
7	10.16	1.45	0.08	23.66	3.38	0.09	48.67	6.95	0.12
8	12.79	1.60	6.08	29.90	3.74	0.10	61.99	7.75	0.14
9	15.36	1.71	0.09	36.10	4.01	0.11	75.43	8.38	0.15
10	17.83	1.78	0.09	42.08	4.21	0.12	88.58	8.86	0.16
11	20.13	1.83	0.09	47.70	4.34	0.12	101.09	9.19	0.16
12	22.13	1.84	0.09	52.89	4.41	0.13	112.87	9.41	0.17
13	24.07	1.85	0.10	57.41	4.42	0.13	123.64	9.51	0.18
14	26.00	1.86	0.10	61.99	4.43	0.14	132.32	9.45	0.18
15	27.94	1.86	0.10	66.26	4.42	0.14	140.10	9.34	0.19
16	29.69	1.86	0.10	69.93	4.37	0.14	146.96	9.18	0.19
17	31.35	1.84	0.10	73.15	4.30	0.14	152.95	9.00	0.19
18	32.84	1.82	0.10	75.94	4.22	0.15	158.33	8.80	0.20
19	33.95	1.79	0.11	78.32	4.12	0.15	162.83	8.57	0.20
20	34.97	1.75	0.11	80.39	4.02	0.15	166.64	8.33	0.20
21	35.91	1.71	0.11	81.70	3.89	0.15	171.00	8.14	0.20
22	36.57	1.66	0.11	83.12	3.78	0.15	174.80	7.95	0.20
23	37.05	1.61	0.11	84.55	3.68	0.15	177.17	7.70	0.20
24	37.32	1.56	0.11	85.50	3.56	0.16	178.60	7.44	0.21
25	37.76	1.51	0.11	86.45	3.46	0.16	179.55	7.18	0.21
26	38.00	1.46	0.11	87.40	3.36	0.16	180.50	6.94	0.21

Table I-7. *Eucalyptus camaldulensis* Yield Tables by Site Index Class - 10' by 10' Spacing, 94 Percent Survival, Second Coppice Crop.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.08	0.08	0.01	0.22	0.22	0.02	0.49	0.49	0.03
2	0.51	0.25	0.03	1.24	0.62	0.03	2.53	1.26	0.04
3	1.44	0.48	0.03	3.37	1.12	0.05	6.77	2.26	0.06
4	2.86	0.71	0.04	6.61	1.65	0.06	13.31	3.33	0.08
5	4.68	0.94	0.05	10.84	2.17	0.07	21.94	4.39	0.09
6	6.81	1.13	0.06	15.78	2.63	0.08	32.19	5.36	0.10
7	9.09	1.30	0.07	21.17	3.02	0.08	43.55	6.22	0.11
8	11.44	1.43	0.07	26.75	3.34	0.09	55.46	6.93	0.13
9	13.74	1.53	0.08	32.30	3.59	0.10	67.49	7.50	0.14
10	15.95	1.59	0.08	37.65	3.76	0.11	79.25	7.92	0.14
11	18.01	1.64	0.08	42.68	3.88	0.11	90.45	8.22	0.14
12	19.80	1.65	0.08	47.32	3.94	0.12	100.99	8.42	0.15
13	21.54	1.66	0.09	51.37	3.95	0.12	110.63	8.51	0.16
14	23.26	1.66	0.09	55.46	3.96	0.13	118.39	8.46	0.16
15	25.00	1.67	0.09	59.29	3.95	0.13	125.35	8.36	0.17
16	26.56	1.66	0.09	62.57	3.91	0.13	131.49	8.22	0.17
17	28.05	1.65	0.09	65.45	3.85	0.13	136.85	8.05	0.17
18	29.38	1.63	0.09	67.95	3.77	0.14	141.66	7.87	0.18
19	30.38	1.60	0.10	70.07	3.69	0.14	145.69	7.67	0.18
20	31.29	1.56	0.10	71.93	3.60	0.14	149.11	7.46	0.18
21	32.13	1.53	0.10	73.10	3.48	0.14	153.00	7.29	0.18
22	32.72	1.49	0.10	74.37	3.38	0.14	156.40	7.11	0.18
23	33.15	1.44	0.10	75.65	3.29	0.14	158.52	6.89	0.18
24	33.57	1.40	0.10	76.50	3.19	0.14	159.80	6.66	0.19
25	33.79	1.35	0.10	77.35	3.09	0.14	160.65	6.43	0.19
26	34.00	1.31	0.10	78.20	3.01	0.14	161.50	6.21	0.19

Table I-8. Eucalyptus camaldulensis Yield Tables by Site Index Class - 6' by 6' Spacing, 74 Percent Initial Survival.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.21	0.21	0.01	0.58	0.58	0.02	1.27	1.27	0.03
2	1.32	0.66	0.03	3.21	1.61	0.04	6.49	3.24	0.05
3	3.66	1.22	0.04	8.60	2.87	0.06	17.17	5.72	0.07
4	7.18	1.79	0.05	16.73	4.18	0.07	33.45	8.36	0.09
5	11.62	2.32	0.06	27.09	5.42	0.08	54.55	10.91	0.10
6	16.64	2.77	0.07	38.98	6.50	0.09	79.18	13.20	0.12
7	21.92	3.13	0.08	51.65	7.38	0.10	105.91	15.13	0.13
8	27.16	3.40	0.08	64.44	8.06	0.11	133.37	16.67	0.14
9	32.16	3.57	0.09	76.82	8.54	0.12	160.40	17.82	0.15
10	36.77	3.68	0.09	88.39	8.84	0.12	189.81	18.98	0.16
11	40.72	3.70	0.09	98.91	8.99	0.13	211.99	19.27	0.17
12	44.53	3.71	0.10	108.24	9.02	0.13	230.86	19.24	0.17
13	48.38	3.72	0.10	116.34	8.95	0.14	247.40	19.03	0.18
14	51.91	3.71	0.10	123.23	8.80	0.14	261.50	18.68	0.18
15	54.91	3.66	0.10	128.98	8.60	0.14	273.47	18.23	0.19
16	57.30	3.58	0.10	133.66	8.35	0.14	283.34	17.71	0.19
17	59.18	3.48	0.11	137.39	8.08	0.14	291.40	17.14	0.19
18	60.64	3.37	0.11	140.27	7.79	0.15	297.70	16.54	0.19
19	61.74	3.25	0.11	142.41	7.50	0.15	302.50	15.92	0.19
20	62.39	3.12	0.11	143.91	7.20	0.15	305.41	15.27	0.19
21	62.90	3.00	0.11	144.40	6.88	0.15	307.50	14.64	0.20
22	63.00	2.86	0.11	144.90	6.59	0.15	309.00	14.05	0.20
23	63.50	2.76	0.11	145.00	6.30	0.15	310.00	13.48	0.20
24	63.50	2.65	0.11	145.00	6.04	0.15	310.00	12.92	0.20
25	63.50	2.54	0.11	145.00	5.80	0.15	310.00	12.40	0.20
26	63.50	2.44	0.11	145.00	5.58	0.15	310.00	11.92	0.20

Table I-9. *Eucalyptus camaldulensis* Yield Tables by Site Index Class - 6' by 6' Spacing, 74 Percent Initial Survival, Replanted to 94 Percent Survival in Year 1.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.21	0.21	0.01	0.58	0.58	0.02	1.27	1.27	0.03
2	1.38	0.69	0.03	3.37	1.68	0.04	6.83	3.41	0.05
3	4.02	1.34	0.04	9.47	3.16	0.06	18.94	6.31	0.07
4	8.18	2.04	0.05	19.05	4.76	0.07	38.13	9.53	0.09
5	13.58	2.72	0.06	31.60	6.32	0.08	63.67	12.73	0.10
6	19.81	3.30	0.07	46.28	7.71	0.09	94.06	15.68	0.12
7	26.46	3.78	0.08	62.16	8.88	0.10	127.51	18.22	0.13
8	33.14	4.14	0.08	78.36	9.79	0.11	162.25	20.28	0.14
9	39.57	4.40	0.09	94.18	10.46	0.12	196.77	21.86	0.15
10	45.54	4.55	0.09	109.09	10.91	0.12	233.55	23.35	0.16
11	50.75	4.61	0.09	122.72	11.16	0.13	264.45	24.04	0.17
12	55.61	4.63	0.10	134.88	11.24	0.13	287.74	23.98	0.17
13	60.52	4.66	0.10	145.49	11.19	0.14	310.38	23.88	0.18
14	65.09	4.65	0.10	154.56	11.04	0.14	328.97	23.50	0.18
15	69.07	4.60	0.10	162.07	10.80	0.14	344.81	22.99	0.19
16	72.19	4.51	0.10	167.95	10.50	0.14	357.91	22.37	0.19
17	74.82	4.40	0.11	172.62	10.15	0.14	368.68	21.69	0.19
18	76.78	4.27	0.11	176.23	9.79	0.15	377.15	20.95	0.19
19	78.28	4.12	0.11	178.91	9.42	0.15	383.69	20.19	0.19
20	79.21	3.96	0.11	180.79	9.04	0.15	387.90	19.39	0.19
21	79.80	3.80	0.11	181.50	8.64	0.15	390.86	18.61	0.20
22	80.20	3.65	0.11	183.00	8.32	0.15	393.00	17.86	0.20
23	80.60	3.50	0.11	184.00	8.00	0.15	394.43	17.15	0.20
24	80.80	3.37	0.11	185.00	7.71	0.15	394.86	16.45	0.20
25	81.00	3.24	0.11	185.00	7.40	0.15	395.29	15.81	0.20
26	81.00	3.12	0.11	185.00	7.12	0.15	395.71	15.22	0.20

Table I-10. Eucalyptus camaldulensis Yield Tables by Site Index Class - 6' by 6' Spacing, 94 Percent Initial Survival.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.27	0.27	0.01	0.74	0.74	0.02	1.61	1.61	0.03
2	1.69	0.84	0.03	4.04	2.02	0.04	8.25	4.13	0.05
3	4.66	1.55	0.04	10.82	3.61	0.06	21.85	7.28	0.07
4	9.13	2.28	0.05	21.04	5.26	0.07	42.58	10.64	0.09
5	14.78	2.96	0.06	34.08	6.82	0.08	69.43	13.89	0.10
6	21.18	3.53	0.07	49.03	8.17	0.09	100.78	16.80	0.12
7	27.89	3.98	0.08	64.96	9.28	0.10	134.79	19.26	0.13
8	34.57	4.32	0.08	81.03	10.13	0.11	169.74	21.22	0.14
9	40.93	4.55	0.09	96.58	10.73	0.12	204.14	22.68	0.15
10	46.80	4.68	0.09	111.12	11.11	0.12	238.81	23.88	0.16
11	51.71	4.70	0.09	124.33	11.30	0.13	269.85	24.53	0.17
12	56.65	4.72	0.10	136.05	11.34	0.13	293.90	24.49	0.17
13	61.50	4.73	0.10	146.22	11.25	0.14	314.85	24.22	0.18
14	66.06	4.72	0.10	154.87	11.06	0.14	332.90	23.78	0.18
15	69.49	4.66	0.10	162.07	10.80	0.14	348.01	23.20	0.19
16	72.98	4.56	0.10	167.95	10.50	0.14	360.65	22.54	0.19
17	75.32	4.43	0.11	172.62	10.15	0.14	370.79	21.81	0.19
18	77.20	4.29	0.11	176.23	9.79	0.14	378.89	21.05	0.19
19	78.50	4.13	0.11	178.91	9.42	0.15	384.95	20.26	0.19
20	79.41	3.97	0.11	180.79	9.04	0.15	389.01	19.45	0.19
21	79.80	3.80	0.11	181.50	8.64	0.15	392.00	18.67	0.20
22	80.20	3.65	0.11	183.00	8.32	0.15	394.00	17.91	0.20
23	80.60	3.50	0.11	184.00	8.00	0.15	396.00	17.22	0.20
24	80.80	3.37	0.11	185.00	7.71	0.15	398.00	16.58	0.20
25	81.00	3.24	0.11	185.00	7.40	0.15	400.00	16.00	0.20
26	81.00	3.12	0.11	185.00	7.12	0.15	400.00	15.38	0.20

Table 1-11. *Eucalyptus camaldulensis* Yield Tables by Site Index Class - 6' by 6' Spacing, 74 Percent Survival, First Coppice Crop.

	Site Index Class								
	9			11			13		
Age (yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.20	0.20	0.01	0.55	0.55	0.02	1.21	1.21	0.03
2	1.25	0.63	0.03	3.05	1.52	0.04	6.17	3.08	0.05
3	3.48	1.16	0.04	8.17	2.72	0.06	16.31	5.44	0.07
4	6.82	1.71	0.05	15.89	3.97	0.07	31.78	7.94	0.09
5	11.04	2.21	0.06	25.74	5.15	0.08	51.82	10.36	0.10
6	15.81	2.63	0.07	37.03	6.17	0.09	75.22	12.54	0.11
7	20.82	2.97	0.08	49.07	7.01	0.10	100.61	14.37	0.12
8	25.80	3.23	0.08	61.22	7.65	0.10	126.70	15.84	0.13
9	30.55	3.39	0.09	72.98	8.11	0.11	152.38	16.93	0.14
10	34.93	3.49	0.09	83.97	8.40	0.11	180.32	18.03	0.15
11	38.68	3.52	0.09	93.96	8.54	0.12	201.39	18.31	0.16
12	42.30	3.53	0.10	102.83	8.57	0.12	219.32	18.28	0.16
13	45.96	3.54	0.10	110.52	8.50	0.13	235.03	18.08	0.17
14	49.31	3.52	0.10	117.07	8.36	0.13	248.42	17.74	0.17
15	52.16	3.48	0.10	122.53	8.17	0.13	259.80	17.32	0.18
16	54.43	3.40	0.10	126.98	7.94	0.13	269.17	16.82	0.18
17	56.22	3.31	0.10	130.52	7.68	0.13	276.83	16.28	0.18
18	57.61	3.20	0.10	133.26	7.40	0.14	282.81	15.71	0.18
19	58.65	3.09	0.10	135.29	7.12	0.14	287.37	15.12	0.18
20	59.27	2.96	0.10	136.71	6.84	0.14	290.14	14.51	0.18
21	59.75	2.85	0.10	137.18	6.53	0.14	292.12	13.91	0.19
22	59.85	2.72	0.10	137.65	6.26	0.14	293.55	13.34	0.19
23	60.32	2.62	0.10	137.75	5.99	0.14	294.50	12.80	0.19
24	60.32	2.51	0.10	137.75	5.74	0.14	294.50	12.27	0.19
25	60.32	2.41	0.10	137.75	5.51	0.14	294.50	11.78	0.19
26	60.32	2.32	0.10	137.75	5.30	0.14	294.50	11.33	0.19

Table I-12. Eucalyptus camaldulensis Yield Tables by Site Index Class - 6' by 6' Spacing, 74 Percent Survival, Second Coppice Crop.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.18	0.18	0.01	0.49	0.49	0.02	1.08	1.08	0.03
2	1.12	0.56	0.03	2.73	1.36	0.03	5.52	2.76	0.04
3	3.11	1.04	0.03	7.31	2.44	0.05	14.59	4.86	0.06
4	6.10	1.53	0.04	14.22	3.56	0.06	28.43	7.11	0.08
5	9.88	1.98	0.05	23.03	4.61	0.07	46.37	9.27	0.08
6	14.14	2.36	0.06	33.13	5.52	0.08	67.30	11.22	0.10
7	18.63	2.66	0.07	43.90	6.27	0.08	90.02	12.86	0.11
8	23.09	2.89	0.07	54.77	6.85	0.09	113.36	14.17	0.12
9	27.34	3.04	0.08	65.30	7.26	0.10	136.34	15.15	0.13
10	31.25	3.12	0.08	75.13	7.51	0.10	161.34	16.13	0.14
11	34.61	3.15	0.08	84.07	7.64	0.11	180.19	16.38	0.14
12	37.83	3.15	0.08	92.00	7.67	0.11	196.23	16.35	0.14
13	41.12	3.16	0.08	98.89	7.61	0.12	210.29	16.18	0.15
14	44.12	3.15	0.08	104.75	7.48	0.12	222.27	15.88	0.15
15	46.67	3.11	0.08	109.63	7.31	0.12	232.45	15.50	0.16
16	48.70	3.04	0.08	113.61	7.10	0.12	240.84	15.05	0.16
17	50.30	2.96	0.09	116.78	7.87	0.12	247.69	14.57	0.16
18	51.54	2.86	0.09	119.23	6.62	0.13	253.04	14.06	0.16
19	52.48	2.76	0.09	121.05	6.37	0.13	257.12	13.53	0.16
20	53.03	2.65	0.09	122.32	6.12	0.13	259.60	12.98	0.16
21	53.46	2.55	0.09	122.74	5.84	0.13	261.37	12.45	0.17
22	53.53	2.43	0.09	123.16	5.60	0.13	262.65	11.94	0.17
23	53.97	2.35	0.09	123.25	5.36	0.13	263.50	11.46	0.17
24	53.97	2.25	0.09	123.25	5.14	0.13	263.50	10.98	0.17
25	53.97	2.16	0.09	123.25	4.93	0.13	263.50	10.54	0.17
26	53.97	2.08	0.09	123.25	4.74	0.13	263.50	10.13	0.17

Table I-13. *Eucalyptus camaldulensis* Yield Tables by Site Index Class - 6' by 6' Spacing, 94 Percent Survival, First Coppice Crop.

	Site Index Class								
	9			11			13		
Age (Yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.26	0.26	0.01	0.70	0.70	0.02	1.53	1.53	0.03
2	1.61	0.80	0.03	3.84	1.92	0.04	7.84	3.92	0.05
3	4.43	1.48	0.04	10.28	3.43	0.06	20.76	6.92	0.07
4	8.67	2.17	0.05	19.99	5.00	0.07	40.45	10.11	0.09
5	14.04	2.81	0.06	32.38	6.48	0.08	65.96	13.19	0.10
6	20.12	3.35	0.07	46.58	7.76	0.09	95.74	15.96	0.11
7	26.50	3.79	0.08	61.71	8.82	0.10	128.05	18.29	0.12
8	32.84	4.11	0.08	76.98	9.62	0.10	161.25	20.16	0.13
9	38.88	4.32	0.09	91.75	10.19	0.11	193.93	21.55	0.14
10	44.46	4.45	0.09	105.56	10.56	0.11	226.87	22.69	0.15
11	49.12	4.47	0.09	118.11	10.74	0.12	256.36	23.31	0.16
12	53.82	4.48	0.10	129.25	10.77	0.12	279.20	23.27	0.16
13	58.42	4.49	0.10	138.91	10.69	0.13	299.11	23.01	0.17
14	62.76	4.48	0.10	147.13	10.51	0.13	316.25	22.59	0.17
15	66.02	4.40	0.10	153.97	10.26	0.13	330.61	22.04	0.18
16	69.33	4.33	0.10	159.55	9.97	0.13	342.62	21.41	0.18
17	71.55	4.21	0.10	163.99	9.65	0.13	352.25	20.72	0.18
18	73.34	4.07	0.10	167.42	9.30	0.13	359.95	20.00	0.18
19	74.57	3.93	0.10	169.96	8.95	0.14	365.70	19.25	0.18
20	75.44	3.77	0.10	171.75	8.59	0.14	369.56	18.48	0.18
21	75.81	3.61	0.10	172.42	8.21	0.14	372.40	17.73	0.19
22	76.19	3.46	0.10	173.85	7.90	0.14	374.30	17.01	0.19
23	76.57	3.33	0.10	174.80	7.60	0.14	376.20	16.36	0.19
24	76.76	3.20	0.10	175.75	7.32	0.14	378.10	15.75	0.19
25	76.95	3.08	0.10	175.75	7.03	0.14	380.00	15.20	0.19
26	76.95	2.96	0.10	175.75	6.76	0.14	380.00	14.62	0.19

Table I-14. Eucalyptus camaldulensis Yield Tables by Site Index Class - 6' by 6' Spacing, 94 Percent Survival, Second Coppice Crop.

	Site Index Class								
	9			11			13		
Age (yrs)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)	Plantation Volume (m^3/ha)	Plantation Mean Annual Growth (m^3/ha/yr)	Average Tree Diameter (m)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.23	0.23	0.01	0.63	0.63	0.02	1.37	1.37	0.03
2	1.44	0.72	0.03	3.43	1.72	0.03	7.01	3.51	0.04
3	3.96	1.32	0.03	9.20	3.07	0.05	18.57	6.19	0.06
4	7.76	1.94	0.04	17.88	4.47	0.06	36.19	9.05	0.08
5	12.56	2.51	0.05	28.97	5.79	0.07	59.02	11.80	0.08
6	18.00	3.00	0.06	41.68	6.95	0.08	85.66	14.28	0.10
7	23.71	3.39	0.07	55.22	7.89	0.08	114.57	16.37	0.11
8	29.38	3.67	0.07	68.88	8.61	0.09	144.28	18.03	0.12
9	34.79	3.87	0.08	82.09	9.12	0.10	173.52	19.28	0.13
10	39.78	3.98	0.08	94.45	9.44	0.10	202.99	20.30	0.14
11	43.95	4.00	0.08	105.68	9.61	0.11	229.37	20.85	0.14
12	48.15	4.01	0.08	115.64	9.64	0.11	249.81	20.82	0.14
13	52.27	4.02	0.08	124.29	9.56	0.12	267.62	20.59	0.15
14	56.15	4.01	0.08	131.64	9.40	0.12	282.96	20.21	0.15
15	59.07	3.94	0.08	137.76	9.18	0.12	295.81	19.72	0.16
16	62.03	3.88	0.08	142.76	8.92	0.12	306.55	19.16	0.16
17	64.02	3.77	0.09	146.73	8.63	0.12	315.17	18.54	0.16
18	65.62	3.65	0.09	149.80	8.32	0.12	322.06	17.89	0.16
19	66.72	3.51	0.09	152.07	8.00	0.13	327.21	17.22	0.16
20	67.50	3.37	0.09	153.67	7.68	0.13	330.66	16.53	0.16
21	67.83	3.23	0.09	154.27	7.35	0.13	333.20	15.87	0.17
22	68.17	3.10	0.09	155.55	7.07	0.13	334.90	15.22	0.17
23	68.51	2.98	0.09	156.40	6.80	0.13	336.60	14.63	0.17
24	68.68	2.86	0.09	157.25	6.55	0.13	338.30	14.10	0.17
25	68.85	2.75	0.09	157.25	6.29	0.13	340.00	13.60	0.17
26	68.85	2.65	0.09	157.25	6.05	0.13	340.00	13.08	0.17

Appendix II

Mathematical Estimation Equations

II-1. Exponential Curve Fitting Method

This procedure uses a least squares solution to fit n pairs of data points $\{(X_i, Y_i), i = 1, 2, \ldots, n\}$ where $Y_i > 0$, to an exponential function of the form

$$Y = b_0 e^{b_1 X}$$

The parameters, b_0 and b_1, are estimated

$$b_1 = \frac{\Sigma(X_i \ln Y_i) - \frac{(\Sigma X_i)(\Sigma \ln Y_i)}{n}}{\Sigma(X_i^2) - \frac{(\Sigma X_i)^2}{n}}$$

$$b_0 = e^{\left[\frac{\Sigma \ln Y_i}{n} - b_1 \frac{\Sigma X_i}{n}\right]}$$

Where: e is base of the natural logarithm
$\ln Y$ is the natural logarithm of Y

This procedure is used in Chapter 3 to estimate price and cost appreciation rates (b_1). The dependent variable Y would represent price or cost values a a point in time and the independent variable X would represent the point in time.

II-2. Linear Curve Fitting Method

This procedure uses a least squares solution to fit 3 pairs of data points {(Xi, Yi), i = 1, 2, 3} to a linear function of the form

$$Y = a_0 + a_1 X$$

The parameters, a_0 and a_1, are estimated

$$a_1 = \frac{\Sigma X_i Y_i - \frac{(\Sigma X_i)(\Sigma Y_i)}{3}}{\Sigma X_i^2 - \frac{(\Sigma X_i)^2}{3}}$$

$$a_0 = \frac{\Sigma Y_i}{3} - A_1 \frac{\Sigma X_i}{3}$$

This procedure is used in Chapter 5 to estimate the relationships between NPV and stumpage price or establishment cost. The dependent variable Y would represent NPV for a given price or cost assumption and the independent variable X would represent the stumpage price or the proportion of establishment cost.

II-3. Geometric Curve Fitting Method

This procedure uses a simultaneous solution to fit 3 pairs of data points {(Xi, Yi), i = 1, 2, 3} to a quadratic function of the form

$$Y = b_0 + b_1 D + b_2 D^2$$

This procedure is used in Chapter 5 to estimate the relationship between NPV and discount rate. The dependent variable Y would represent NPV for a given discount rate and the independent variable X would represent the discount rate.

For the three discount rates, these equations can be written

$$NPV_{10} = b_0 + b_1 \cdot 10 + b_2\ 100$$

$$NPV_6 = b_0 + b_1 \cdot 6 + b_2\ 36$$

$$NPV_{14} = b_0 + b_1 \cdot 14 + b_2\ 196$$

The parameters, b_0, b_1 and b_2 are estimated

$$b_2 = \frac{(NPV_{10} - NPV_6) + (NPV_{10} - NPV_{14})}{-32}$$

$$b_1 = \frac{(NPV_6 - NPV_{14}) + 160.b_2}{-8}$$

$$b_0 = NPV_1 - 10b_1 - 100b_2$$

Appendix III

Graphical Presentation of Sensitivity Analyses

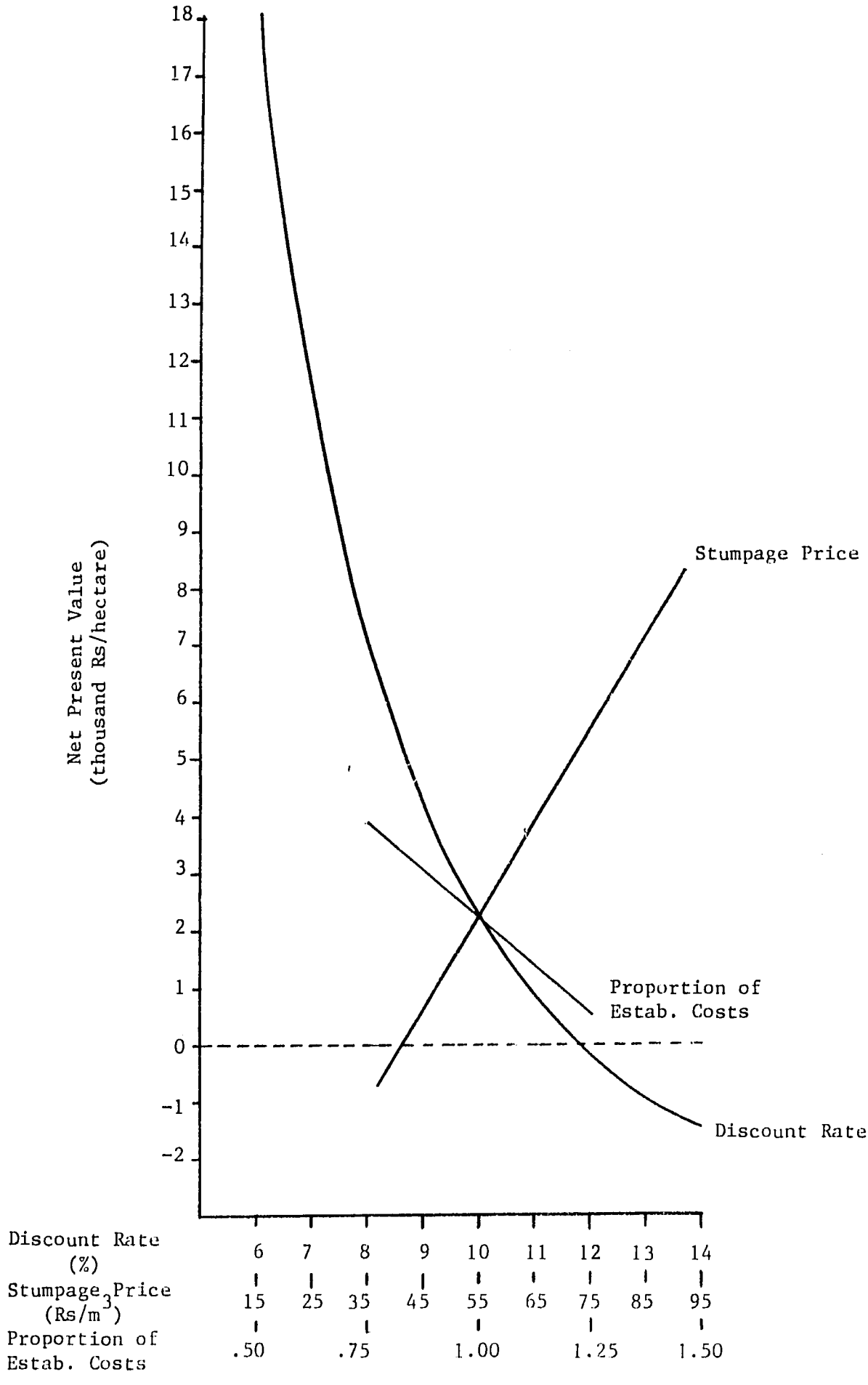


Figure III-1. Regime: Site Index 13 - 10' x 10' Spacing - 74% Survival - Non-taungya Planting System

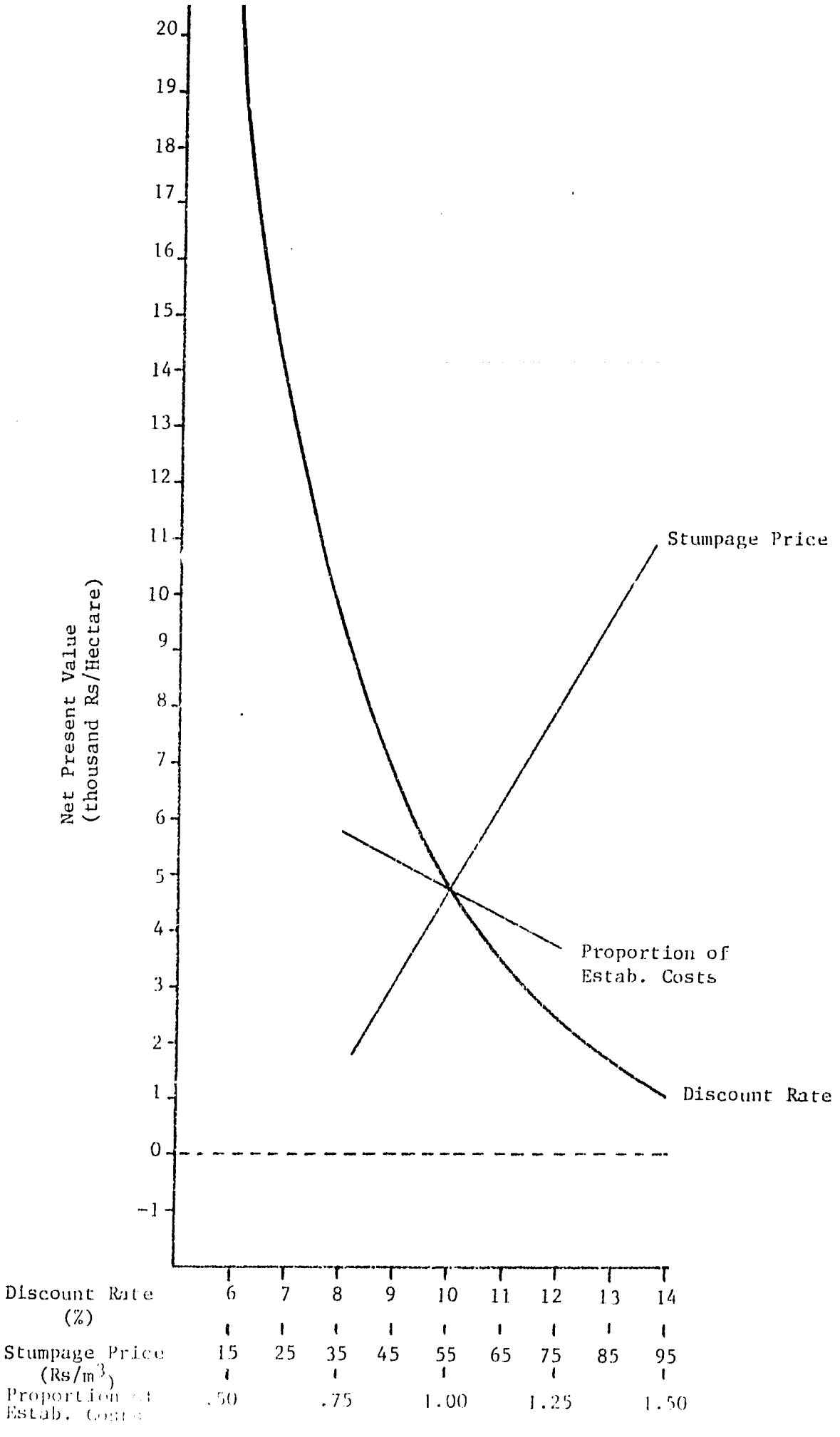


Figure III-2. Regime: Site Index 13 - 10' x 10' Spacing - 74% survival - Taungya Planting System

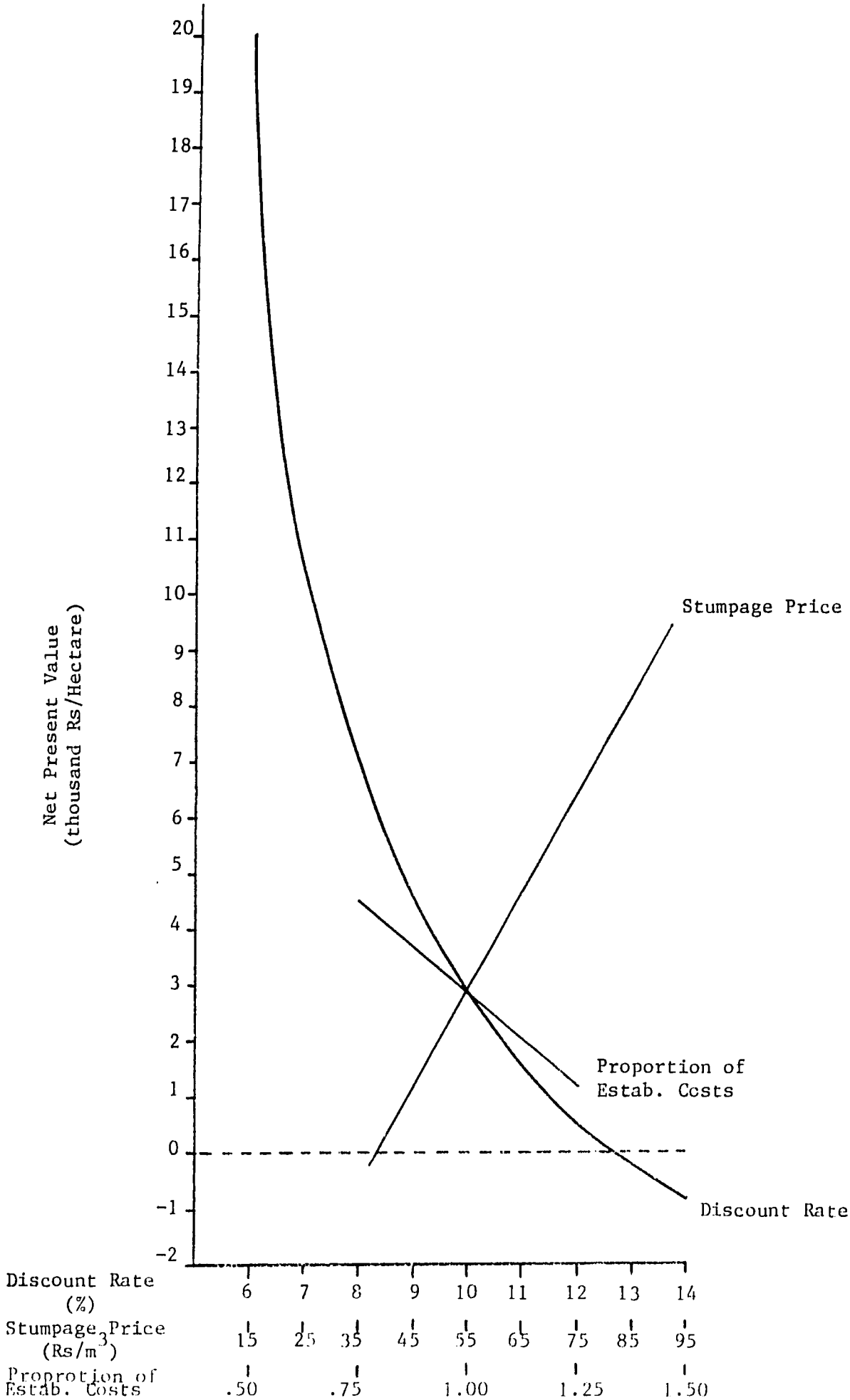


Figure III-3. Regime: Site Index 13 - 10' x 10' Spacing - 94% Survival - Non-taungya Planting System

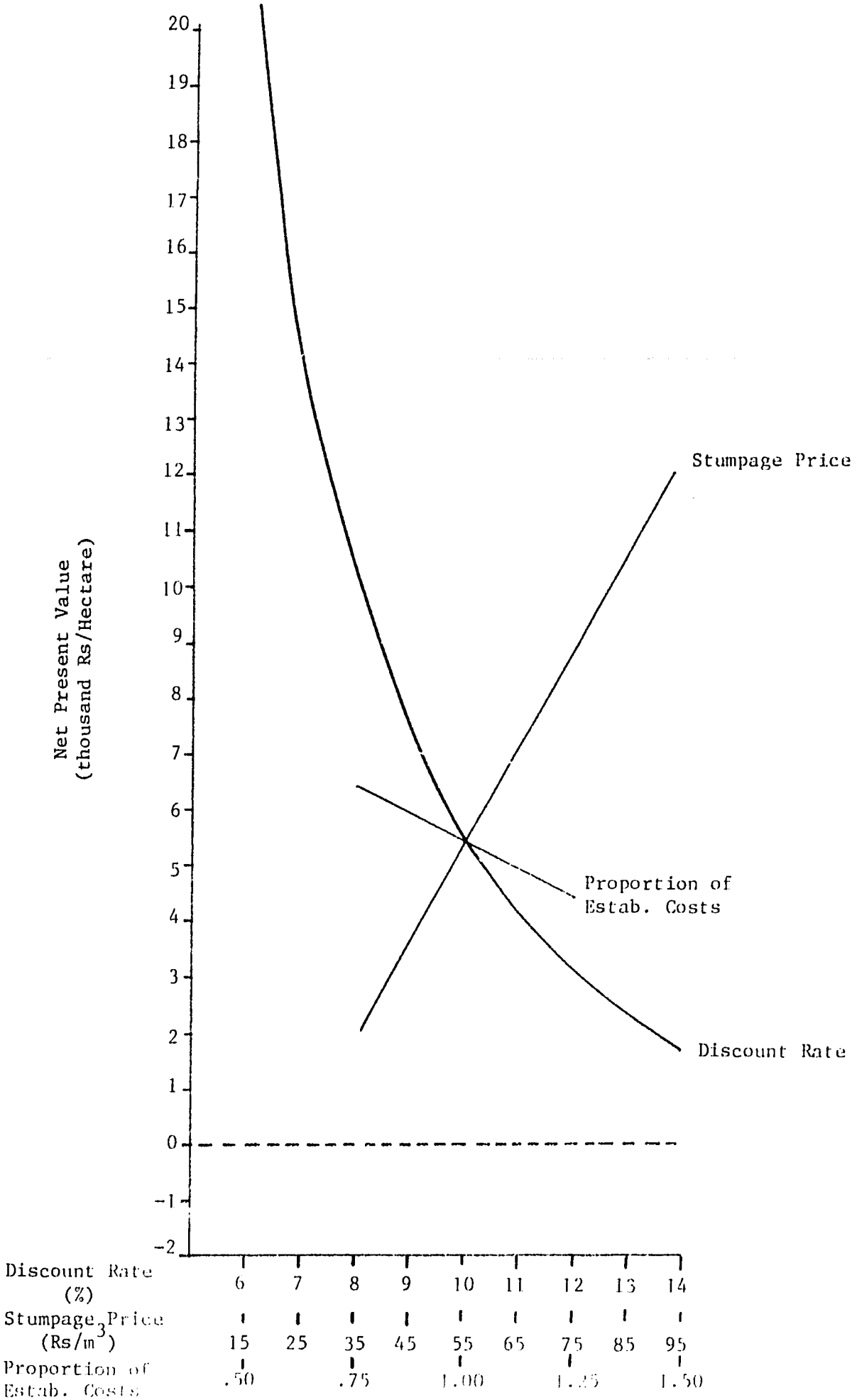


Figure III-4. Regime: Site Index 13 - 10' x 10' Spacing - 94% Survival - Taungya Planting System

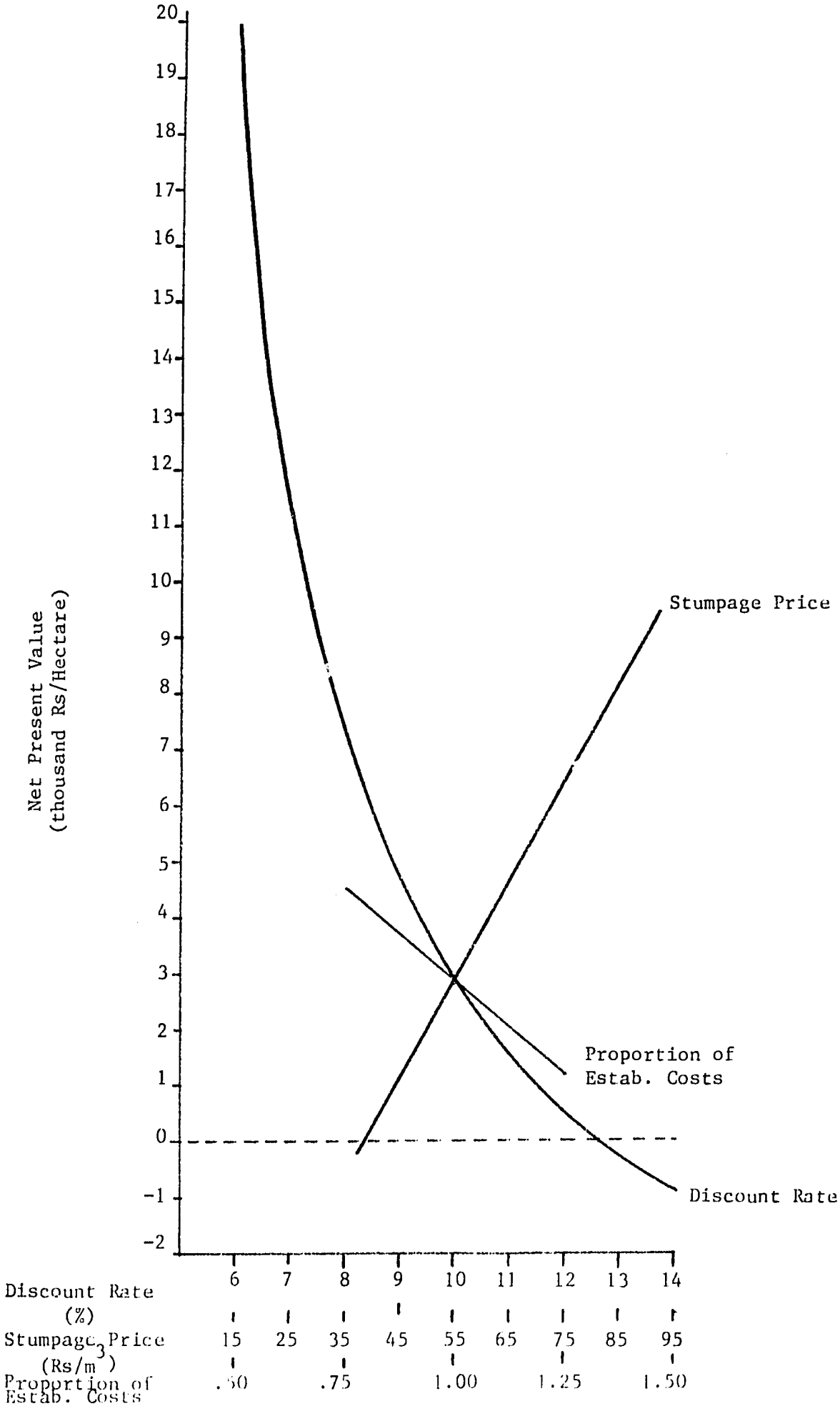


Figure III-5. Regime: Site Index 13 - 10' x 10' Spacing - 94% Survival - Non-taungya Planting System

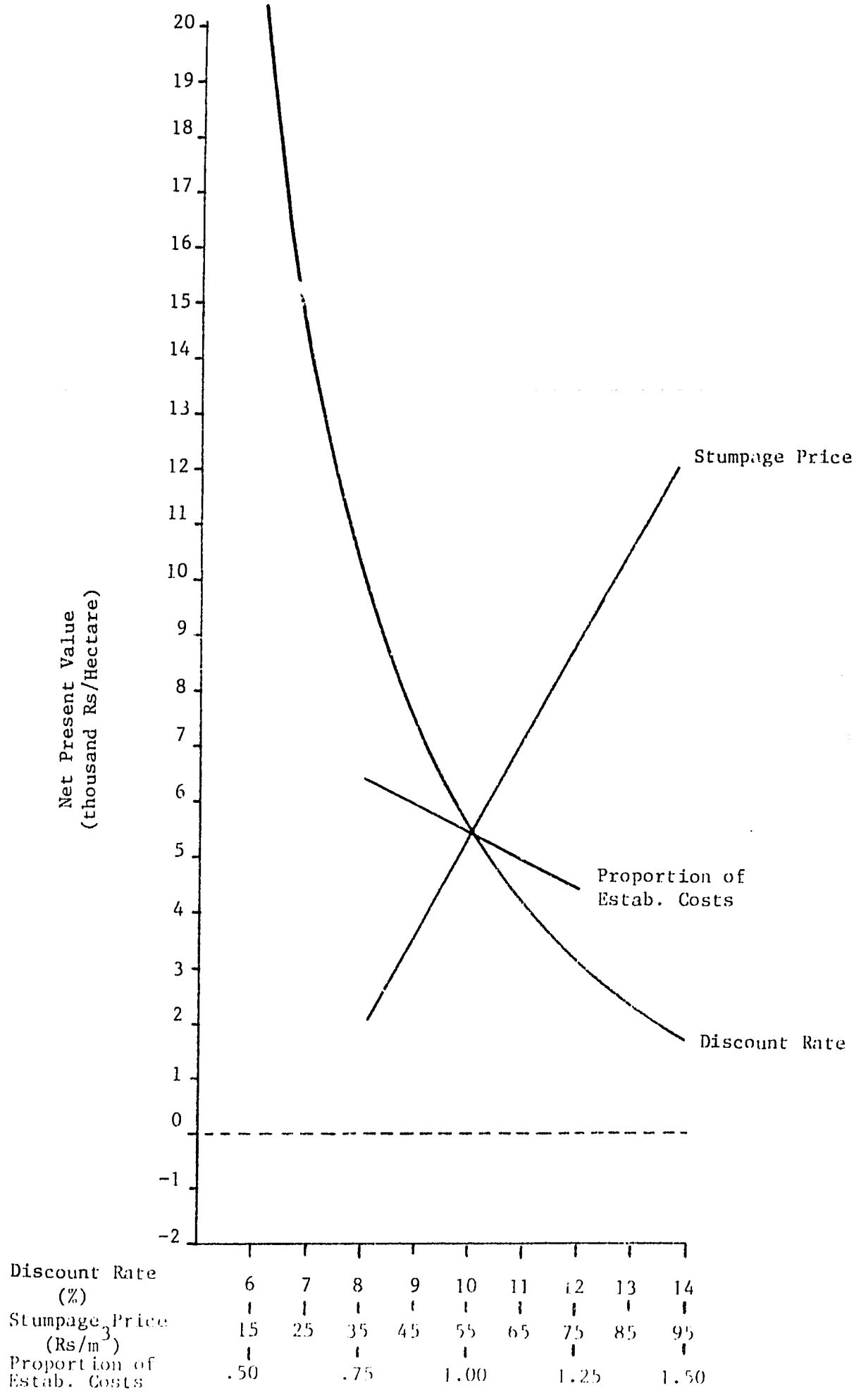


Figure III-6. Regime: Site Index 13 - 10' x 10' Spacing - 94% Survival - Taungya Planting System

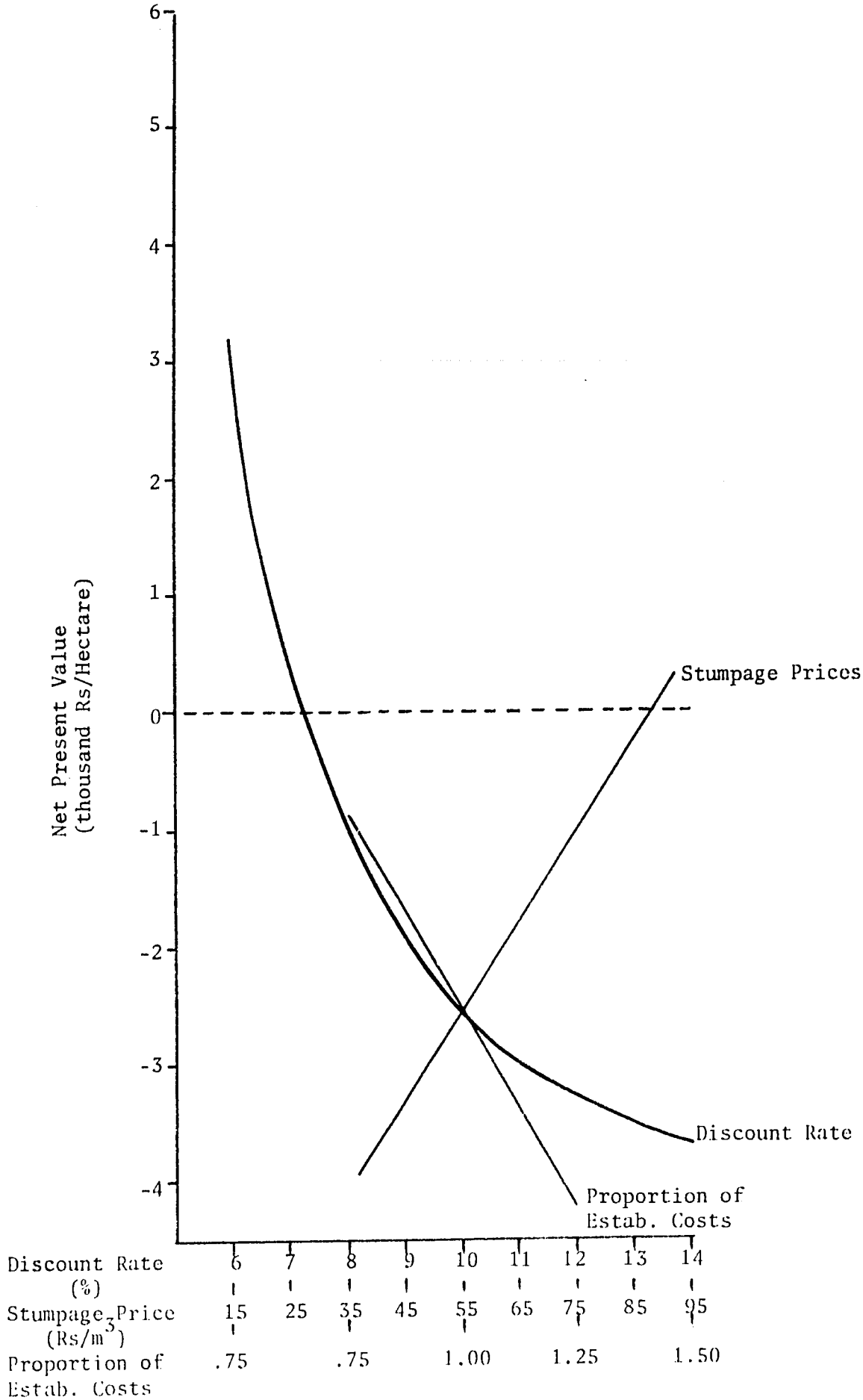


Figure III-7. Regime: Site Index 11 - 10'x10' Spacing - 74% Survival - Non-taungya Planting System

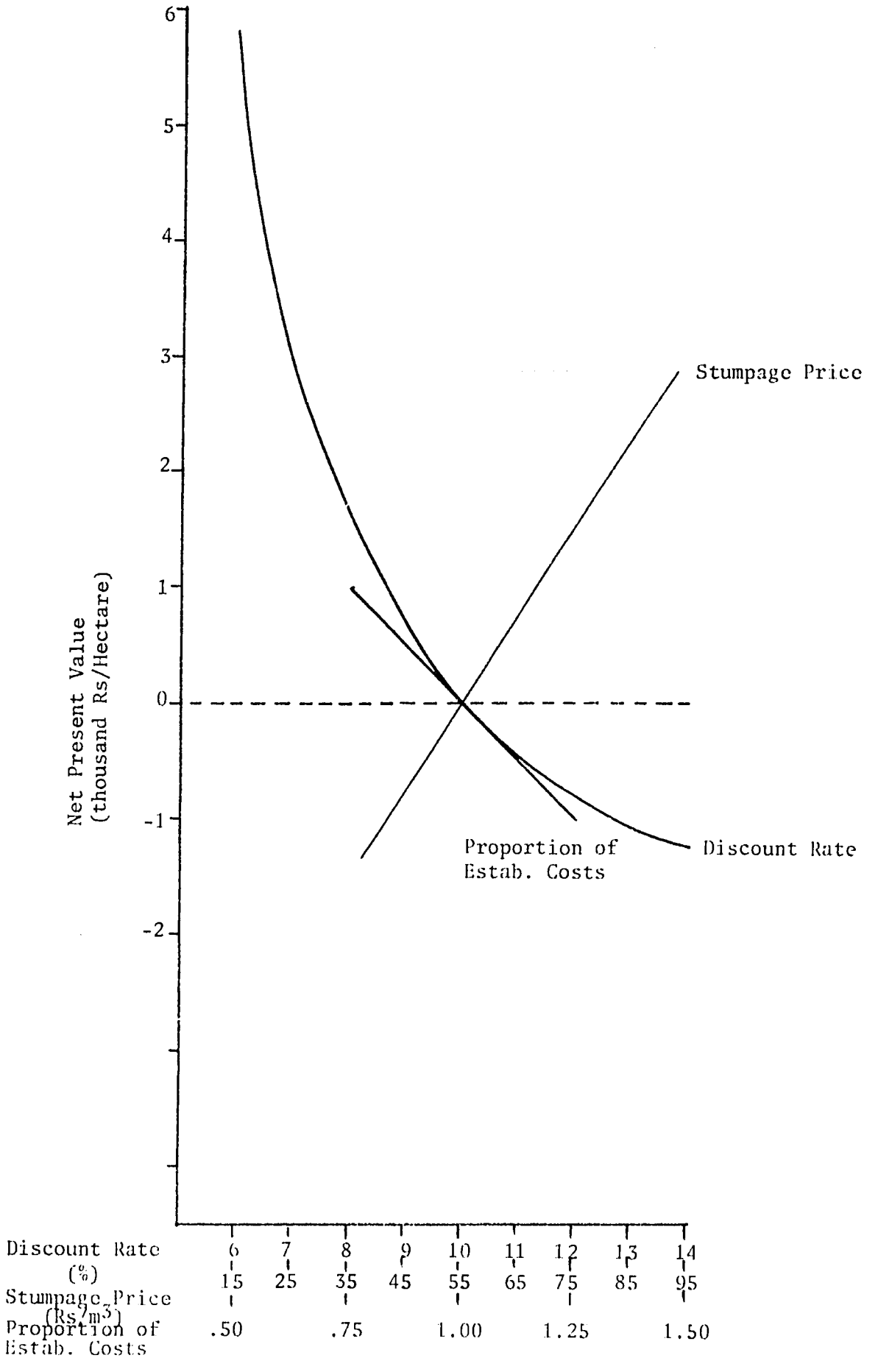


Figure III-8. Regime: Site Index 11 - 10'x10' Spacing - 74% Survival - Taungya Planting System

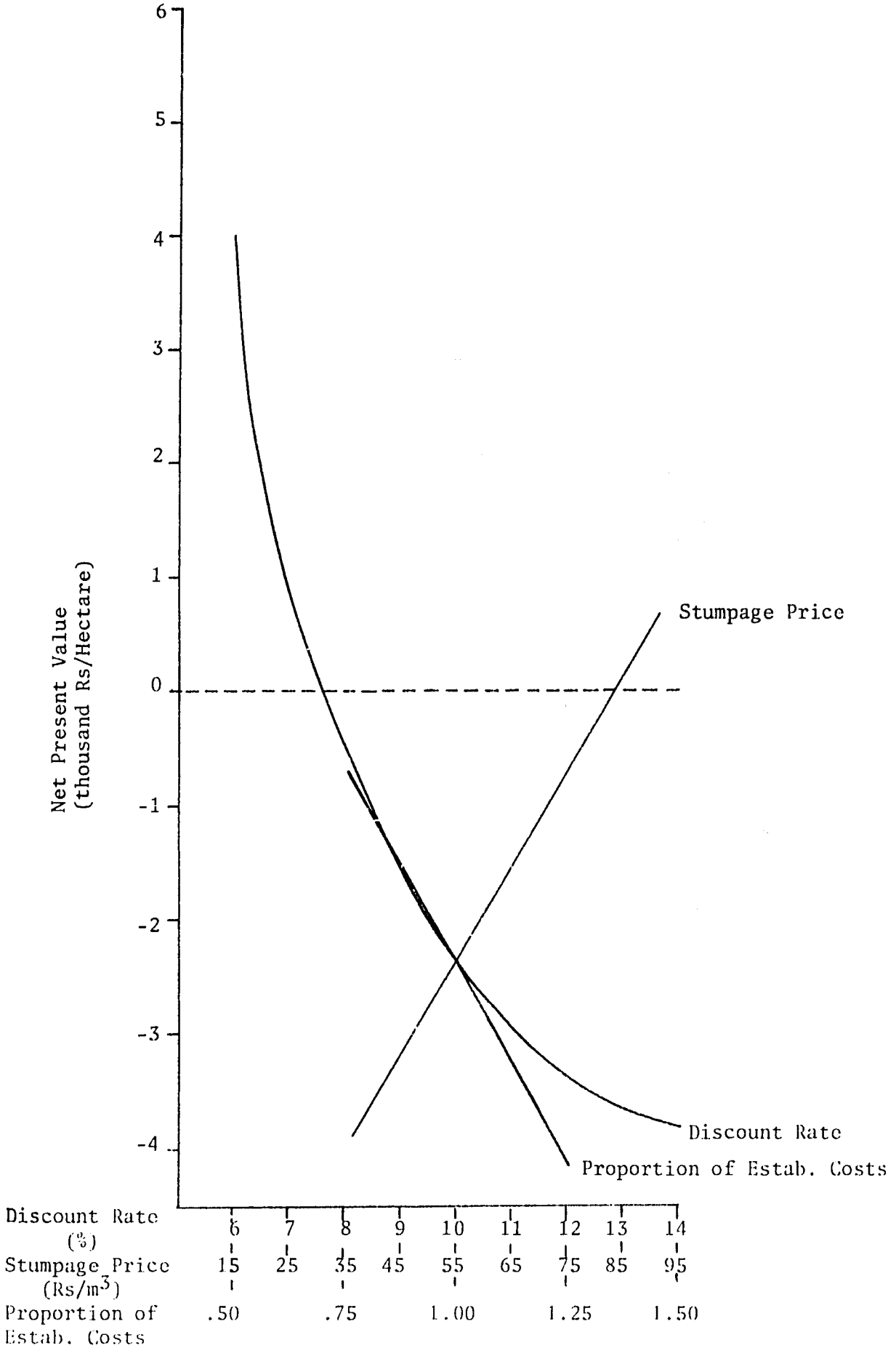


Figure III-9. Regime: Site Index II - 10'x10' Spacing - 94R% Survival - Non-taungya Planting System

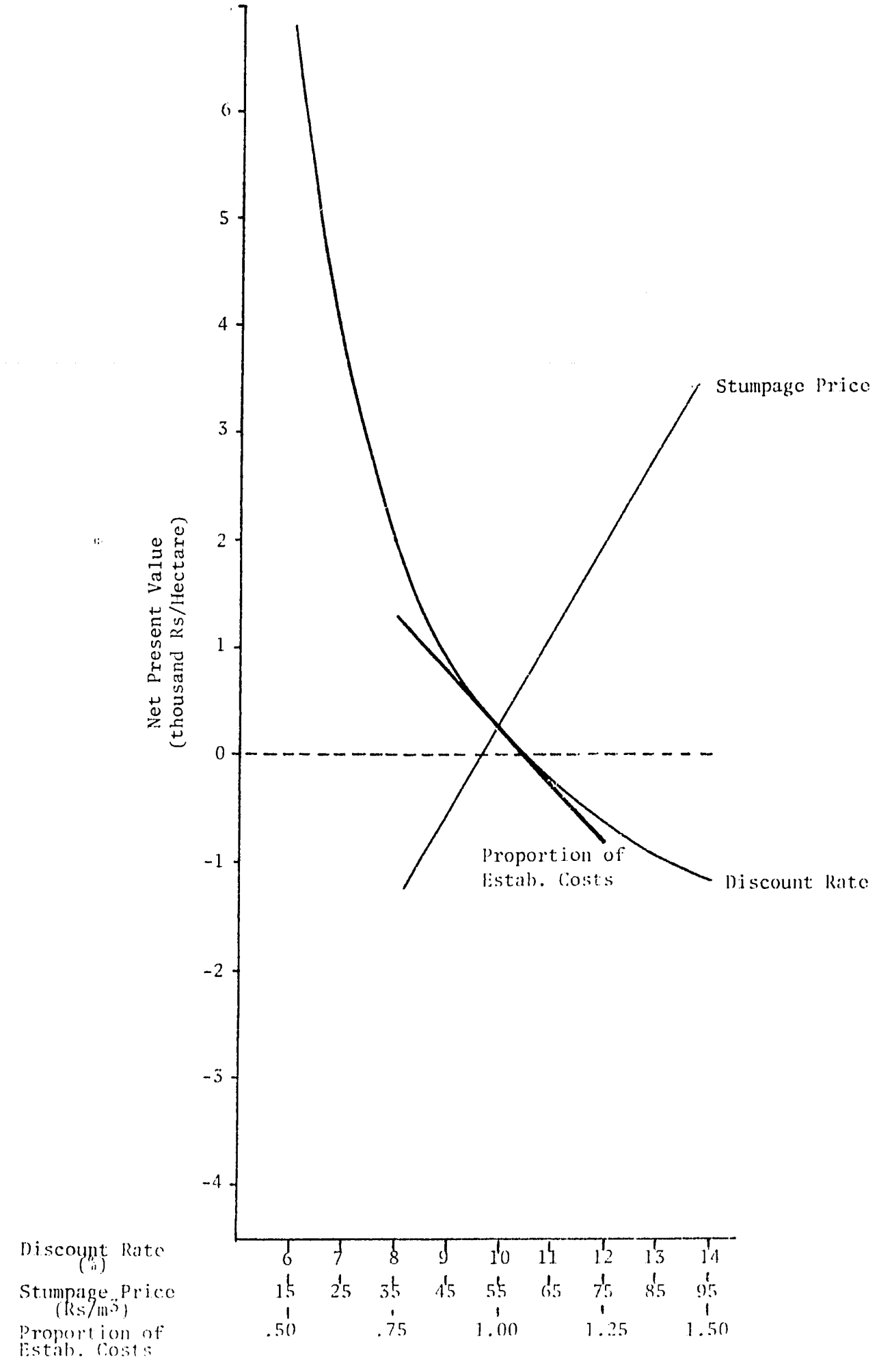


Figure III-10. Regime: Site Index 11 - 10'x10' Spacing - 94R% Survival - Taungya Planting System

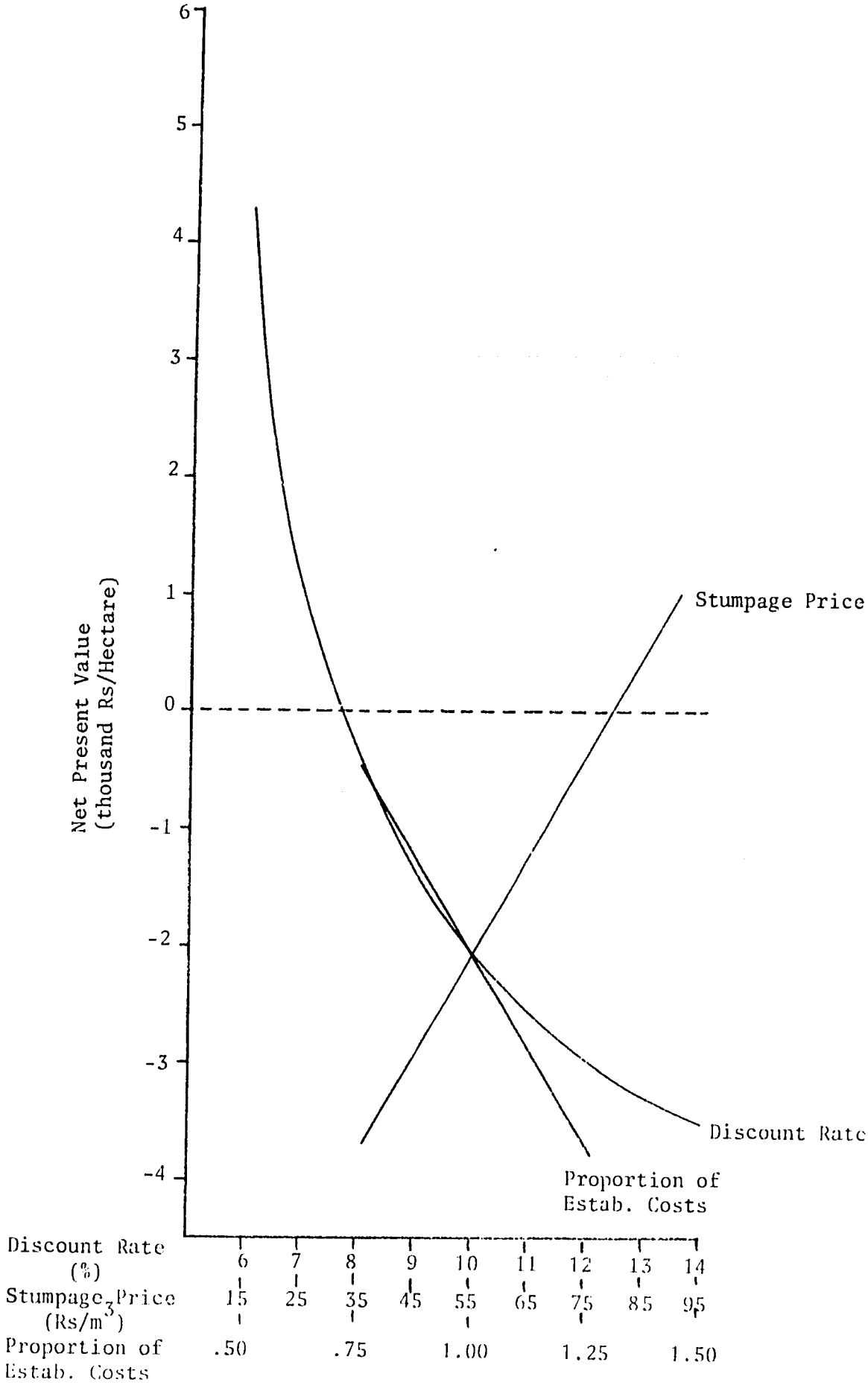


Figure III-11. Regime: Site Index 11 - 10'x10' Spacing - 94R% Survival - Non-taungya Planting System

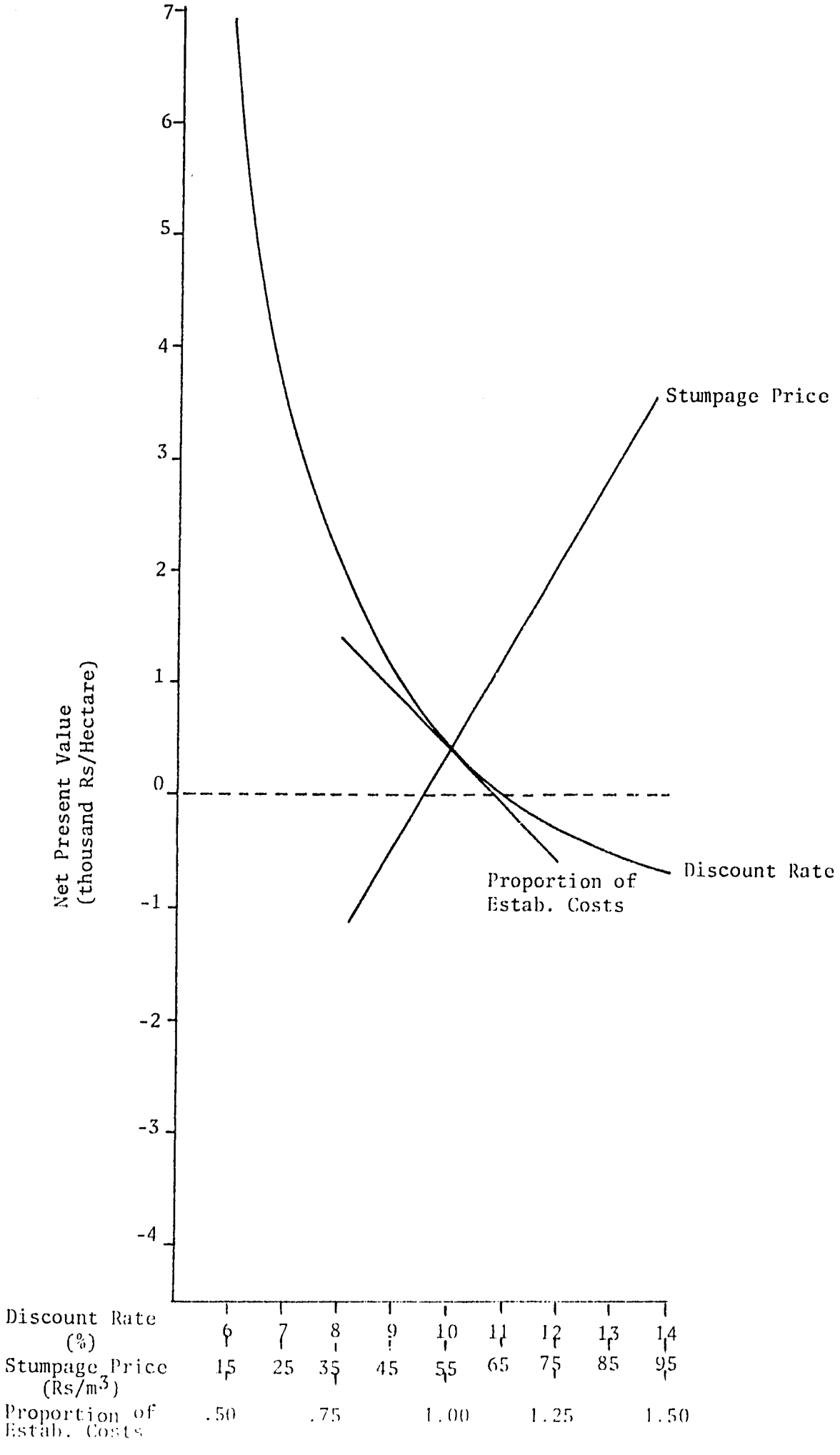


Figure III-12. Regime: Site Index II - 10'x10' Spacing - 94% Survival - Taungya Planting System

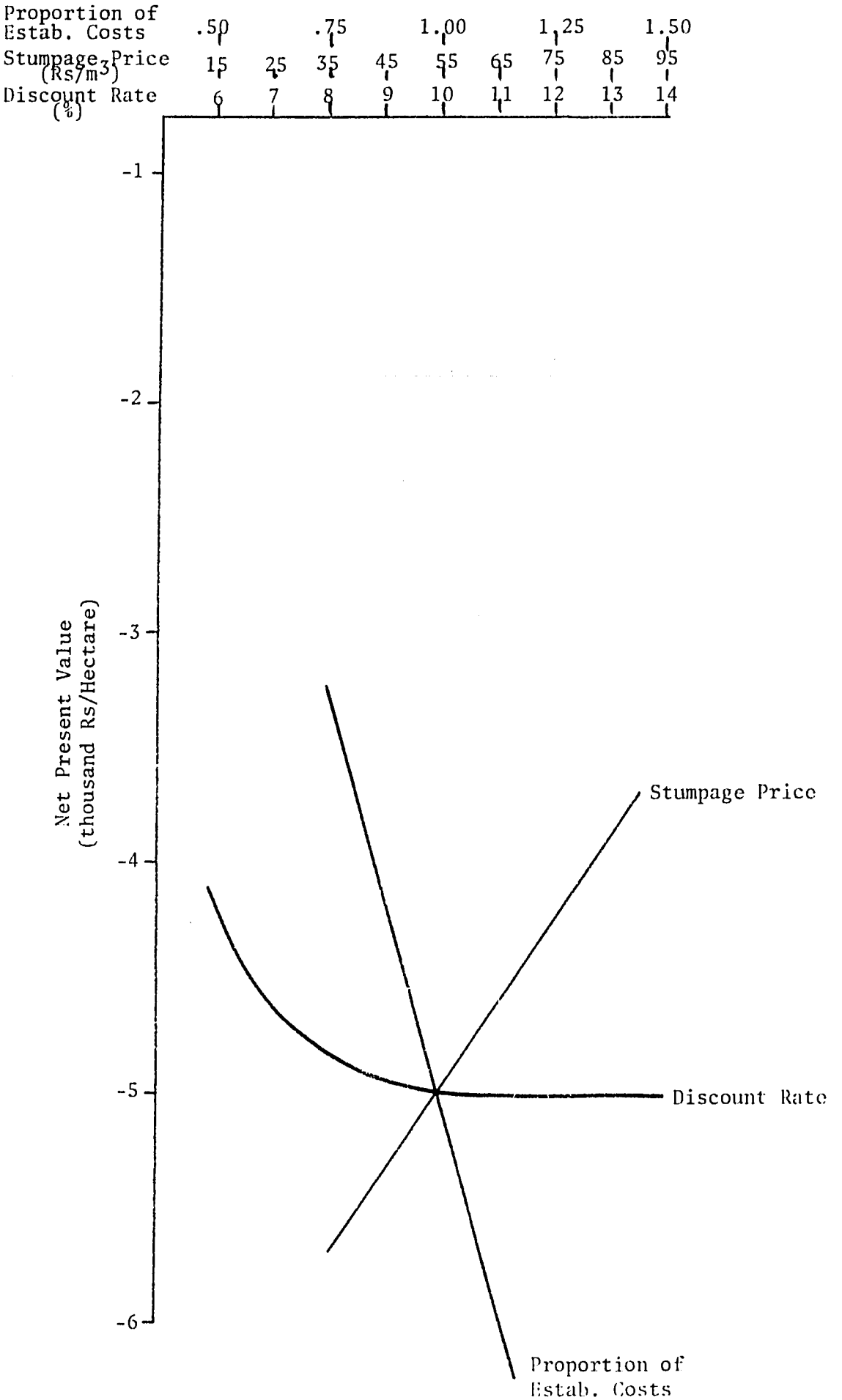


Figure III-13. Regime: Site Index 9 - 10'x10' Spacing - 74% Survival - Non-taungya Planting System

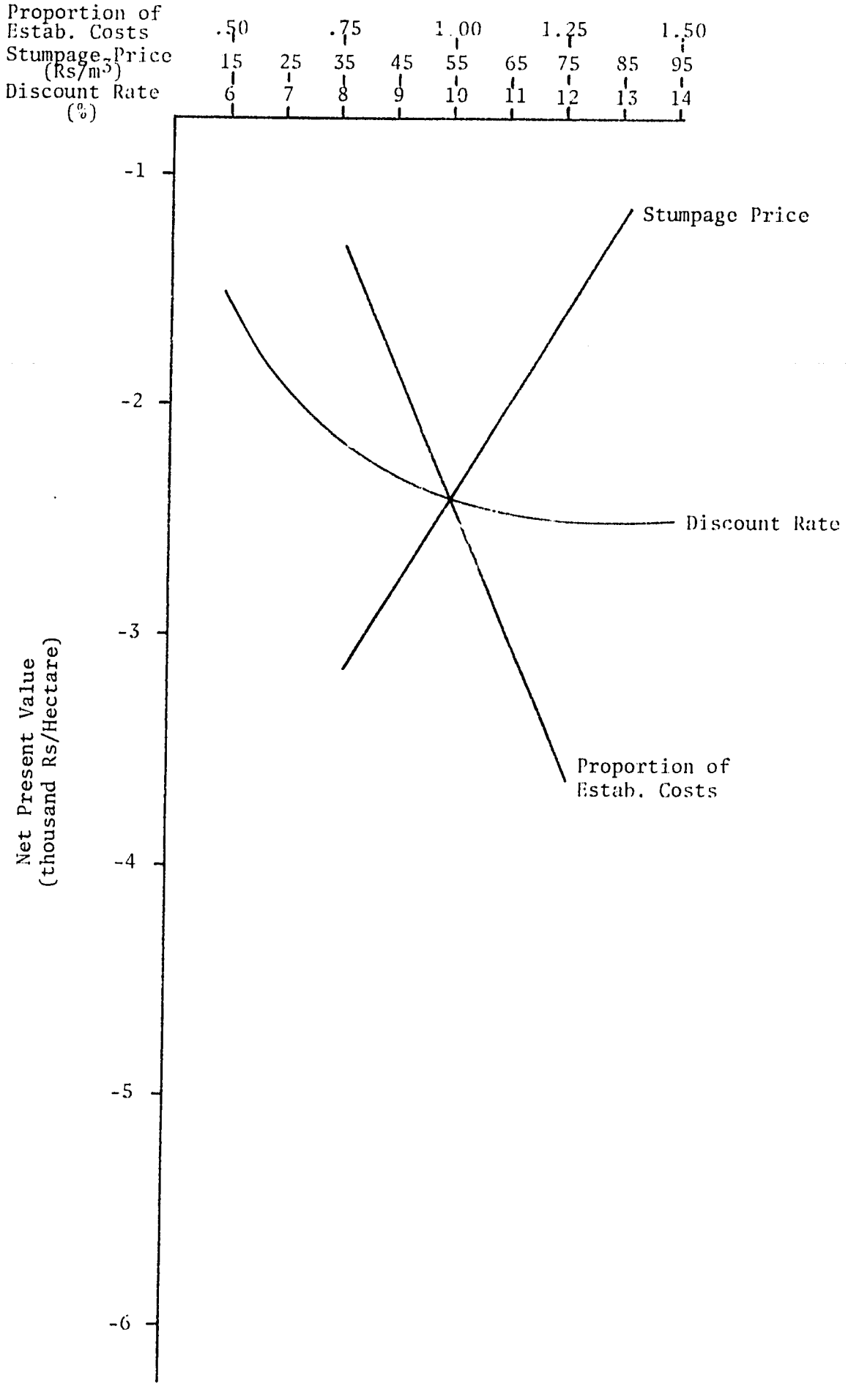


Figure III-14. Regime: Site Index 9 - 10'x10' Spacing - 74% Survival - Taungya Planting System

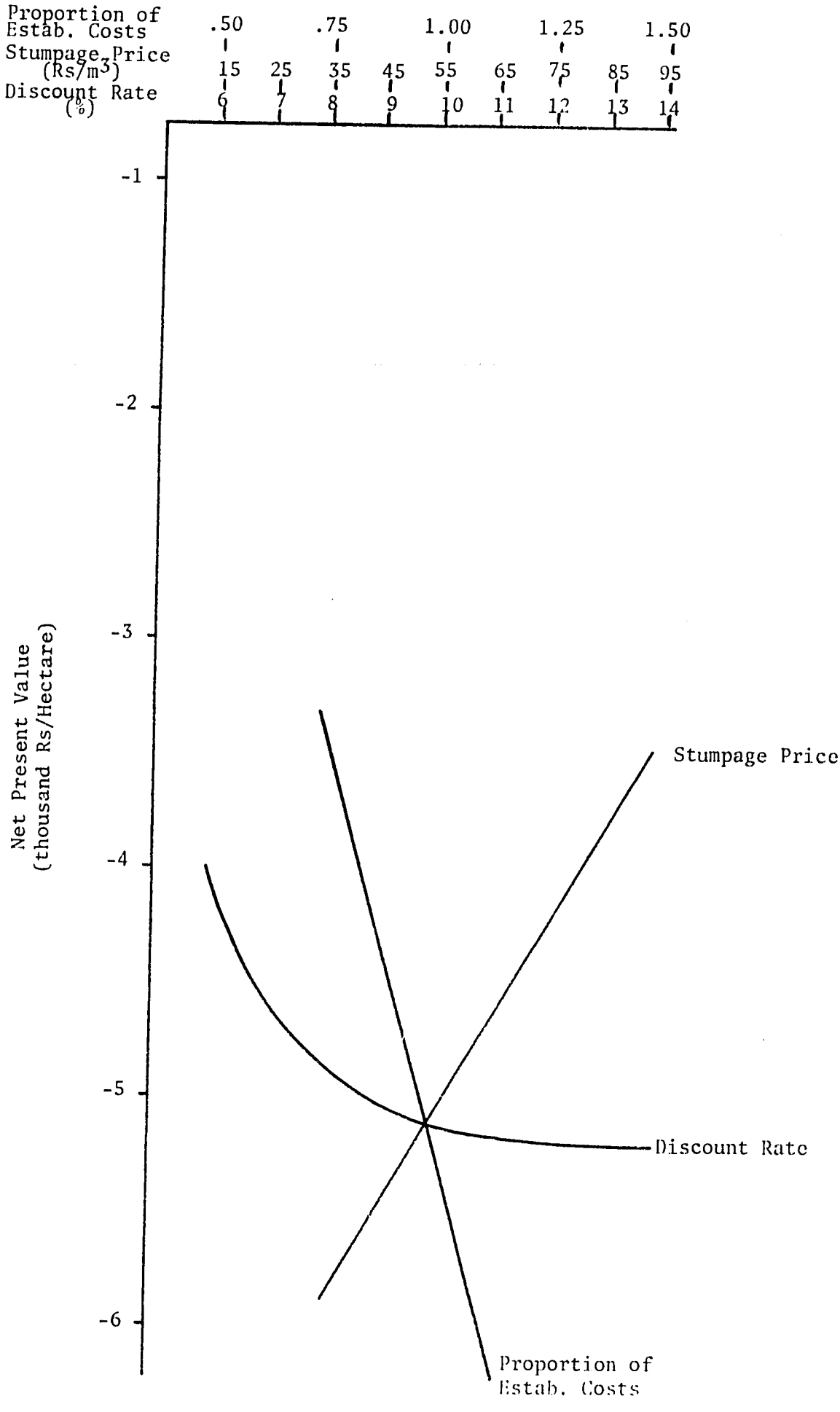


Figure III-15. Regime: Site Index 9 - 10'x10' Spacing - 94R% Survival - Non-taungya Planting System

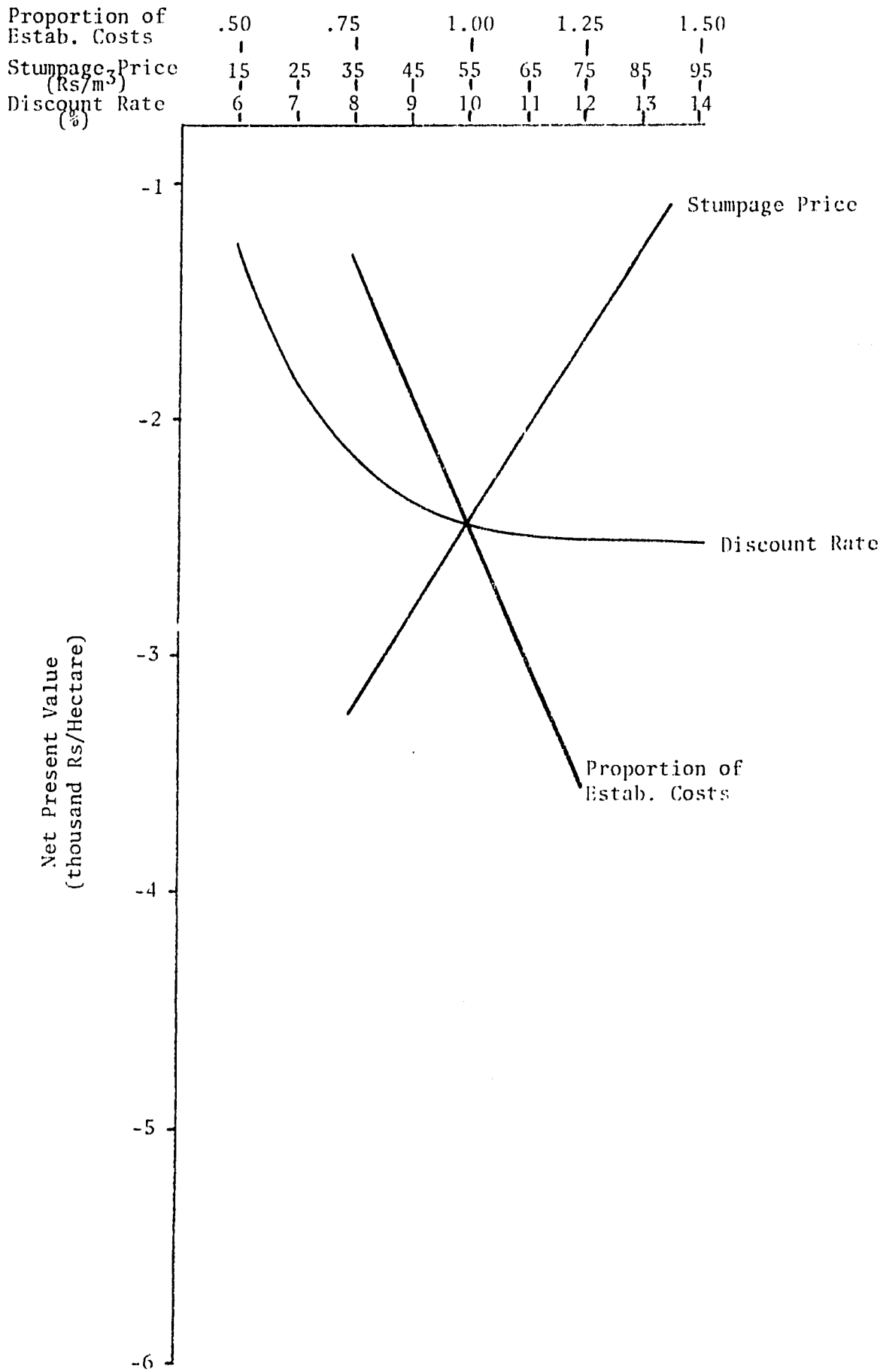


Figure III-16. Regime: Site Index 9 - 10'x10' Spacing - 94R% Survival - Taungya Planting System

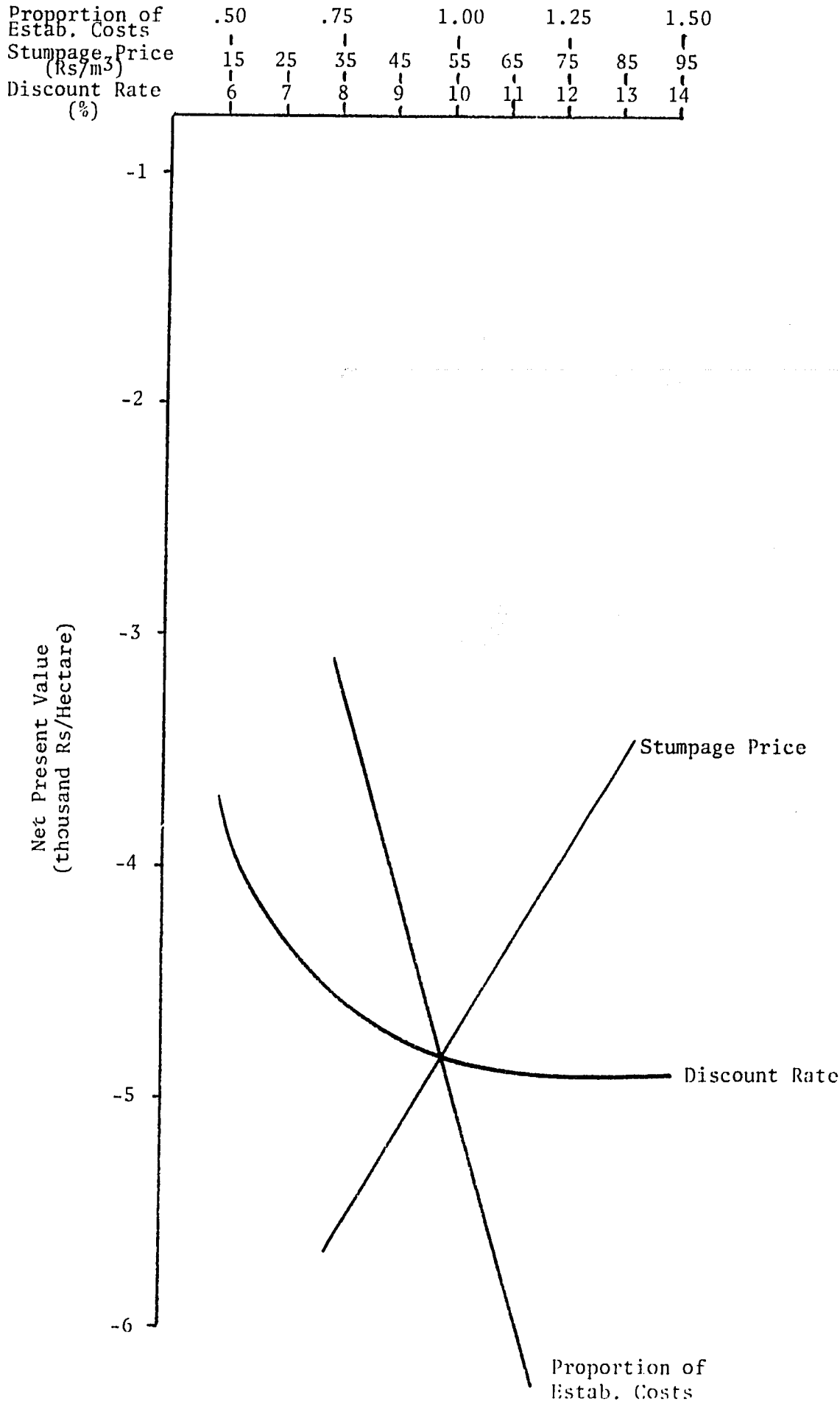


Figure III-17. Regime: Site Index 9 - 10'x10' Spacing 94% Survival - Non-taungya Planting System

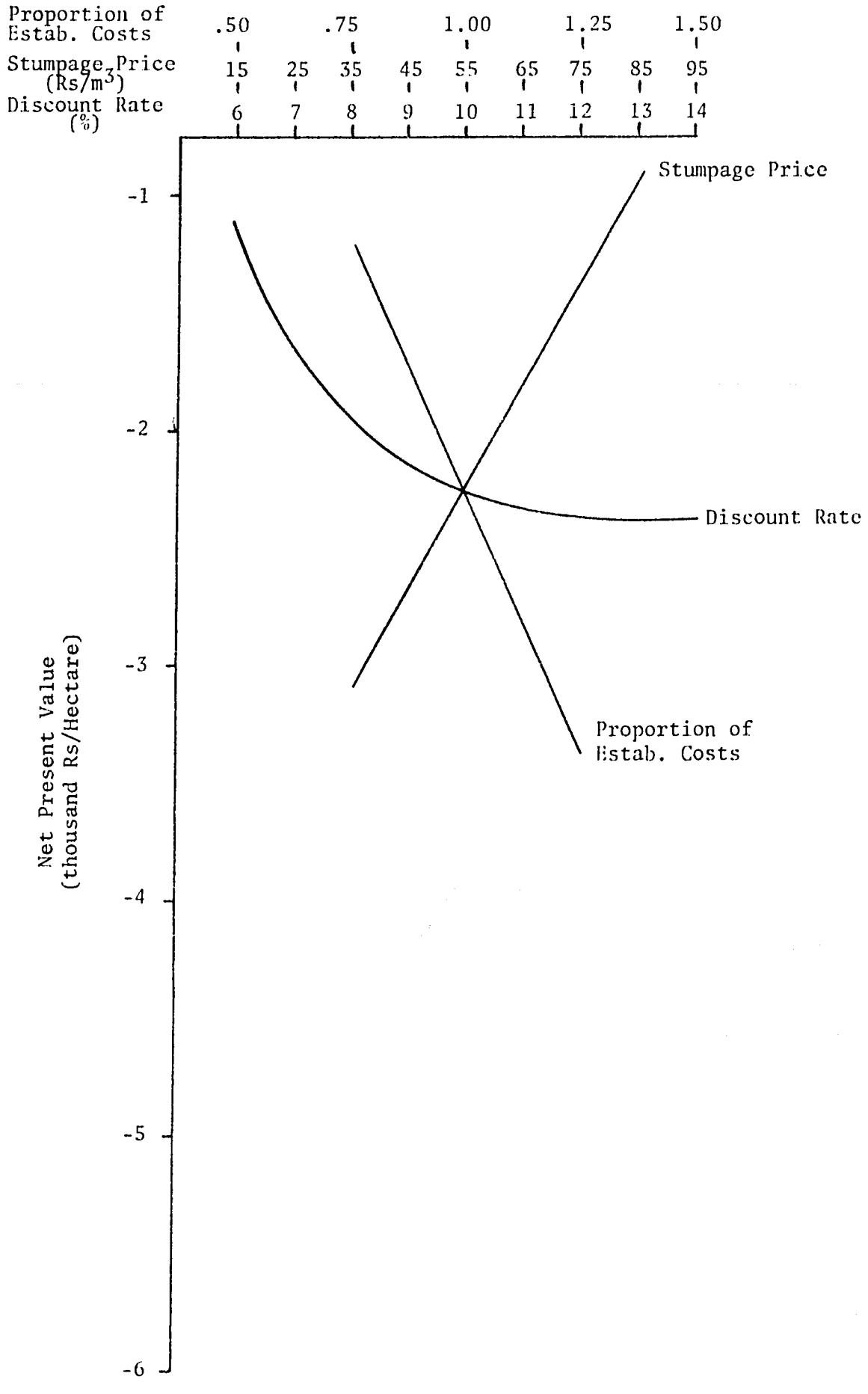


Figure III-18. Regime: Site Index 9 - 10'x10' Spacing - 94% Survival - Taungya Planting System

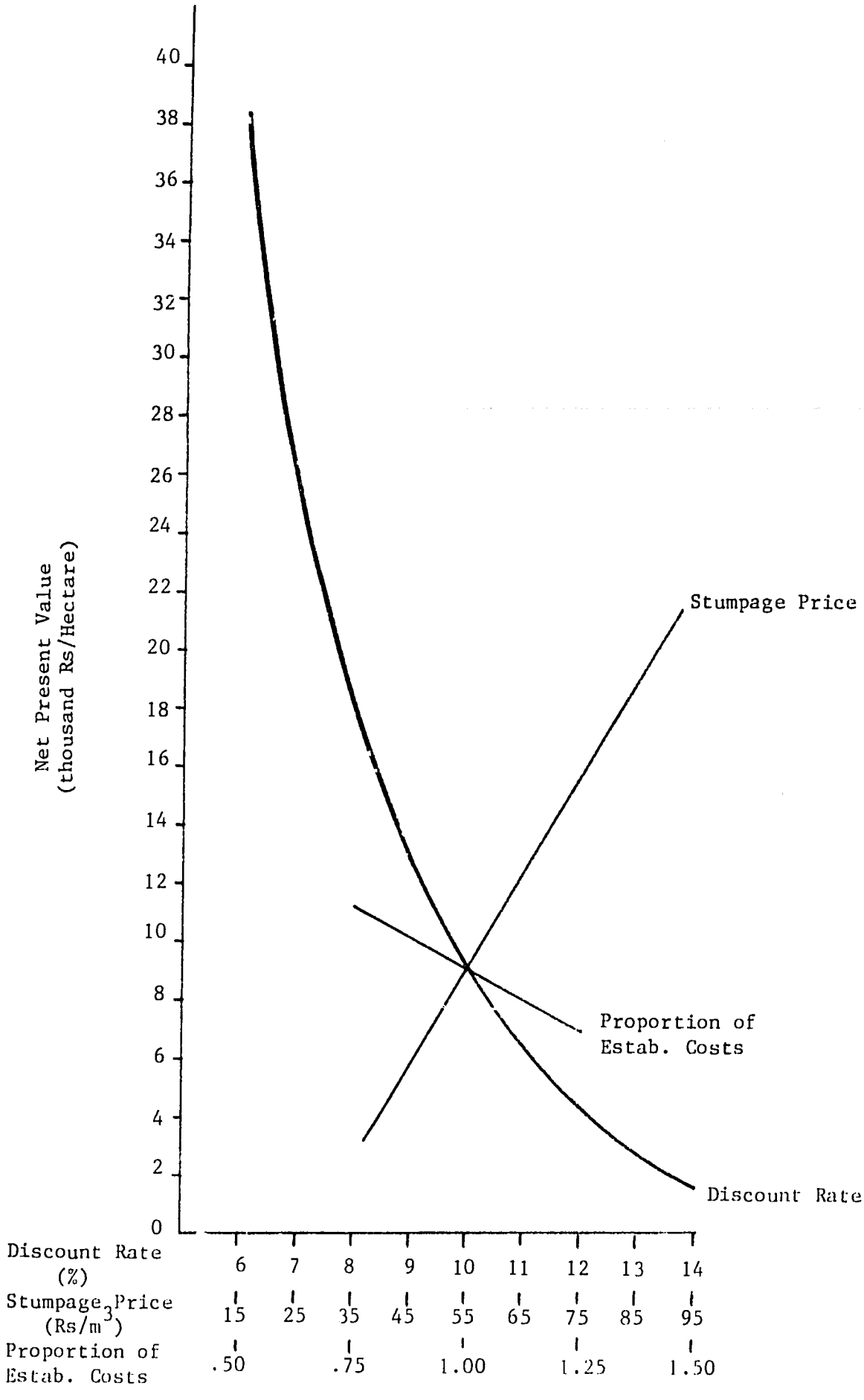


Figure III-19. Regime: Site Index 13 - 6' x 6' Spacing - 74% Survival - Non-taungya Planting System

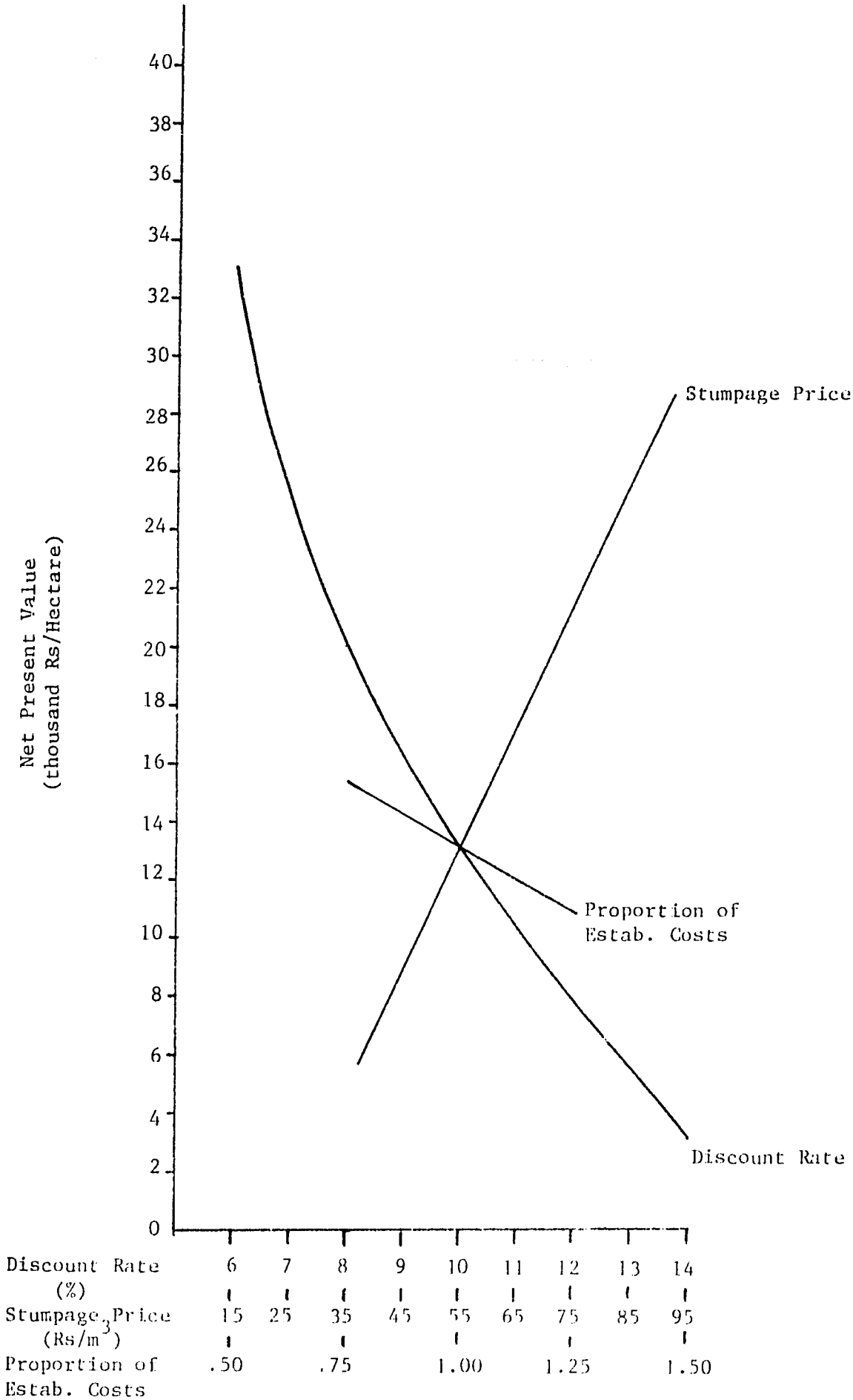


Figure III-20. Regime: Site Index 13 - 6' x 6' Spacing - 94R% Survival - Non-taungya Planting System

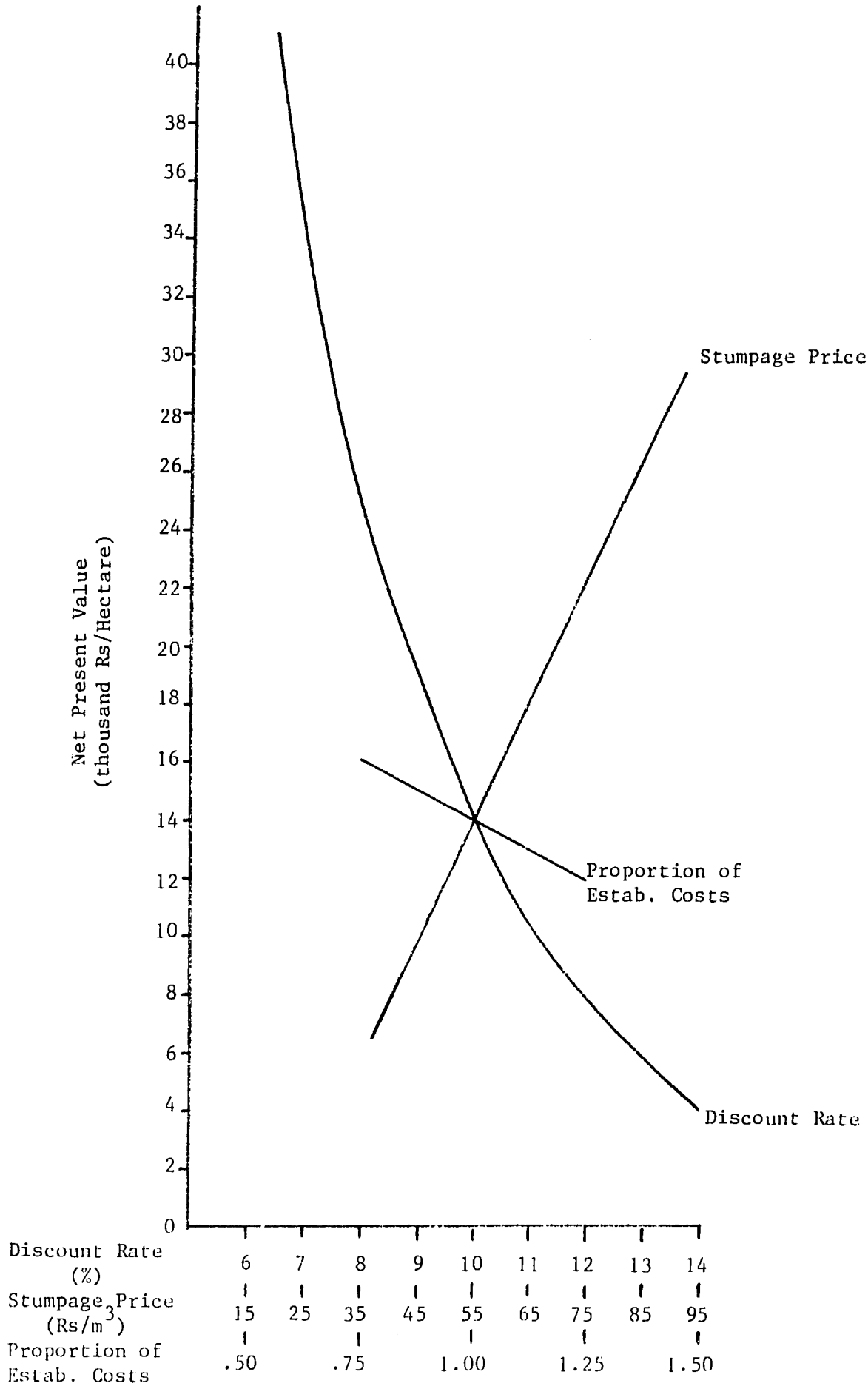


Figure III-21. Regime: Site Index 13 - 6' x 6' Spacing - 94% Survival - Non-taungya Planting System

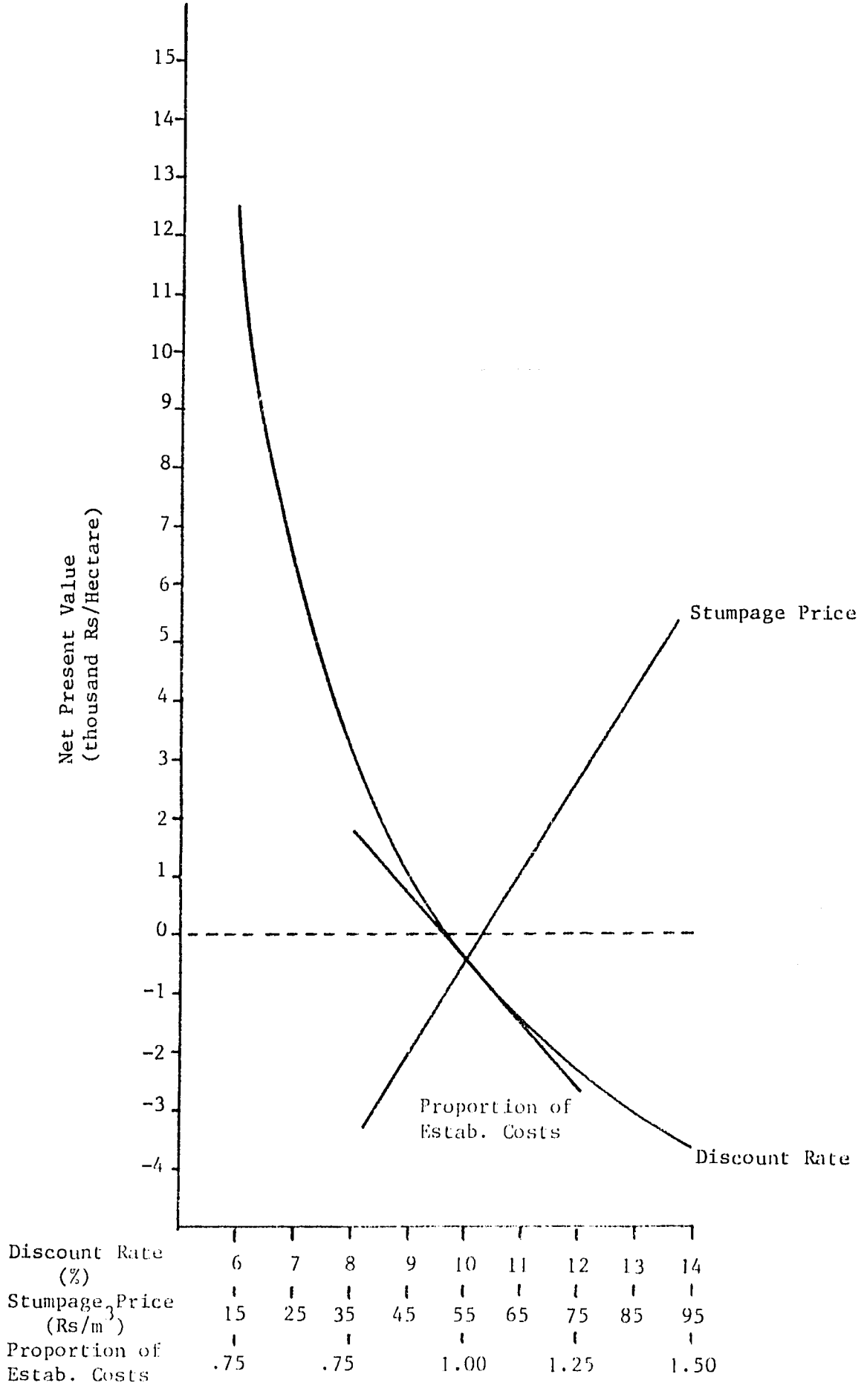


Figure III-22. Regime: Site Index 11 - 6' x 6' Spacing - 74% Survival - Non-taungya Planting System

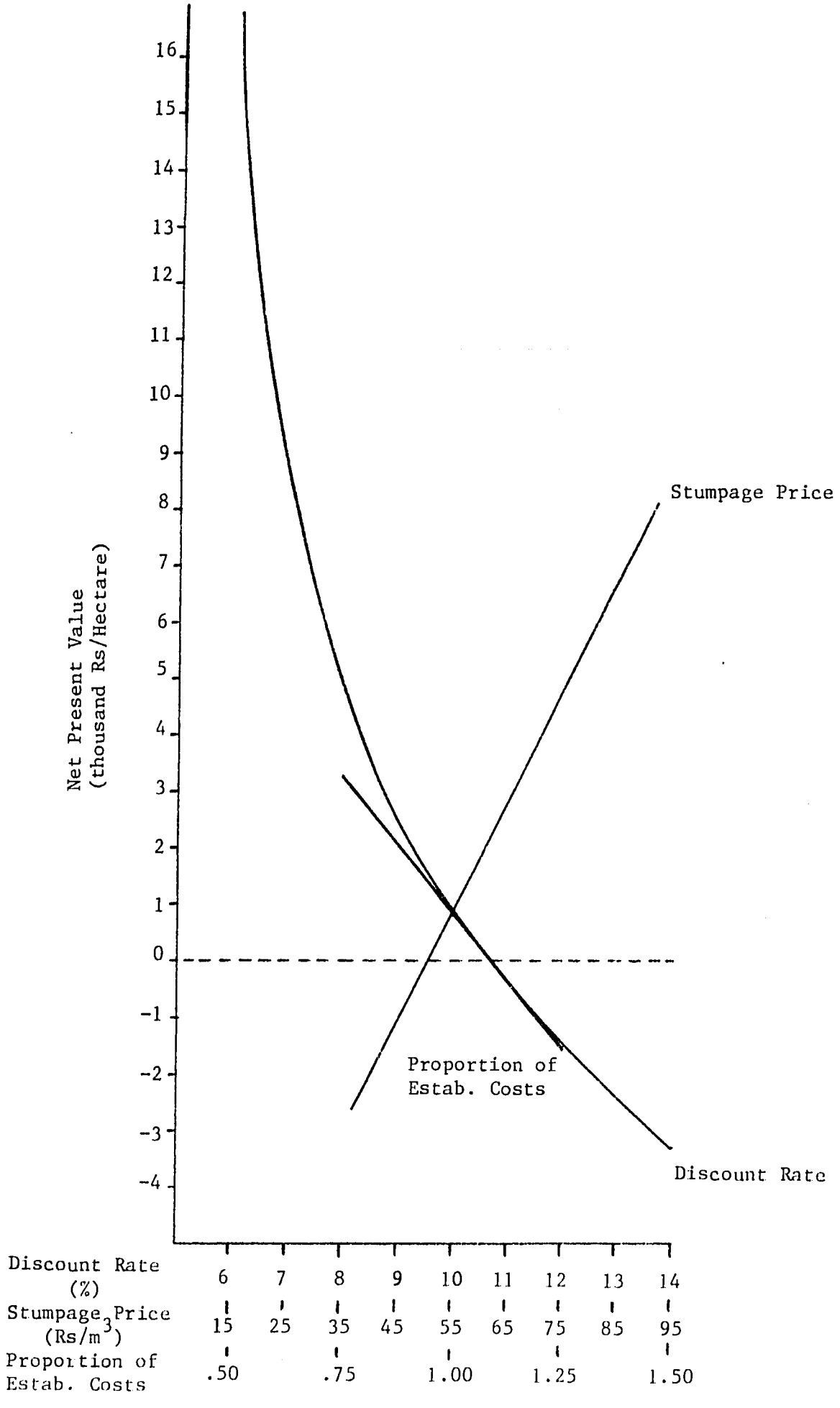


Figure III-23. Regime: Site Index 11 - 6' x 6' Spacing 94R% Survival - Non-taungya Planting System

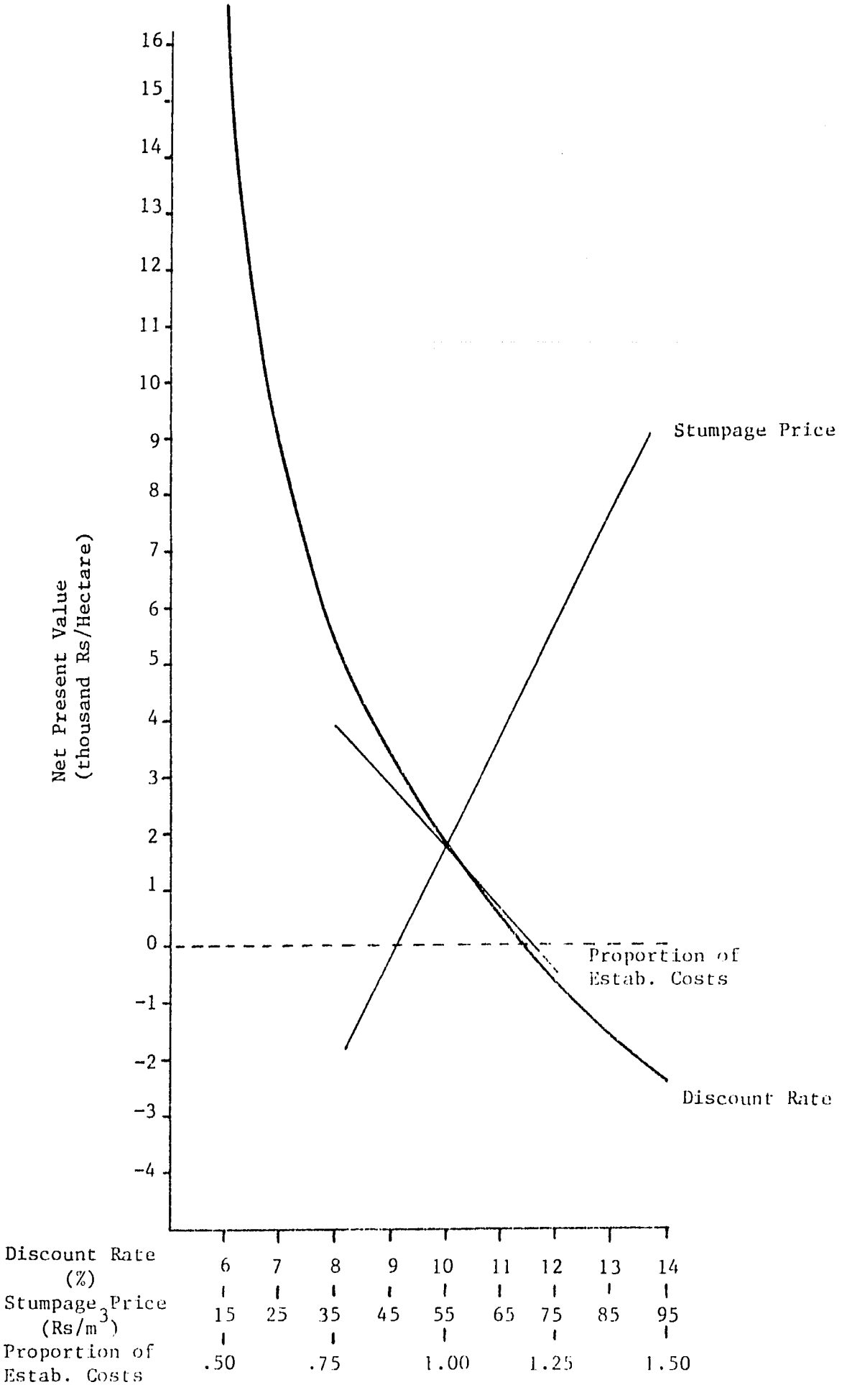


Figure III-24. Regime: Site Index 11 - 6' x 6' Spacing - 94% Survival - Non-taungya Planting System

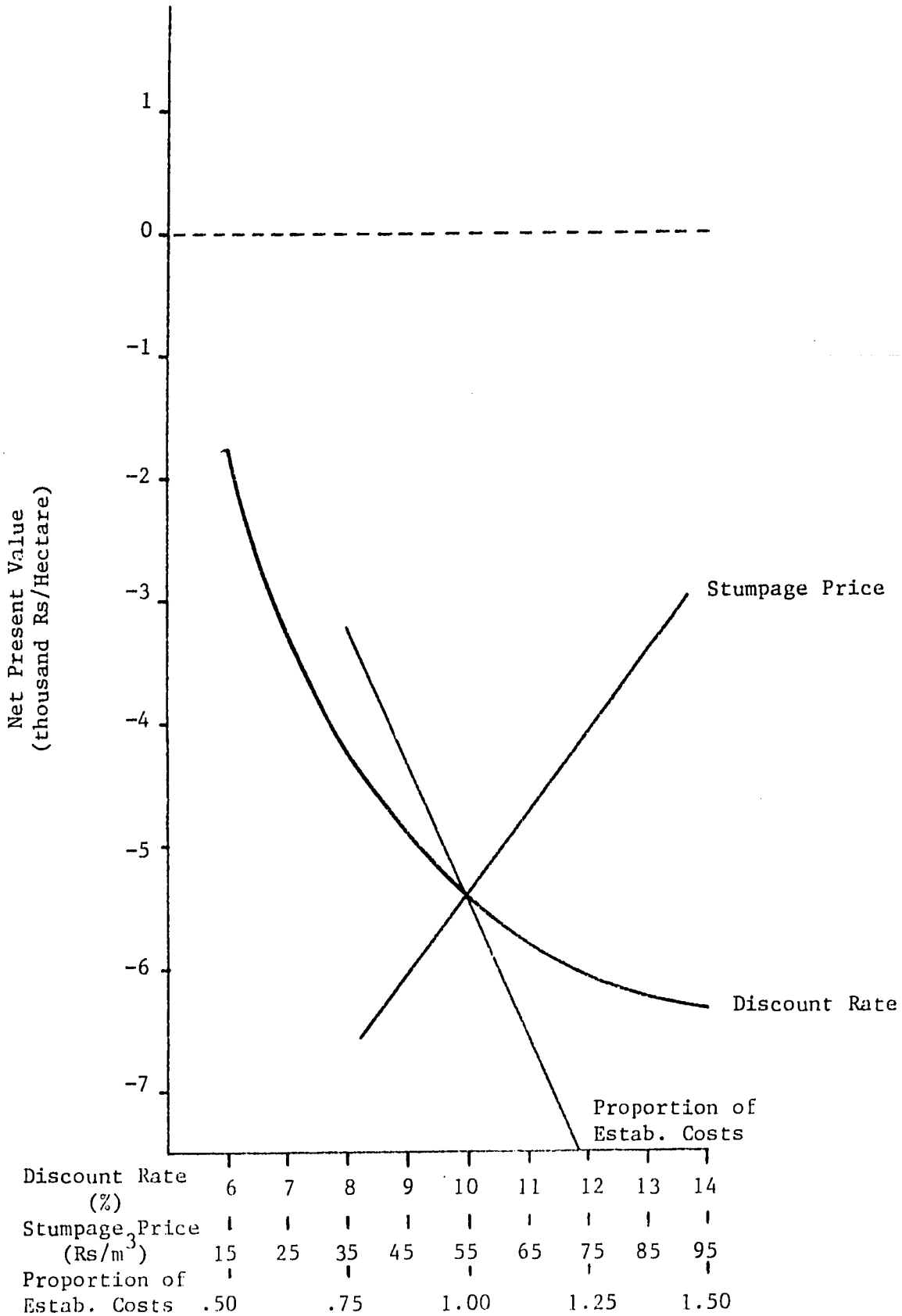


Figure III-25. Regime: Site Index 9 - 6' x 6' Spacing 74% Survival - Non-taungya Planting System

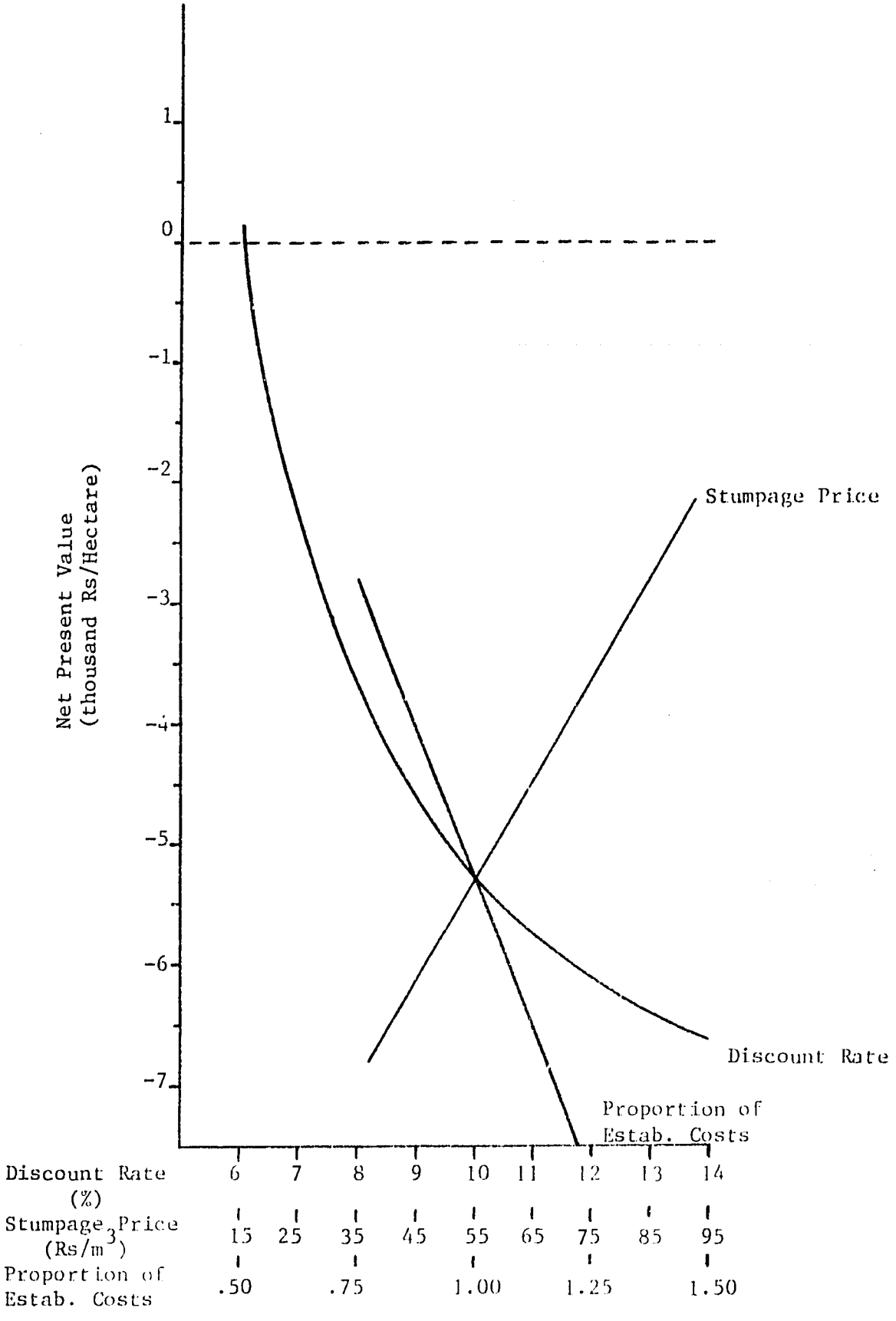


Figure III-26. Regime: Site Index 9 - 6' x 6' Spacing - 94% Survival - Non-taungya Planting System

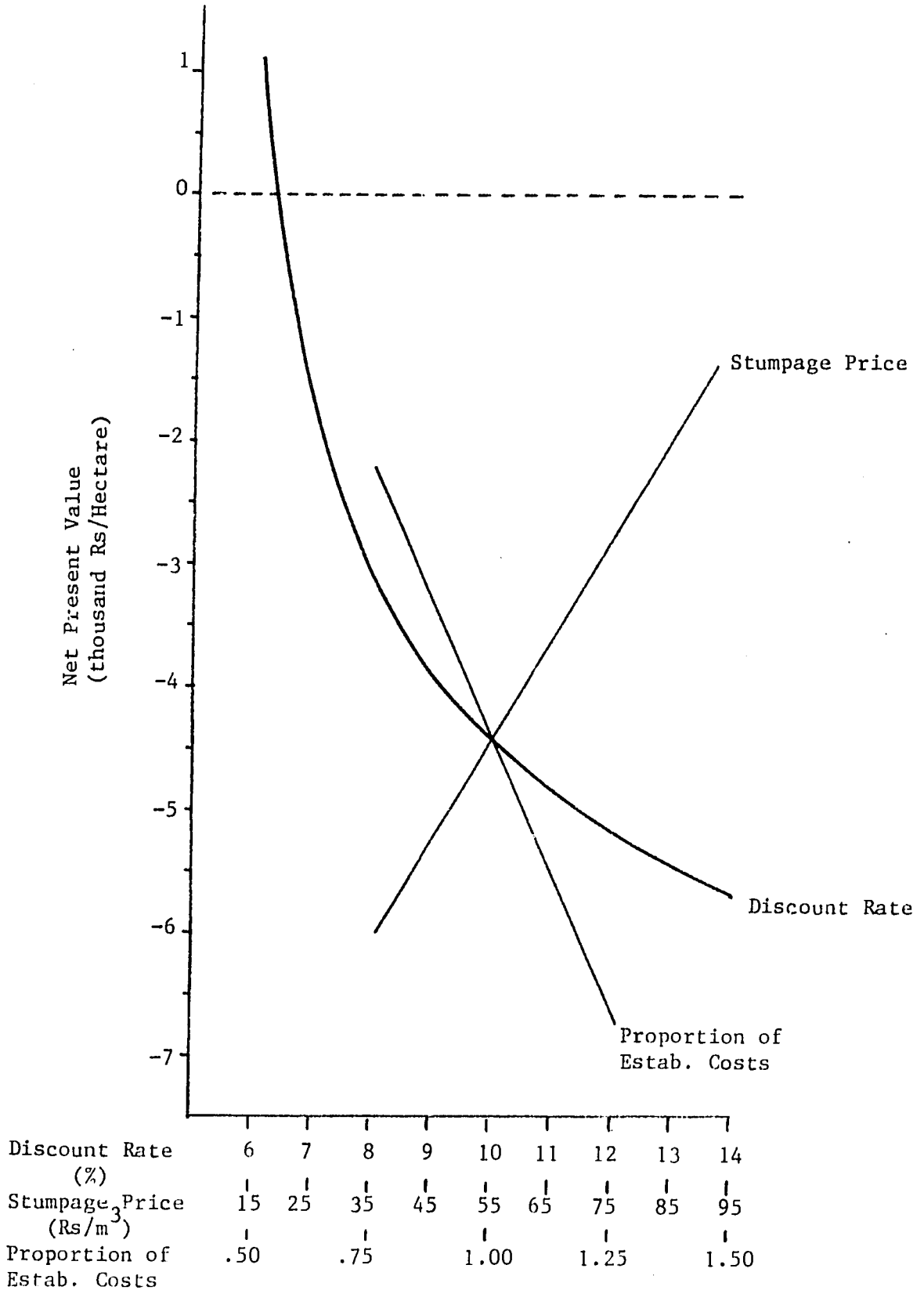


Figure III-27. Regime: Site Index 9 - 6' x 6' Spacing 94% Survival - Non-taungya Planting System

Appendix IV

Glossary of Terms

appreciation rate	The rate at which the relative values of cost and revenue items are changing over time.
base case	The most likely estimates of revenues, costs, discount rate and appreciation rates.
coppice crop	The yield obtained from a forest that has been vegetatively propagated.
culmination of MAI	Culmination of MAI (mean annual increment) is the point in time where the average annual growth rate of a plantation in cubic meters per hectare is maximized.
cwt.	Hundred weight. Conversion from cwt to m^3 of fuelwood used in this report was 13.902 cwt/m^3. This conversion factor was derived assuming: (1) 19.6839 cwt/tonne, (2) 50 ft^3/tonne of fuelwood, and (3) 35.3147 ft^3/m^3.
discount rate	The mechanism for expressing future revenues and costs in present value terms taking into consideration the opportunity cost of capital and, if in nominal terms, the rate of inflation.
economic analysis	An investment analysis where the relative values of costs and benefits are determined by shadow prices. It reflects the perspective of a government agency investor.
financial analysis	An investment analysis where the relative values of costs and benefits are determined by market prices. It reflects the perspective of a private enterprise investor.
financially desirable	An investment is financially desirable if it has a net present value greater than 0. Thus the present value of the revenues obtained are greater than the present value of the costs incurred.

financially preferred	An investment is financially preferred if it has a greater net present value than the alternative investment. The net present value of the financially preferred alternative may be less than zero.
GOSL	An acronym for the Government of Sri Lanka.
ha	Hectare. One hectare is equivalent to 2.4710 acres.
internal rate of return	The discount rate which makes the present value of the revenues accruing from an investment equal to the present value of the costs incurred.
m^3	Cubic meter. One cubic meter is equivalent to 35.3147 cubic feet.
net present value	The discounted value of the revenues accruing from an investment minus the discounted value of the costs incurred.
nominal rate	The discount or appreciation rate which includes inflation.
NPV	An acronym for net present value.
plantation	An artificially established forest obtained by planting tree seedlings.
real rate	The discount or appreciation rate which excludes inflation.
Rs	Sri Lankan rupee. In March 1981, $1 U.S. was equivalent to 17.8 Sri Lankan rupees.
SEV	An acronym for soil expectation value.

shadow prices	Prices which differ from market prices and reflect the "real" values to society of revenues and costs. The shadow prices differ from market prices because of market distortions resulting from taxes, subsidies, various government controls, income distribution, and/or economic externalities.
site index	A system for classifying and ranking plantations by their productive capacity. Site index relates the height of the tallest trees in a plantation to their age. For plantations of a given age, the taller the trees, the more productive the plantation.
soil expectation value	A special case of a net present value analysis. The soil expectation value is the net present value of an infinite series of plantation investments on a particular parcel of land.
STC	An acronym for the State Timber Corporation.
taungya planting system	A system of tree planting where a farmer is hired to clear a site, plant the trees and maintain the site in exchange for a fee and the right to intercrop the land.
tree spacing	The distance, on a horizontal grid, between planted trees. Two spacings used in this analysis were 6' by 6' and 10' by 10'.
yield curve	The graphically presented relationship between the biological production of a plantation in cubic meters per hectare and the age of the plantation in years.
yield table	A tabular relationship between the biological production of a plantation in cubic meters per hectare and the age of the plantation in years.