YIELD AND FINANCIAL ANALYSIS OF *AZADIRACHTA INDICA* A. JUSS

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HOAMUANGKAEW, W., MEDEMA, L. & CHUNTANAPARB, L. 1990. Yield and financial analysis of *Azadirachta indica* A. Juss. Yields were determined by site index classes and alternative spacing regimes for *Azadirachta indica* using data from plantations in Thailand. For all site index classes, a 2 × 4 *m* spacing yielded greater volume than a 4 × 4 *m* spacing. Net present value was used to determine the financially preferred rotation ages and spacing regimes. The 2 × 4 *m* spacing was preferred on only the highest yielding site whereas, for the lowest yielding site, no planting was preferred. A sensitivity analysis was conducted by varying the economic assumptions regarding discount rate, prices and costs. A break even analysis was also conducted.

Key words: *Azadirachta indica* - volume yield - site index - net present value - break even analysis

Introduction

Azadirachta indica A. Juss is a fast growing tree of the tropical arid zones of Asia. Commonly known as neem, or sadao (Thailand), it can adapt to and tolerate a wide range of conditions including shallow, nutrient deficient soils (TDRI 1989). As a multipurpose tree, it has commercially exploitable by-products: neem bark yields tannin oil which is a useful ingredient in soap, pharmaceuticals, and cosmetics; seed and leaves contain an azadirachtin compound which is an insect and nematode repellent; and the wood is used for construction and furniture making as well as for firewood and charcoal. These characteristics make neem a promising multipurpose tree species for both commercial plantations and planting by rural communities or homesteads.

Although these characteristics have been identified, studied and known to foresters and farmers for years, little is known about the yields and financial viability of growing neem. The objectives of this paper are to describe the growth and yield of neem and present a financial analysis of its cultivation.

Basic procedures

Yield analysis

Plantations in Thailand were chosen to represent traditional plantations of 4 to 10 *y* age-classes. The plantations were located in the Sa Kaew and Wattana Nakhon Districts of Prachinburi Province located 250 and 275 *km*, respectively, east of Bangkok.

Individual *A. indica* plantations were not ranked in order of biological productivity. Therefore, site index was the quantitative 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. Site index was selected because it provides a relatively easy procedure for indexing biological productivity and can be related to climatic and edaphic factors.

Sample plots of 40 × 40 *m* were established for each spacing (2 × 4 *m* and 4 × 4 *m*) and age-class. Age, diameter at breast height, total height, height of 16 dominant trees, and the number of trees within plots were recorded for site index determination.

Ten sample trees were measured in each plot for total height, merchantable height, and bark thickness. Girth was measured at stump height, 1.3 *m*, and at 1 *m* intervals up to the merchantable height.

Data on dominant tree height were used for site index classification by anamorphosis method (Chapman & Demeritt 1936, Patsi 1989). Single tree estimates for merchantable volume were calculated from sample tree data. Relationships of tree estimates with dbh and total height (Spurr 1952) were determined by site index. From these estimates, average values per *rai* (*rai* = 1600 m^2) were obtained for total height, dbh, basal area and merchantable volume. The average values then were used to find reliable regression models by a stepwise regression method to predict total stand yield.

Financial analysis

The financial analysis focuses on measuring the returns to an investor based on the costs and revenues accruing to the investor and uses net present value as the decision criterion to determine financial desirability, rotation age, and preferred spacing regime. Plantation establishment and maintenance costs were obtained from the Royal Forest Department of Thailand. Stumpage prices were obtained from the Thai Plywood Corporation.

The decision to invest in neem plantations entails the commitment of resources now in exchange for future volume yields and revenue. In an

analytical sense, the investment may be viewed as flows of costs and revenues over time. Analysis of these flows are based on predictions about future market conditions that determine the assumed relevant values and costs. Since markets are subject to unanticipated fluctuations, such predictions and corresponding analytical results must be interpreted with caution.

In view of the uncertainties, this paper presents a base case analysis which reflects a likely estimate of future market conditions in Thailand and a sensitivity analysis which reflects the results of fluctuations around the base case value and cost assumptions. Additionally, since potential investors may have alternative expectations of future market conditions, the base case assumptions 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 small change in a base case assumption results in a large change in the analytical results.

Results

Site index classification

Site indices were obtained from relationships of average height of dominant trees on age. At base age 7 *y*, average height of dominant tree was about 7 *m* for site index III, 9 *m* for site index II, and 11 *m* for site index I (Figure 1).

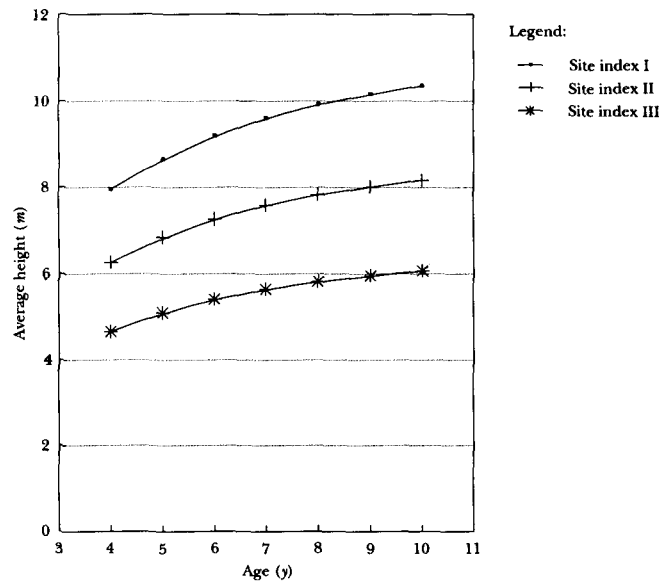

Figure 1. Site index curves

Yield per unit area

Determination of tree variables was obtained from the following models:

Site I : $V = 0.000074\ D^{1.464}$ ($R^2 = 0.99$) (1)
Site II : $V = 0.000013\ D^{2.849}$ ($R^2 = 0.99$) (2)
Site III : $V = 0.000025\ D^{2.635}$ ($R^2 = 0.87$) (3)

where, V = underbark merchantable volume (m^3), H = total height (m), and D = diameter at breast height (cm).

From these models the volume of each tree in the plots was obtained and combined. Regression models for four variables were determined to provide estimates per *rai* (*rai* = 1600 m^2).

$$\log H = 0.1409 - 0.7681/A + 1.1842 \log S \quad (R^2 = 0.84) \quad (4)$$

$$D = -9.5216 + 1.6632\ S + 0.2793\ SP + 0.0445\ AS \quad (R^2 = 0.89) \quad (5)$$

$$BA = -0.9704 + 0.0519\ A - 0.0751\ SP + 0.0198\ SV + 0.1209\ D \quad (R^2 = 0.99) \quad (6)$$

$$\log V = -0.7585 + 0.1467\ S - 1.3651/A - 0.0002\ SP + 0.5839 \log BA \quad (R^2 = 0.99) \quad (7)$$

where,
H = average total height (m),
D = average diameter at breast height (cm),
BA = average basal area ($m^2\ rai^{-1}$),
V = underbark merchantable volume ($m^3\ rai^{-1}$),
A = age of plantation (y),
S = site index, average height of dominant tree (m),
SP = spacing per tree (m^2), and
SV = survival rate (assumed to be 90%).

From regression models (4) to (7), estimates were obtained for merchantable volume by age, site, and spacing (Figure 2). A pattern is observable: the 2×4 m spacing yields greater volume than the 4×4 m spacing, and this yield differential increases on more productive sites.

Financial analysis

The base case assumptions for plantation establishment and maintenance costs are based on estimates obtained from the Royal Forest Department of Thailand (Table 1). The costs are based on plantations of 4×4 m spacing. For analysis of 2×4 m spacing, cost items that vary with the number of trees planted per *ha*, such as line preparation, planting, replanting and seedlings, were assumed to be 67% higher.

Table 1. Stand establishment and maintenance costs

Item	Baht/*rai*[1]	US$/*ha*[2]
1. First year costs:		
Labour		
Surveying and mapping	55	13.50
Land preparation	227	55.63
Line preparation	73	17.88
Planting	178	43.63
Weeding (twice)	151	37.00
Watchman	70	17.19
Replanting	36	8.81
Materials and machinery		
Gasoline	50	12.25
Construction materials	5	1.25
Machine repair	28	6.88
Seedlings	120	29.44
Miscellaneous	7	1.69
Total first year costs	1000	245.13
2. Cost for years 2-6:		
Labour		
Replanting	6	1.47
Weeding	120	29.41
Repair of fire lines and roads	9	2.21
Materials	10	2.45
Miscellaneous	5	1.23
Total costs for years 2-6	150	36.76

[1]Conversion factors used are 6.25 *rai* = 1 *ha* and Baht 25.5 = US$ 1.00, [2]Based on planting at 4 × 4 *m* spacing (Costs that vary with the number of trees *ha*[-1] planted are assumed to be 67% higher for planting at 2 × 4 *m* spacing); Source: Royal Forest Department, Bangkok, Thailand

Using these cost estimates, the volume yields from Figure 2, and a net stumpage value of Baht 1300 m^3 (US$ 50.98) (Thai Plywood Corporation), net present values were calculated for each site index, spacing, and rotation age (Figure 3). The base case discount rate used to determine the present values was 9%.

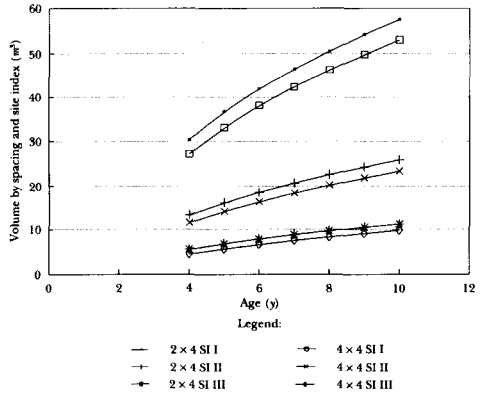

Figure 2. Yield by spacing and site index

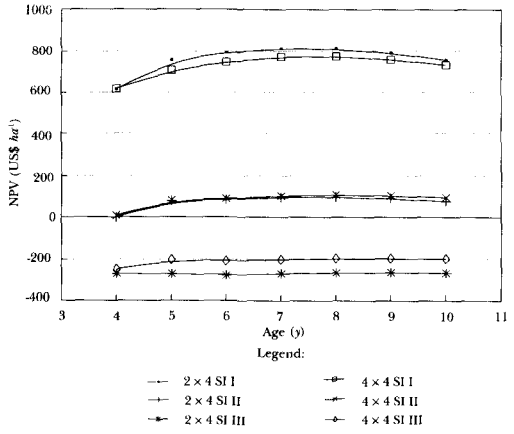

Figure 3. Base case financial result

The net present value analysis can determine if the plantation investment is financially desirable, as well as the preferred financial rotation age and spacing regime. An investment is financially desirable if the net present value is greater than zero. The preferred rotation age and spacing regime is that which yields the largest net present value.

Site index I and site index II plantations yield positive net present values and are financially desirable. Site III plantations are not, and hence, the preferred regime is not to plant.

The preferred rotation age and spacing regime for the site index I plantation is 7 *y* at 2×4 *m*. For the site index II plantation, it is 8 *y* and 4×4 *m*. The increase in plantation establishment costs of the 2×4 *m* spacing is only offset by the increase in volume yield on the high yield site index I plantation - not on the lower yielding site index II and III plantations.

Sensitivity analysis

A sensitivity analysis was undertaken on the base case financial results through varying the assumptions of the values of the discount rate, establishment costs and stumpage price.

The results of varying the discount rate are shown in Figure 4. Relatively small changes in the base case discount rate of 9% result in relatively large changes in the net present values of the plantations. The net present value changes geometrically with changes in the discount rate. For example, a 1% change (increase) in the discount rate resulted in a 9.3% change in the net present value for site index I plantations, 19.8% for site index II and 6.1% for site index III plantations.

Varying the base case cost (Figure 5) and stumpage price (Figure 6) assumptions result in linear changes in the net present values and are thus less than that of varying the discount rate. For example, a 1% change (increase) in plantation establishment and maintenance costs resulted in a 0.6% change in net present value for a site index I plantation and a 1.0% for site index II and

III plantations. Similar figures for a 1% change in stumpage price are 1.6% for site index I, 1.2% for site index II and 1.0% for site index III plantations.

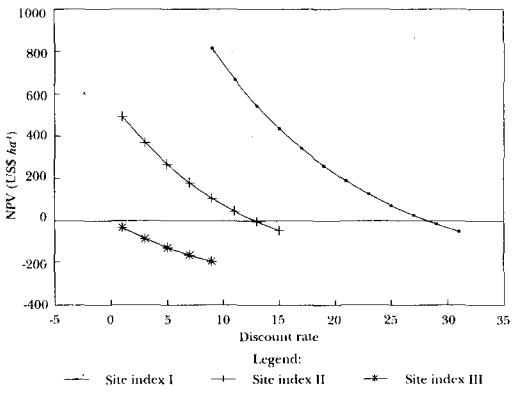

Figure 4. Sensitivity analysis results - discount rate

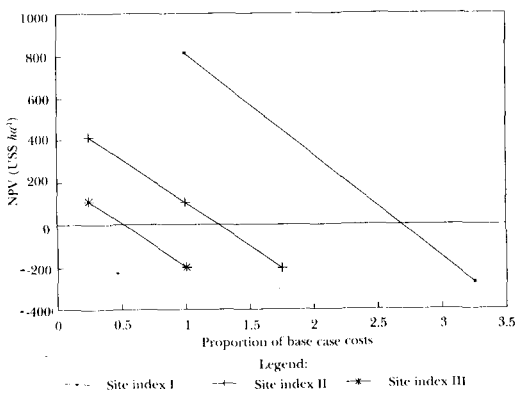

Figure 5. Sensitivity analysis results - establishment and maintenance costs

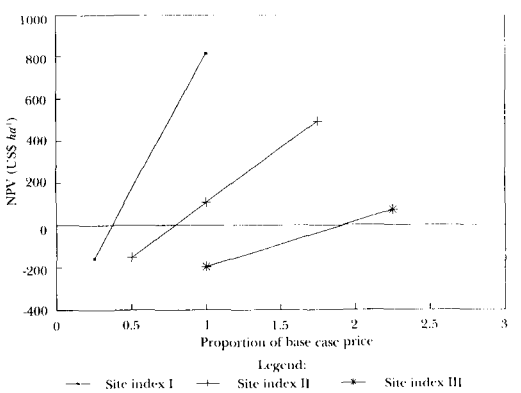

Figure 6. Sensitivity analysis results - stumpage price

Figures 4 to 6 can also be used to undertake a break even analysis as they demonstrate under what assumptions the net present value will be equal to zero (or breaking even as the present value of the revenues equal the present value of the costs). These break even assumptions for the discount rate, stumpage price, and plantation establishment and maintenance costs are given in Table 2.

Table 2. Break even analysis

	Site I	Site II	Site III
Discount rate[1]	28%	13%	0%
Costs[2]	4.02	1.25	0.52
Stumpage price[2]	0.37	0.89	1.92

[1]The discount rate that makes the net present value equal to zero. This is also the internal rate of return; [2]The proportion (or magnitude) base case costs or stumpage price would have to change to make the net present value equal to zero. A proportion of 1.00 would equal the base case costs or stumpage price.

The discount rates in Table 2 are, by definition, internal rates of return (the discount rate that makes the net present value equal to zero). The figures for establishment and maintenance costs and for stumpage price reflect the proportion (or magnitude) that these items would have to change for the investment to just break even. For example, for the site index I plantation, if costs were actually 4.02 times the base case costs, the net present value would equal zero and, for the site index III plantation, these costs would have to be reduced to 0.37 times the base case for the net present value to be zero.

The sensitivity analysis provides the financial results for a wide range of potential market conditions under which investments in *A. indica* plantations could be undertaken. Therefore, the analytical results presented could be extrapolated to meet the investment conditions throughout the range in which *A. indica* is grown.

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