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SITE QUALITY ASSESSMENT OF *LEUCAENA LEUCOCEPHALA* IN THE PHILIPPINES

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URIARTE, M.T. 1997. Site quality assessment of *Leucaena leucocephala* in the Philippines. A comprehensive study was undertaken to determine the relationship between age and dominant height (tree-site index method) and between site index and site properties (soil-site index method) for *Leucaena leucocephala* (also locally known as giant ipil-ipil). Development of tree-site index prediction equation was based on temporary sample plots established at sites representing the four climatic types of the Philippines. The variation in tree-site index as explained by age accounted for 66, 82, 88 and 79% for climatic types 1, 2, 3 and 4 respectively. The factors that most influenced soil-site index were depth; phosphorus, magnesium and calcium contents; cation exchange capacity; and pH. The results showed that the tree-site index method was a more practical method to use than the soil-site index method.

Key words: *Leucaena leucocephala* - site quality - tree-site index - soil site index

URIARTE, M.T. 1997. Penilaian kualiti tapak *Leucaena leucocephala* di Filipina. Kajian komprehensif dijalankan untuk menentukan kaitan antara umur dan ketinggian dominan (kaedah indeks tapak pokok) dan antara indeks tapak dan ciri-ciri tapak (kaedah indeks tapak tanah) bagi *Leucaena leucocephala* (nama tempatan ipil-ipil gergasi). Perkembangan persamaan ramalan indeks tapak pokok adalah berdasarkan plot sampel sementara yang ditubuhkan di tapak yang mewakili empat jenis iklim di Filipina. Kepelbagaian dalam indeks tapak pokok seperti yang diterangkan oleh umur iaitu 66, 82, 88 dan 79% bagi jenis-jenis iklim 1,2, 3 dan 4, masing-masing. Faktur yang banyak mempengaruhi indeks tapak tanah ialah kedalaman; kandungan fosforus, magnesium dan kalsium; keupayaan pertukaran kation; dan pH. Keputusan menunjukkan kaedah indeks tapak pokok lebih praktikal untuk digunakan berbanding kaedah indeks tapak tanah.

Introduction

The ability of *Leucaena leucocephala* (Lam.) de Wit (giant ipil-ipil) to thrive on poor soils and in areas with long dry season makes it a prime species for restoring forests, watersheds and other lands that have been denuded of trees. It competes vigorously against natural grasses, a common feature of areas degraded or depleted by excessive agriculture. Robust nitrogen fixing trees like *Leucaena* seem ideal to restore vegetative cover on such sites.

Evaluation of site quality has always been an important part of forest management. It is an expression of the complex edaphic, climatic and biotic factors that influence tree growth. As forest management intensifies, accurate estimates of site productivity have become increasingly important. In stands with existing trees, site index is estimated from measurements of dominant height and age by means of site index curves. If there are no stands or if the stands are not acceptable (understocked stands, cut-over areas and old fields), site index curves cannot be used for unbiased estimation of site quality. In these cases, functional relationship between site index and site factors can be used (Hagglund & Lundmark 1977).

Materials and methods

The study areas

Study areas were selected from the four major climatic regions of the country. Climatic type 1 has two pronounced seasons: dry from November to April, and wet during the rest of the year (Ilocos Norte, Ilocos Sur and Pangasinan). Climatic type 2 has no dry season with a very pronounced maximum rainfall from November to January (Davao). Climatic type 3 has very pronounced seasons; relatively dry from November to April, and wet during the rest of the year (Batangas, Cebu, Iloilo and Nueva Viscaya). Climatic type 4 has rainfall more or less evenly distributed throughout the year (Cotabato). Mean annual rainfalls for climatic types 1, 2, 3 and 4 during the growth period were 170.1, 179.1, 132.9 and 154.9 mm respectively. Mean temperature was 27.61°C, from a range of 27.0 to 29.2 °C. Relative humidity, ranging from 75.8 to 82.0%, had a mean of 79.2%.

Areas were primarily cogonal (*Imperata cylindrica*) before *Leucaena* plantations were established. Complete clearing was done before planting. The existing *Leucaena* stands (Hawaiian: K8, K22, K28 and K27: Salvador and Peruvian cultivars combined) selected were free from disease, insect infestation or other major disturbances.

Data collection and collation

To determine tree-site index, sample plots representing various ages and stand density were established in each climatic type using the Bitterlich method (del Rosario 1979) with basal area factor (BAF) of 2 m^2 ha^{-1}. Trees within each plot were measured for total height (TH) and age (A).

For soil-site index, one kilogram composite soil samples from the A- and B- horizons were collected from each plot for analysis.

Physical and chemical analyses of the soil were conducted using the procedures described in the Standard Methods of Analysis for Soil, Plant, Water and Fertilizer (PCARR 1980) as follows:

A. Physical Properties

1. % MC	-	Gravimetric method
2. Bulk density	-	Paraffined clod method
3. Particle density	-	Pycnometer method
4. Soil porosity	-	Pycnometer method
5. Texture (silt, clay, sand,loam)	-	Hydrometer method

B. Chemical Properties

1. Soil reaction (pH)	-	Potentiometric method
2. Organic matter	-	Walkley-Black method
3. Total available nitrogen	-	Modified Kjeldahl's method
4. Available phosphorus	-	Bray's method
5. Cation exchange capacity	-	Ammonium acetate method
6. Exchangeable cations		
Calcium	-	Sodium nitrate extraction method
Magnesium	-	Sodium nitrate extraction method
Sodium	-	Flame photometer method
Potassium	-	Flame photometer method

Most of the plots were clayey in texture, with pH of A- and B-horizons ranging from 3.20 to 7.30 and from 3.70 to 7.80 respectively. Elevation was between 15 and 806 m above sea-level. Depth of the A-horizon ranged from 12 to 49 cm.

Model development

The following site index equations were determined using regression analyses:

a. Tree-site index (TSI)
   TSI = f (A, TH)

b. Soil-site index (SSI)
   SSI = f (soil properties, topographic features, climatic factors)

Tree-site index equations were developed for each climatic zone. Due to the high cost of laboratory analyses, only one soil site index equation for the whole country was developed. Based on goodness of fit and significance of the regression coefficients as shown by the R^2 (coefficient of determination), *t*-values and MSE (mean square error), the "best" equations for each method were selected and compared in terms of precision (size of variance) and cost of data gathering.

Results and discussion

Tree-site index

The tree-site index guide equations and the site index equations at base age = 5 y are as follows:

1. Climatic type 1

$$\log_{10}(TH) = 0.5815 + 0.5729 \log_{10}(AGE)$$
$$R^2 = 0.66;\ n = 261;\ p = 0.0001;$$
$$MSE = 0.0055$$
$$\log_{10}(TSI) = 0.4000 - 0.5721 \log_{10}(AGE) + \log_{10}(TH)$$

2. Climatic type 2

$$\log_{10}(TH) = 0.5139 + 0.7000 \log_{10}(AGE)$$
$$R^2 = 0.82;\ n = 50;\ p = 0.0001;$$
$$MSE = 0.0051$$
$$\log_{10}(TSI) = 0.4893 - 0.7000 \log_{10}(AGE) + \log_{10}(TH)$$

3. Climatic type 3

$$\log_{10}(TH) = 0.4729 - 0.7833 \log_{10}(AGE)$$
$$R^2 = 0.88;\ n = 200;\ p = 0.0001;$$
$$MSE = 0.0045$$
$$\log_{10}(TSI) = 0.5475 - 0.7832 \log_{10}(AGE) + \log_{10}(TH)$$

4. Climatic type 4

$$\log_{10}(TH) = 0.7180 + 0.6939 \log_{10}(AGE)$$
$$R^2 = 0.79;\ n = 50;\ p = 0.0001;$$
$$MSE = 0.0041$$
$$\log_{10}(TSI) = 0.4340 - 0.6209 \log_{10}(AGE) + \log_{10}(TH)$$

5. Overall equation (all data combined)

$$\log_{10}(TH) = 0.5970 + 0.6434 \log_{10}(AGE)$$
$$R^2 = 0.79;\ n = 561;\ p = 0.0001;$$
$$MSE = 0.0047$$
$$\log_{10}(TSI) = 0.4497 - 0.6434 \log_{10}(AGE) + \log_{10}(TH)$$

The coefficients of determination (R^2) of the guide equations of all TSI equations show that 66 to 88% of the variation in total height is attributed to age. Mean total height value of *L. leucocephala* at different ages and site indices are shown in Tables 1 to 5.

Table 1. Mean total height of *Leucaena leucocephala* for climatic type 1 at different ages and site classes

Age	Site index (m)					
(y)	4	8	12	16	20	24
2	2.37	4.74	7.10	9.47	11.84	14.21
3	2.99	5.97	8.96	11.94	14.93	17.92
4	3.52	7.04	10.56	14.08	17.66	21.12
5	4.00	8.00	12.00	16.00	20.00	24.00
6	4.44	8.88	13.32	17.76	22.20	26.64
7	4.85	9.70	14.54	19.40	24.24	29.09
8	5.23	10.47	15.70	20.94	26.17	31.40
9	5.60	11.20	16.80	22.39	27.99	
10	5.95	11.89	17.84	23.79	29.73	
11	6.28	12.56	18.84	25.12	31.40	
12	6.60	13.20	19.80	26.40		
13	6.91	13.82	20.73	27.64		
14	7.21	14.42	21.63	28.84		
15	7.50	15.00	22.50	30.00		

Table 2. Mean total height of *Leucaena leucocephala* for climatic type 2 at different ages and site classes

Age	Site index (m)					
(y)	4	8	12	16	20	24
2	2.11	4.21	6.32	8.42	10.53	12.64
3	2.80	5.59	8.39	11.19	13.99	16.78
4	3.42	6.84	10.26	13.69	17.11	20.53
5	4.00	8.00	12.00	16.00	20.00	24.00
6	4.54	9.09	13.63	18.18	22.72	27.57
7	5.06	10.12	15.19	20.25	25.31	30.37
8	5.56	11.12	16.68	22.23	27.79	
9	6.04	12.07	18.11	24.14	30.18	
10	6.50	13.00	19.49	25.99	32.49	
11	6.95	13.89	20.84	27.78		
12	7.38	14.76	22.15	29.53		
13	7.80	15.62	23.42	31.13		
14	8.22	16.45	24.67			
15	8.63	17.26	25.89			

Table 3. Mean total height of *Leucaena leucocephala* for climatic type 3 at different ages and site classes

Age (y)	Site index (m) 4	8	12	16	20	24
2	1.95	3.90	5.85	7.81	9.76	11.70
3	2.68	5.30	8.04	10.72	13.40	16.08
4	3.36	6.72	10.08	13.43	16.79	20.15
5	4.00	8.00	12.00	16.00	20.00	24.00
6	4.61	9.23	13.84	18.46	23.07	27.68
7	5.21	10.41	15.62	20.82	26.03	31.23
8	5.78	11.56	17.34	23.12	28.90	
9	6.34	12.67	19.02	25.36	31.69	
10	6.88	13.77	20.65	27.54		
11	7.42	14.84	22.25	29.67		
12	7.94	15.88	23.82	31.76		
13	8.46	16.91	25.36			
14	8.96	17.92	26.88			
15	9.46	18.92	28.37			

Table 4. Mean total height of *Leucaena leucocephala* for climatic type 4 at different ages and site classes

Age (y)	Site index (m) 4	8	12	16	20	24
2	2.26	4.53	6.79	9.06	11.32	13.59
3	2.91	5.93	8.74	11.65	14.56	17.48
4	3.48	6.97	10.45	13.93	17.41	20.90
5	4.00	8.00	12.00	16.00	20.00	24.00
6	4.47	8.96	13.44	17.92	22.40	26.88
7	4.93	9.86	14.79	19.73	24.65	29.58
8	5.36	10.71	16.07	21.42	26.78	32.13
9	5.76	11.52	17.29	23.05	28.81	
10	6.15	12.30	18.45	24.61	30.75	
11	6.53	13.05	19.58	26.11	32.63	
12	6.89	13.78	20.67	27.56		
13	7.24	14.48	21.72	28.96		
14	7.58	15.16	22.74	30.32		
15	7.91	15.83	23.74	31.65		

Table 5. Mean total height of *Leucaena leucocephala* in the Philippines at different ages and site classes

Age (y)	Site index (m) 4	8	12	16	20	24
2	2.22	4.44	6.65	8.87	11.09	13.31
3	2.88	5.76	8.64	11.52	14.40	17.28
4	3.46	6.93	10.40	13.86	17.32	20.79
5	4.00	8.00	12.00	16.00	20.00	24.00
6	4.50	9.00	13.50	17.99	22.49	26.98
7	4.97	9.93	14.90	19.87	24.83	29.80
8	5.41	10.82	16.24	21.65	27.06	32.47
9	5.84	11.68	17.52	23.35	29.19	
10	6.25	12.80	18.74	25.00	31.24	
11	6.64	13.29	19.93	26.64		
12	7.03	14.05	21.08	28.10		
13	7.40	14.80	22.19	29.59		
14	7.76	15.52	23.28	31.03		
15	8.11	16.22	24.33			

These tables indicate that as age increases, height also increases. At 2 y of age and site index of 12 m, climatic type 1 had the highest total height followed by climatic types 4, 2 and 3 successively. Height may be affected by rainfall in the area. The greatest total height growth was attained during the first year, then slowly decreased as the tree became older. These results conformed with those of Revilla (1982) and Pinol *et al.* (1985).

Using the Chapman-Richards model (Clutter *et al.* 1983), a non-linear model to determine tree-site index, the TSI equation at base age = 5 y was

$$TSI = \frac{TH}{1.7144 * (1 - \exp(-0.2500 * AGE) * 1.6)};$$

$R^2 = 0.90$: $n = 561$; $p = 0.0001$; $MSE = 0.0023$

The mean total heights at different ages and site indices of the derived Chapman-Richards Model are given in Table 6. The height growths by age are as follows:

Age (y)	Height growth (m)
1	1.53
2	2.33
3	2.30
4	2.07
5	1.77
6	1.45
7	1.18
8	0.95
9	0.77
10	0.60
11	0.47
12	0.38

The resulting height curve from the Chapman-Richards model followed a sigmoid shape and was more reflective of the true site curve (Figure 1) than the curves resulting from linear models.

Table 6. Mean total height of *Leucaena leucocephala* using the Chapman-Richards model

Age	Site index (m)					
(y)	4	8	12	16	20	24
2	1.5	3.1	4.6	6.2	7.7	9.3
3	2.5	4.9	7.4	9.9	12.3	14.8
4	3.3	6.6	9.9	13.2	16.5	19.8
5	4.0	8.0	12.0	16.0	20.0	24.0
6	4.6	9.2	13.7	18.3	22.9	27.5
7	5.1	10.1	15.2	20.2	25.3	30.3
8	5.4	10.9	16.3	21.8	27.2	
9	5.7	11.5	17.2	23.0	28.7	
10	6.0	12.0	17.9	23.9	29.9	
11	6.2	12.3	18.5	24.7	30.9	
12	6.3	12.6	19.0	25.3	31.6	
13	6.4	12.9	19.3	25.8		
14	6.5	13.1	19.6	26.1		
15	6.6	13.2	19.8	26.4		

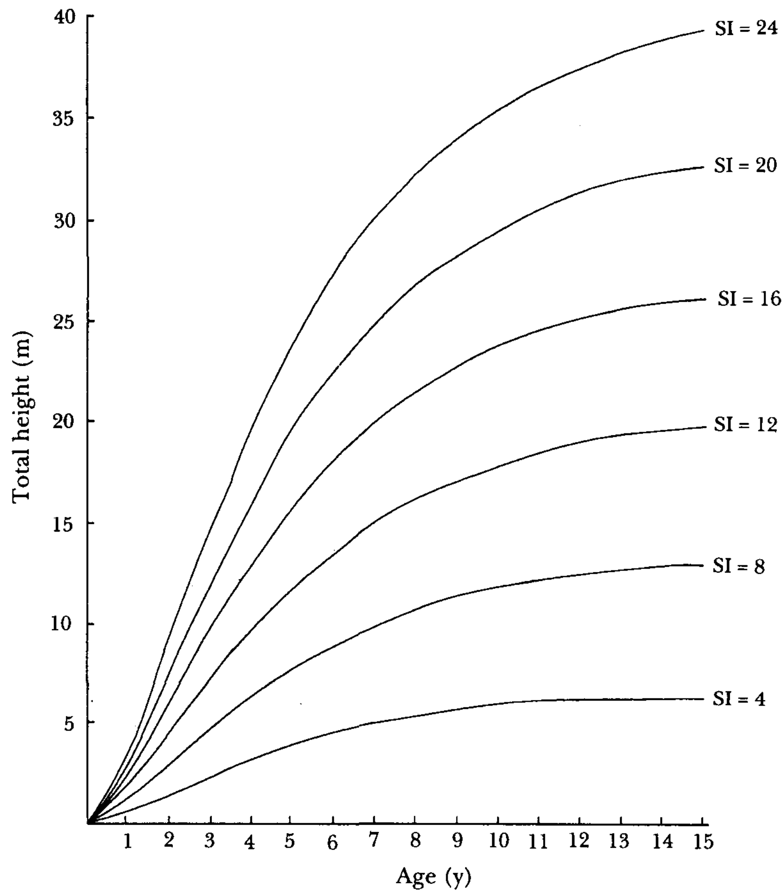

Figure 1. Tree-site index curves of *Leucaena leucocephala*

Soil-site index

Using linear regressions the "best" soil-site index (SSI) equation was:

$$SSI = 17.068 - 1.7068 * AGE - 1.501 * pH + TH$$
$$R^2 = 0.84;\ n = 46;\ p = 0.0001;\ MSE = 0.0047$$

Values of mean total height of *L. leucocephala* at different site indices and pH = 5 (average pH) are given in Table 7.

Table 7. Mean total height of *Leucaena leucocephala* using the soil-site index method at pH = 5

Age	Site index (m)					
(y)	4	8	12	16	20	24
2		1.9	5.9	9.9	13.9	17.9
3		3.6	7.6	11.6	15.6	19.6
4	1.3	5.3	9.3	13.3	17.3	21.3
5	3.0	7.0	11.0	15.0	19.3	23.0
6	4.7	8.7	12.7	16.7	20.7	24.7
7	6.4	10.4	14.4	18.4	22.4	26.4
8	8.1	21.1	16.1	20.1	24.1	28.1
9	9.8	13.8	17.8	21.8	25.8	29.8
10	11.5	15.5	19.5	23.5	27.5	31.5
11	13.2	17.2	21.2	25.2	29.2	
12	14.9	18.9	22.9	26.9	30.9	
13	16.6	20.6	24.6	28.6		
14	18.3	22.3	26.3	30.3		
15	20.0	24.0	28.0			

Another significant equation generated was

$$\log_{10}(SSI) = 1.2603 + 0.0009 + DA - 0.0301\ BpH$$
$$- 0.0032\ BCa - 0.0021\ BCEC + 0.0020\ AP$$
$$R^2 = 0\ 45;\ n = 46;\ p = 0.0002;\ MSE = 0.0029$$

where

DA	=	depth of A-horizon in cm
BpH	=	pH of B-horizon
BCa	=	calcium content of B-horizon
BCEC	=	cation exchange capacity of B-horizon
AP	=	phosphorus content of A-horizon

Calcium and pH had greater influence (14 and 12% respectively) on total height than the other factors. The results confirm the findings of Hill and Tilo (1971), Tilo (1976), Tandug (1983) and Dalmacio (1984) that phosphorus, calcium, and cation exchange capacity are critical elements in the nutrition of giant ipil-ipil.

Equations by aspect were also determined. These were:

Northwestern:

$$\log_{10}(SSI) = 1.1585 + 0.0019\ DA - 0.0024\ ACa - 0.00345\ ACEC$$
$R^2 = 0.62$; $n = 17$; $p = 0.0046$; $MSE = 0.0018$

Southwestern:

$$\log_{10}(SSI) = 1.0833 - 0.0051\ BCa$$
$R^2 = 0.32$; $n = 14$; $p = 0.0425$; $MSE = 0.0056$

Northeastern:

$$\log_{10}(SSI) = 1.2229 - 0.0348\ BpH$$
$R^2 = 0.37$; $n = 15$; $p = 0.0161$; $MSE = 0.0019$

The equations generated by slopes were

Lower Slopes:

$$\log_{10}(SSI) = 1.6262 - 0.0048\ ACEC - 0.0916\ BpH + 0.0047\ AP$$
$R^2 = 0.84$; $n = 10$; $p = 0.0082$; $MSE = 0.0014$

Flat:

$$\log_{10}(SSI) = 1.1198 - 0.0174\ AMg$$
$R^2 = 0.41$; $n = 11$; $p = 0.0335$; $MSE = 0.0180$

where

ACa = calcium content of A-horizon
ACEC = cation exchange capacity of A-horizon
AMg = magnesium content of A-horizon

All other variables are previously defined.

It is shown that as depth of A-horizon and phosphorus content increased, site index also increased. However, increasing the CEC, pH and calcium content of the B-horizon and magnesium content and CEC of the horizon could bring down the site index values.

Efficiency of TSI over SSI

Results showed that the soil-site index (SSI) method is about seven times more expensive than the tree-site index method. Data used in the tree-site index (SI) method is much easier to gather. It involves only two variables, age and total height. This method is more practical in the sense that no laboratory analyses are needed. In terms of efficiency, the tree-site index method is about four times more efficient than the soil-site index method. This conforms with the findings of Bowersox and Ward (1972) that the tree-site index method is more practical to use than the latter. Hence, the use of soil-site functions should be restricted to situations where tree-site index curves cannot be applied. They should be used as a supplemental technique where the tree-site index method is not applicable.

Conclusion

Acceptable equations for site quality assessment for *Leucaena leucocephala* were developed in the Philippines. Results show that as age increases the tree-site index also increases. For the soil-site index method, SSI increases as depth and phosphorus content of the A-horizon increase. However, it was inversely proportional to cation exchange capacity, pH and calcium. Increase in acidity results in the reduction of the absolute amount of exchangeable bases thus resulting in slower growth.

The tree-site index method was found to be more efficient, less expensive and more practical than the soil-site index method. Thus, the use of soil-site functions should be restricted in cases where tree-site index curves cannot be applied. The equations so developed offer only a partial solution to the problem of predicting site quality of *L. leucocephala* using physiographic, climatic, edaphic and tree factors. Additional research has yet to be conducted to determine the most limiting factor which significantly affects site index and associated growth and yield of *L. leucocephala*.

In some instances, the model's tendency to give unrealistic values beyond the given ranges necessitates further refinement. This indicates that more samples and more variables may have to be included in the model.

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