1. Introduction

Dual-purpose cattle production systems have been traditionally preferred by family farms in the lowland tropics due to the low risk of price changes, higher economic benefit per unit of area than meat production, adaptation to the climatic conditions in the lowland tropics, and less capital investment and technical support required than for specialized milk production (SERE and DeVACCARO, 1985; HOLMANN, 1989). Traditional cattle system in the low Western Region of Ecuador (IWRE) is characterized by a diversity of woody perennials which significantly improve animal productivity and conserve natural resources. The selection and management of a commercial woody perennial as live fences in silvopastoral systems can increase substantial productivity and provide greater social and environmental benefits than traditional cattle production systems in IWRE. Dual-purpose cattle production systems, comprising milk and meat production, are traditionally utilized by family farms on open pastures in the lowlands of the IWRE. However, Zebu-European crossbred cattle suffer from heat stress and therefore would benefit from shading. A tree species that provides shade and has adapted to management conditions of pastures with seasonal burning is the Teak (*Tectona grandis*). It is planted as live fence, by this forming a silvopastoral system. The net incomes of silvopastoral farmers are higher than compared to the incomes of traditional farmers, taking into account the initial investments of planting trees. Published evidence of positive contributions of trees to cattle production has mostly been based on investigations or experiments of limited scale. The objective of this study was to determine the growth of the teak and time of harvesting, thus defining a yield model for *Tectona grandis* for silvopastoral systems in IWRE.
2. Material and Methods

2.1 Data acquisition and information matrix Generation

Permanent sample plots (40 ha) have been established by the National Department of Tropical Cattle Production of the INIAP in the Tropical Research Station Pichilingue. These are mostly line design, comprising a line of 3 x 3 trees planted as a live fence with a total of 133 trees/ha. The 479 interval plots on 600 ha have been divided into four zones according to ecological differences (mostly slope), geographical situation and plantation date: Zone 1: flat terrain in Buena Fé, El Empalme, Pueblo Viejo, Palestiana, Balzar (2,000 mm/year) Zone 2: Esmeraldas-Quinindé (1,990 mm/year) Zone 3: Western part of the Mountain Range Chongón-Colonche (500-800 mm/year) Zone 4: Eastern part of the Mountain Range Chongón-Colonche (1,000 to 1,300 mm/year). Each plot consisting of a lineal form of about 100 m was coded with both name and number. All the teak trees within the plot were measured by its diameter at breast height (DBH) and total height between 2008/2009.

2.2 Site Index

Three different models were used, following other studies on site index equations. The equations used were those developed by Hossfeld (PESCHEL, 1938) (Eq. 1), Richards (1959) (Eq. 2) and Bailey and Clutter (1974) (Eq. 3):

\[
H_0 = \frac{t^2}{a + bt + ct^2} \quad \text{Eq. 1}
\]

\[
H_0 = a(1 - e^{-bt})^c \quad \text{Eq. 2}
\]

\[
H_0 = e^{a-bct} \quad \text{Eq. 3}
\]

where \(H_0\) is the top height; \(t\) the age (years); \(a, b, c\), the parameters. The guide-curve method was used in the present study for the development of a site index equation.

2.2 Yield Tables

The first relationship is of \(H_0=f(age)\), which was obtained during the development of site index curves (\(H_0\) is top height). Different expressions were used for different site quality classes. In silvopastoral systems, only projections of the DBH and height are necessary because there is no mortality by competition due to low stand density.

2.3 Determination of the volume

The total stem volume from gelling cut up to a top diameter of 7 cm. The volume was estimated with the Smalian formula for two sections. A multiple regression model was fitted having the following form:

\[
V = a \cdot DBH^b \cdot H^c \quad \text{Eq 4}
\]

Where by \(V\) = Volume in m³

\(a,b,c\) = Empirical Parameters

\(DBH\) = diameter at breast height (130 cm) of tree

\(H\) = Total height

All data were analyzed using the Statistica Program and Mean annual volume increment (M) and Current Annual Increment (CAI) was determined.
3. Results

3.1 Top High

The Bailey and Clutter (1974) equation was chosen since both Richards’ (1959) and Hossfeld (PESCHEL, 1938) equation give very poor height values once the age of the stand reaches 8–10 years. Bailey and Clutter equation resulting for the guide curve is as follows:

Site Index curves

\[ H_0 = e^{3.88 - 2.99 t^{0.38}} \]  

Eq. 5

DBH-age curves

\[ r = e^{4.37 - 2.29 t^{0.44}} \]  

Eq. 6

Figure 2 shows the mean data from permanent and temporal plots in each ecological zone of IWRE. Pichingue, Quinindé and El Emplame silvopastoral systems showed site quality indices of 22, 20 and 18 respectively at the age of 10 years.

Figure 1. Guide curves obtained from temporal and permanent plots in the IWRE of Ecuador. Site Index age 10 years.

Figure 2. DBH-age curves in the IWRE, OF ECUADOR

Differences in Carbon allocation between trees of different age state in silvopastoral systems, is presented in Figure 3.

Figure 3. Relationship between Form Factor and Diameter at the Breast High for Tectona grandis in the IWRE of Ecuador. Index age 10 years.
Young individuals allocate more Carbon to height growth than diameter growth. Trees with longer crowns have a more conical stem form. Pruning of green crown make trees more cylindrical.

The variation of form factor with the age in silvopastoral systems is established with the following equation:

\[ FF = 1.11 \times DBH^{-0.09} \quad \text{Eq. 7} \]

\[ n=200 \]
\[ r^2=0.78 \]

3.2 Volume

The mean tree volume is obtained by using a general double-entry equation estimated in the above section (Eq. 8). This parameter can be calculated as follows:

\[ V = 0.0001 \times DBH^{1.87} \times H^{0.99} \quad \text{Eq. 8} \]

The comparison of the calculated and model Volume is presented in Figure 4.

\[ \text{Figure 5. Comparison of the calculated and estimated Volume model for Tectona grandis in the IWRE of Ecuador.} \]

3.3 MEAN ANNUAL VOLUME INCREMENT AND CURRENT ANNUAL INCREMENT

According to Gadow v. (2004) the cut point is produced when the Mean Annual Increment is below the Current Annual Increment. For the \textit{T. grandis} in silvopastoral systems (Site Index 22), the harvest point was established at 13 years with a final height of .58 m. which means an annual increment of 21.95 m$^3$/ha/year (Figure 6). For Site Index 20 the harvest point was established at 17 years with an annual increment of 17.90 m$^3$/ha/year (Figure 7) and for Site Index 18 the harvest point was established at 21 years with an annual increment of 14.29 m$^3$/ha/year (Figure 8).
Figure 6. Total volume, current and mean annual increment for Site Index 22, (Pichinlingue).

Figure 7. Total volume, current and mean annual increment for Site Index 20, (Quinide).

Figure 8. Total volume, current and mean annual increment for Site Index 18, (El Empalme).

Literature


