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PAR conversion efficiencies of a tropical rain forest

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Introduction

The mean annual quantities of photosynthetically active radiation (PAR) absorbed during various stages of regeneration of a tropical rain forest in the upper Rio Negro region of Colombia and Venezuela were estimated for the intervals between clear-cut and 1, 3, 10, 20, 35, 60, 80, and 200 yr of growth. The forest phytomass and litter-fall at each stage were obtained from previous studies, and the data were used to calculate the mean annual quantity of net dry matter production per unit of absorbed PAR, the PAR conversion efficiency.

Methods

The basic equation for the calculation is given by:

Total dry matter production ($g \cdot m^{-2} \cdot yr^{-1}$)	=	PAR conversion efficiency ($g \cdot MJ^{-1}$)	x	Absorbed PAR ($MJ \cdot m^{-2} \cdot yr^{-1}$)	(1)

Saldarriaga *et al.* (1986) investigated forest succession at 23 sites representing a chronosequence ranging from recently abandoned areas after slash-and-burn agriculture to mature rain forest. Aboveground and belowground living phytomass, litter and root production, standing dead mass, and leaf area indices were estimated with allometric regression relationships using diameter, height, dry weight and wood density data from each of the 23 sites. Recently available data for 1 and 3 yr regrowth forest stands were also included in this analysis.

Regression equations for converting leaf phytomass to leaf area were used with number of trees per hectare (Saldarriaga *et al.*, 1986) to derive leaf area index *(LAI)* values for the forest stands. The value of *LAI* for the 1–3 yr period was 3.9, and this increased up to a mean value of 6.7 for the oldest stand (80–200 yr).

Results

The annual quantities of PAR absorbed by the forest stands (Table I) were calculated from the Bouguer–Lambert (Beers) Law using appropriate *LAI* values with an extinction coefficient for PAR of 0.74 and an annual net incoming PAR of 2.75 $GJ \cdot m^{-2} \cdot yr^{-1}$. This latter value was obtained from the mean annual solar radiation (5.2 $GJ \cdot m^{-2} \cdot yr^{-1}$) measured in the area since 1971, by using a factor of 0.55 for the proportion of PAR (Stigter and Musabilha, 1982) and a PAR albedo of 0.04 (Dickinson, 1983).

Dry matter production for the 8 growth periods (Fig. 1) shows the highest rates during the first 10 yr. A significant change

Table I. Mean leaf area indices for periods of forest succession and the estimated annual PAR absorption by the vegetation.

	Period (yr)							
	0–1	*1–3*	*3–10*	*10–20*	*20–35*	*35–60*	*60–80*	*80–200*
Mean *LAI* ($m^2 \cdot m^{-2}$)	2.3[a]	3.9	4.5	6.0	6.1	6.2	6.3	6.7
PAR absorbed ($GJ \cdot m^{-2} \cdot yr^{-1}$)	2.23	2.59	2.65	2.72	2.72	2.72	2.72	2.73

[a] One-half of the maximum value for the 1st yr *LAI* due to herbaceous component (Uhl, 1987); other *LAI* data from Saldarriaga *et al.* (1986) and Saldarriaga (unpublished).

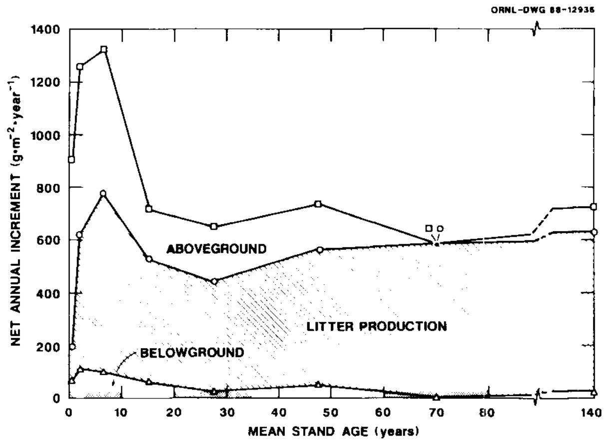

Fig. 1. Annual dry matter increments of above- and belowground living phytomass and litter production for 8 growth periods of a tropical rain forest.

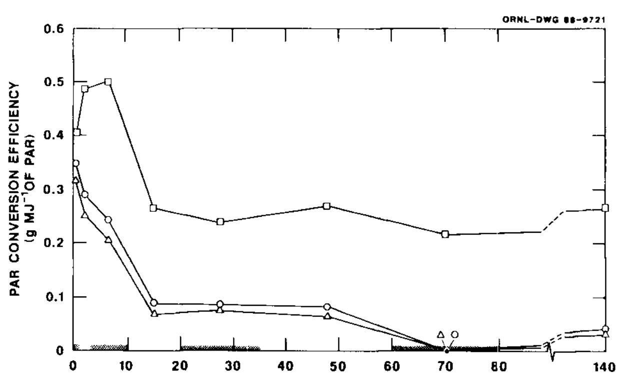

Fig. 2. PAR conversion efficiency based on aboveground living phytomass (Δ), above- and belowground phytomass (O) and net primary production (❑).

in stand structure occurs at about 60–80 yr with the replacement of several early successional species by the mature stand species. This results in no increment in the living phytomass.

The PAR conversion efficiencies determined from eqn 1 show the highest values in the first year, decreasing to zero by year 70 (Fig. 2). When above- and belowground production is combined with litterfall (net primary production), the PAR conversion efficiencies are much higher for years 20–140.

Discussion and Conclusion

The PAR conversion efficiency values for aboveground growth are very much lower than the 1.7 $g \cdot MJ^{-1}$ reported by Linder (1985) for several temperate forests; however, the results are consistent with the low-end values in the 0.2–1.0 $g \cdot MJ^{-1}$ range of PAR energy conversion values derived from Jordan (1971) for 17 forest types, including temperate and tropical ecosystems. The analysis by Jordan included coarse roots in the dry matter production. A value of 20 $kJ \cdot g^{-1}$ for the heat of combustion of dry matter, as suggested by Leith (1968), was used in the conversion of Jordan's values from an energy to a mass basis.

This analysis shows that PAR conversion efficiency decreases with the increase in successional stage and that efficiency values are generally low in comparison with data for temperate forests. One implication for agroforestry in tropical areas similar to the upper Rio Negro valley is that short rotation times (<10 yr) are desirable so that relatively high energy conversion into aboveground phytomass can be obtained.

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