Primary productivity of an Hevea forest in Ivory Coast.

MONTENY,B.A. ORSTOM, Bioclimatologie - Inra, 78850 Thiverval-Grignon, France

1. INTRODUCTION

The objective of the study is to understand the impact of climatic parameters and soil-water factors on Hevea brasiliensis productivity (rubber). The primary production rates of an Hevea forest located in the humid tropical zone of the Ivory Coast have been calculated from a mathematical model based on determined experimental equations. Carbon dioxide flux density above the forest is measured by the energy balance method coupled with the Bowen ratio. This ratio β and the ratio of photochemical heat flux density of CO_2 fixation to latent heat flux density f are determined from vertical profile of points. The light-CO_2 assimilation response curve of the Hevea forest, in relation with rain distribution and solar radiation availability, is used to calculate the daily estimates of organic carbon accumulation and so the yearly dry matter production.

2. MATERIAL and METHODS

The equations describing individual inflows and outputs fluxes of forest stand productivity require :

- the photosynthetic response of plant stand and its evolution under the most important factors which control the photosynthesis (radiation and water);
- the daily and seasonal distribution of these factors;
- the stand biomass (aerial and root) and the evolution of leaf area.

Net primary productivity **NP** results from the difference between leaf carbon assimilation rate **A** and biomass respiration **Rb** (JONES, 1983) :

$$NP = \Sigma (A - Rb) = \Sigma (A - Rbd - Rbn) = \Sigma (NA - Rbn) \quad (1)$$

where Rbd : biomass respiration rate during day time; Rbn : biomass respiration rate during night time; A : gross photosynthesis rate; NA : net assimilation rate (day time hours). Biomass respiration in the day time (12h) is assumed to be equal to that at night (Rbd=Rbn).

The respiration rate R, extrapolated from the light response curve at zero solar radiation, corresponds to :

$$R = Rbn + CO_2\ soil = Rbn + Rroot + Rsoil = Rb + Rsoil \quad (2)$$

Soil carbon flux, CO_2soil, originates from the decomposition of litter and subsurface root hairs + root respiration : $CO_2\ soil = \Sigma (Rsoil + Rroot)$. Soil CO_2 measurements (involving an enclosure and an air flow system, PERRIER et al. 1976) show that the fluxes do not change during 24h period but that they vary more particularly with the decrease of the subsurface soil humidity.

Measurements were carried out in a SAPH Hevea plantation, at Dabou-Ousrou, near Abidjan (5°19' N, 04°30' W), Ivory Coast. The tropical forest zone is under the influence of the InterTropical Convergence Motion (ITC) which determines the climate. The climate of the forest zone has 2 dry seasons: december to march and during august- september and 2 wet seasons with the most important from april to july. The plantation is a 7000ha more or less flat land, situated in the south part of the ivorian tropical forest zone, 50km from the Guinea golf coast.

From air and soil CO_2 flux measurements using micrometeorological methods, (ALLEN et al. 1974; SAUGIER et al. 1974) experimental equations have been determined which express the net assimilation rate as a function of stand characteristics in relation with environmental factors (for more details, see : MONTENY 1987).

3. RESULTS and DISCUSSION

The light-photosynthesis curves for the Hevea forest canopy presents a maximum net photosynthesis at 1.85 $10^{-6}kgCO_2.m^{-2}.s^{-1}$ for a young canopy (2-3 month) and decreases to 0.5 $kgCO_2.m^{-2}.s^{-1}$ for an older one, both of them without soil water deficit (Fig. 1), fitted results from different days of measurement during 2 months.

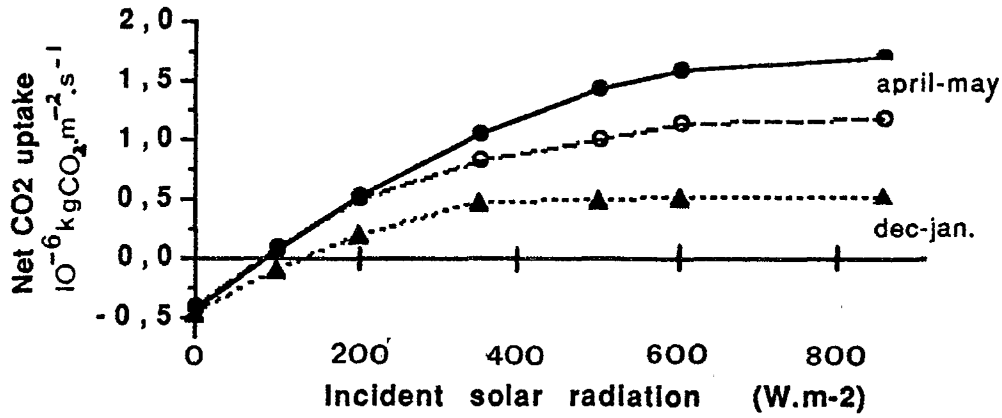

Fig.1 : Photosynthetic light response curves for the whole Hevea forest :
- young canopy without water limitation : • april - may
- young canopy with water limitation : o april - may
- older canopy without water limitation : Δ dec. jan.

The light response curves show a tendency to light saturation. The observed decrease in the net CO2 assimilation is partly due to the deposition of cuticular wax (leaf ageing) and to the effect of a water stress period during the august short dry season. The carbon assimilation is sensitive to soil water status which affects the stomatal resistances as seen for april-may second photosynthesis curve.

The global outgoing CO2 flux at night is equal to 4.4 $10^{-7}kgCO_2.m^{-2}.s^{-1}$. Root respiration is assumed to be proportionnal to root dry weight as it is for the respiration rate of the shoots. From the soil CO2 flux and the biomass measurements, the calculated respiration of aboveground biomass Rbn is 1.5 $10^{-7}kgCO_2.m^{-2}.s^{-1}$. During wet season, the ratio of CO2 soil flux to the CO2 canopy fixation is nearly unit, indicating that, in humid tropics, the carbon turnover is very fast until the subsurface soil humidity limits the litter decomposition or when the leaf photosynthesis decrease.

The daily net productivity **NP** of the Hevea forest is the difference between the net CO2 absorption calculated at 15 minute intervals from 6.00 to 18.00h (based on solar radiation data available on 16 days and the light response curves in Fig.1) and the total biomass respiration from 18.00 to 6.00h. The depletion of soil water in the root zone affects the photosynthetic leaf capacities as it does for the water vapour exchanges (Fig. 1.). We consider the ratio of the actual evapotranspiration to the equilibrium evaporation ETR/ETo as a modulation factor representing the effect of a water stress on the net stand productivity (MONTENY, 1987). The coefficient of conversion from carbon dioxide to dry matter is $0.56 kgDM.kgCO_2^{-1}$.

The annual evolution of the calculated primary production rate of a 19 year old rubber forest is presented in Fig.2. It shows important variations during the year :

may-june : high dry matter production rates after leaves regrowth without soil water limitation;

july-august-september : dry matter production rates decrease in relation with the attenuation of the solar radiation by clouds from the ITC and the depletion of soil water at the end of the short dry season;

october-november : the physiological evolution of leaves (age) associated with stomata increasingly plugged with cuticular wax reduce the daily net canopy assimilation rates of CO_2;

january and february : soil water availability is the main factor responsible for leaf photosynthetical activities reduction and physiological modification before leaf fall. At the end of the leaf span, global respiration rate of the stand is higher than the canopy assimilation rate, which explains the negative rates of dry matter production.

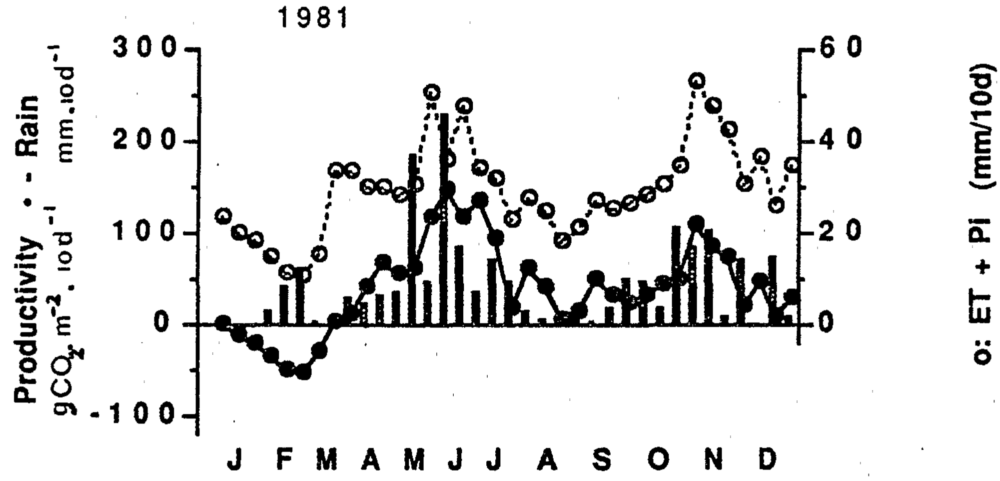

Fig. 2 : Seasonal changes of the dry matter simulated production (•) of a 19 year old Hevea stand in relation with rainfall (▪) and total evaporation rate ET+Pi (o).

The estimated annual net productivity of the Hevea forest is 13.8 TDM.ha-1.y-1 compared with the current annual increment : 8.1 TDM.ha-1.y-1 measured between 11 and 19 years. Taking account of the leaf and shoots fall and the latex sampling(2.4+3.8+1.6 TDM.ha-1.y-1 respectively), the total annual increment would be 15.9 TDM.ha-1.y-1 or 15% higher than the estimated net productivity. The efficiency of solar radiation conversion is 1.7%.

4. CONCLUSION

In the humid tropical regions of West Africa, two climatic factors affect the forest dry matter production : rain distribution and radiation quantities. These factors, depending on the shift of the ITC, are responsible of the low atmospheric CO2 assimilation rate by forest. The wet seasons are commonly cloud cover and it is the litter decomposition which supplies most of the CO2 to the canopy. Leaves lifespan activities are influenced by morphological modifications with ageing, reducing on the other side, the Hevea photosynthetic efficency.

5. REFERENCES

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