Investigations on tree species suitable for the recultivation of degraded land areas in Central Amazonia

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2. Investigations carried out in 1997 and scientific results

2.1. Water and element supply of the plantation systems and their significance for the xylem production of *Swietenia macrophylla* and *Carapa guianensis*

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Cooperation: G. Schroth, W. Zech, H.Preisinger (SHIFT-projects ENV 23, 45)

Material and methods

In this study the influence of the water and K supply on growth and wood formation of plantation grown *Swietenia macrophylla* and *Carapa guianensis* is investigated. As to study the influence of the plantation management on important site factors such as (1) the water and (2) the K supply and with that on (3) wood formation of the trees, monoculture systems of *Swietenia macrophylla* and *Carapa guianensis* (system I) are compared with a corresponding enrichment system (system III). The experimental plots are located at the CPAA/EMBRAPA, Manaus 3°8´S, 59°52´W.

System I (established January 1992):

- Former monoculture of *Hevea brasiliensis* (H.B.K.) Muell.Arg., clear cut in 1991
- Monoculture systems of 20 selected tree species with 4 repeats and 25 plants per plot
- Spacing 3 x 3m
- Fertilization 1992: 150g superphosphate per tree
- Spontaneous vegetation is suppressed by cover crops *Pueraria phaseolides* (Rosed.) Benth and *Homolepis aturensis* (H.B.K.) Chase and cutting by field workers.

System III (established January 1992):

- Former monoculture of *Hevea brasiliensis*
  Enrichment of a 25 years old secondary vegetation with 10 species.
  10 plants per species, 4 repeatings
- Spacing 3 x 6m
- Fertilizaton 1992: 150g superphosphate per tree
  Spontaneous vegetation was not cut or suppressed since 25 years; Dense vegetation with 76 genera out of 39 families.

(1) The suction force of the soil was monitored by tensiometer measurements in a soil depth of 10, 20 and 60cm (planned for 1998 aöso 120 cm). The air temperature, the air humidity, the precipitation, the throughfall and the stem flow are quantified. The transpiration of the trees was quantified by calibrated xylem flux measurements (Granier 1985, comp. also Erbreich 1997, appendix 3).

(2) The K supply of the soil solution was quantified in one week intervals in a depth of 10, 20 and 60cm. The K content of the soil (total K content and Ake) was quantified annually from 1995 until 1997. The element input via litterfall, throughfall and stem flow was also determined

in monthly intervals. Decomposition rates were calculated from litter bag experiments. The element content of the plant tissues was studied by bulk analyses (ICP-OES, comp. Berneicke et al. 1985) as well as by subcellular element analyses (TEM-EDXS, Dünisch et al. 1998).

(3) The structural dynamics in wood formation expressed in terms of monthly increment rates was quantified by the pin marker technique (comp. Mariaux 1969, Kuroda 1986) for 3 trees of each plot.

Results

The water supply of plantation grown Swietenia macrophylla and Carapa guianensis

As to quantify differences in water supply between the wet period from December until June and the drier period from July until November water fluxes for the two plantation systems I and III were studied (comp. also Morais et al. 1998, Schroth et al. 1998). In Swietenia monocultures soil evaporation, in Carapa monocultures evaporation from the crown are of main importance for the water output out of the plantation (Fig.1). Furthermore in Swietenia monocultures a high amount of water runthrough in the soil was quantified, which indicates a high leaching of mineral elements in this system (comp. also Fig. 3 and Fig.4). The high amount of water runthrough in the *Swietenia* monoculture compared to *Carapa* is mainly caused by the reduced transpiration of *Swietenia* trees compared to *Carapa* especially in June, July and November.

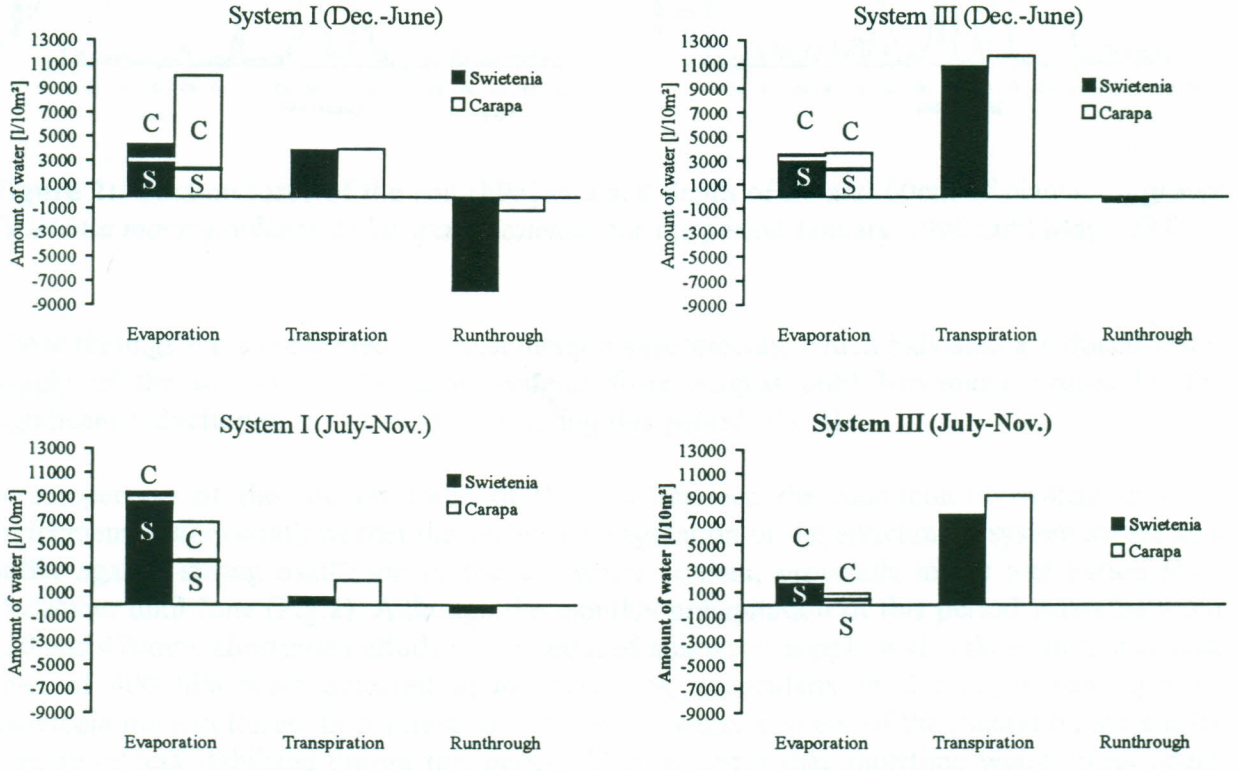

Figure 1: Evaporation of the soil (S) and from the crown (C), transpiration and water runthrough [l/10m²] of plantation grown *Swietenia macrophylla* and *Carapa guianensis* for the wet period from Decemer 1996 until June 1997 and the dry season from July unil November 1997, plantation systems I and III.

In contrast to that 40 to 70% of the water output out of the plantation system III is caused by transpiration, whereas soil evaporation and runthrough are strongly reduced (Fig.1). A comparison of the transpiration of the monocultures and the enrichment system during the drier season from July until November indicates that the trees and shrubs of the secondary vegetation are more adapted to drier periods compared to the planted timber trees, which is indicated by high transpiration rates in system III even from July until November. This is confirmed by further studies on the plant-water relationships of the secondary vegetation carried out in cooperation with the SHIFT project ENV 23 (comp. Morais et al. 1998).

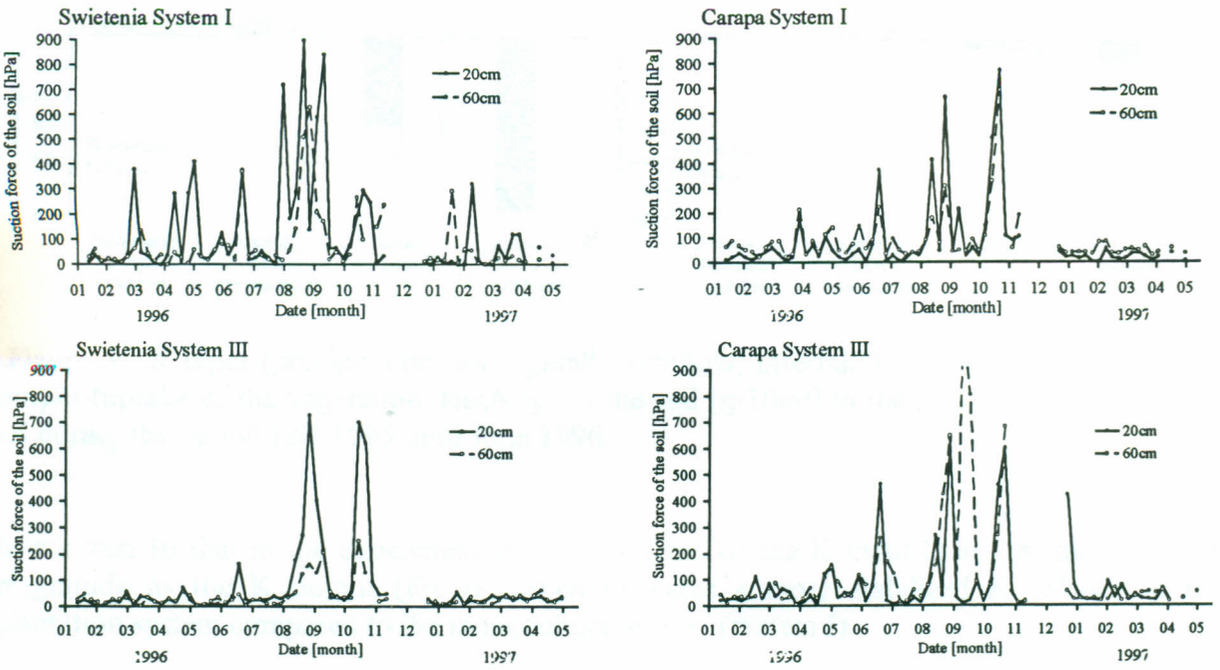

Figure 2: Suction force of the soil [hPa] in a soil depth of 20 and 60cm of plantation grown *Swietenia macrophylla* and *Carapa guianensis* for the period January 1996 until May 1997.

These findings were confirmed by tensiometer measurements, which indicated a reduced water supply of the soil in all plantation systems from August until November caused by the significant reduction of the precipitation during this period (Fig.2).

A comparison of the suction force of the soil between the monoculture system and the enrichment system confirms that the secondary vegetation of the enrichment system serves as a buffer against strong oszillation of the soil water content, especially in the wet period from December until June (Fig.2). Although the monthly precipitation of this period varies between 120 and 470mm, shorttime periods with a reduced soil water supply with values up to a critical level of 400 hPa were detected in monocultures, particularly in the upper soil layer of Swietenia monocultures. In contrast to that the soil water content of the plantation system III is more or less stabilized during this period. This indicates that shorttime water stress might occur in 5-year-old monocultures even during the wet season from December until June.

The K supply of plantation grown Swietenia macrophylla and Carapa guianensis

The K supply of the trees was studied in terms of quantified input and output data within the plantation systems since March 1995. From these investigations it becomes obvious that in the 4-year-old monoculture system the K input and K output is not balanced (Fig.3), which is mainly caused by high K leaching out of the soil in *Swietenia* plantations and high K uptake rates in *Carapa* plantations. This indicates a better absorbance capacity for mineral elements of *Carapa guianensis* compared to *Swietenia macrophylla*.

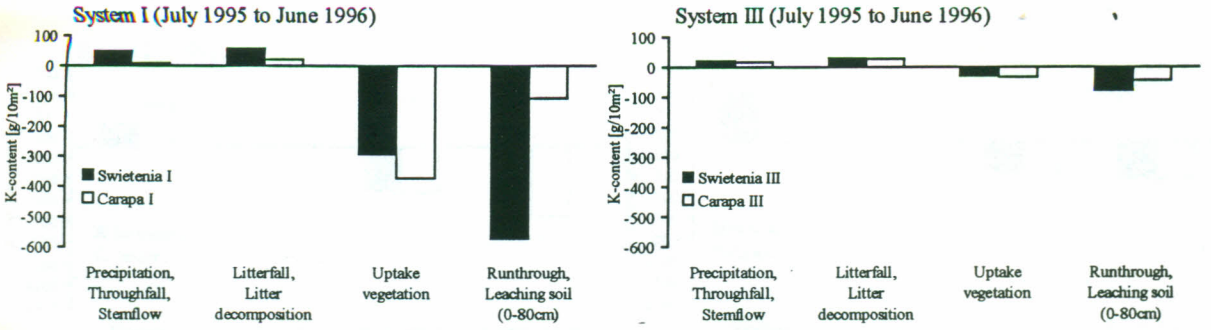

Figure 3: K input (precipitation, throughfall, stemflow, litterfall/litter decomposition) and K output (uptake of the vegetation, leaching) of the soil [g/10m²] in the plantation systems I and III during the period July 1995 until June 1996.

In contrast to that in the enrichment system (system III) the K input is in the same order of magnitude as the K output (Fig.3), which indicates a more stabilized K balance in this plantation system compared to the monoculture system (system I).

Consequently to that during the first years of the plantation a reduction of the K stock of the soil was observed in the plantation system I (Fig.4). Under monoculture conditions the K stock of the soil is strongly reduced in 1996 compared to 1995, whereas no corresponding increase of the K content located in the biomass could be observed. This is explained by the high leaching of K out of the soil in the 4-year-old monoculture system. On the other hand no significant alteration of the K stock of the soil was found in the enrichment system in 1996 compared to 1995.

Nevertheless the total K content of the soil of the 4 and 5-year-old monoculture system is higher compared to the 29 and 30-year-old secondary vegetation of the enrichment system (Fig.4), which indicates a strong competition for K uptake between the spontaneous vegetation and the planted trees in the plantation system III.

The K content located in the litter layer increased from 1995 to 1996 in the monoculture system, whereas only small amounts of K are located in the litter layer of the plantation system III (Fig.4). This is caused by an improved litter decomposition in the enrichment system compared to the monoculture, which also indicates that even after 5 years the K supply of the monoculture system is not stabilized (comp. also SHIFT project ENV 52).

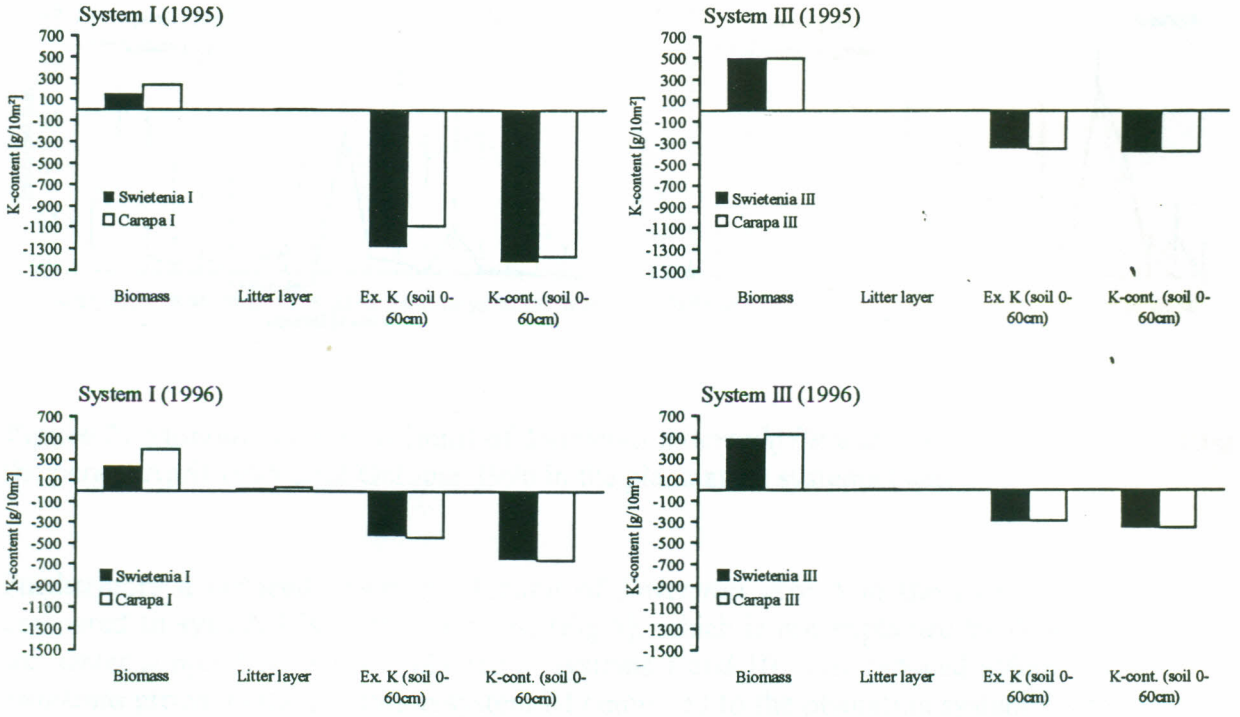

Figure 4: K stocks [g/10m²] located in the biomass, the litter layer and the soil (exchangeable K, total K content) of the plantation systems I and III in December 1995 and December 1996.

Xylem production of plantation grown Swietenia macrophylla and Carapa guianensis

As to study the significance of the water and K supply for the cambial growth dynamics of the trees the monthly increment of the trees was compared with the water and K supply within the plantation systems.

The quantification of the water supply in the plantation systems I and III showed that the seasonal variation of the precipitation causes a strong reduction of the soil water supply from August until December. The intraannual cambial growth dynamics of *Swietenia*, expressed in terms of monthly increment (Fig.5) shows a corresponding decrease of the rate of cambial cell divisions or even a cambial dormancy during this period.

In contrast to that no correlation was found between the reduced soil water content from August to December and the cambial growth periodicity of plantation grown *Carapa* (Fig.5). This indicates that wood formation of *Carapa* is less influenced by drier periods than wood formation of *Swietenia*.

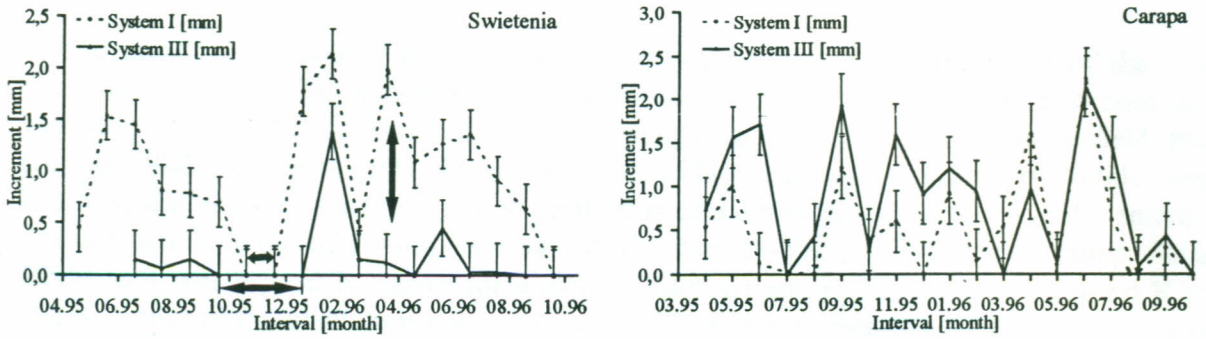

Figure 5: Monthly increment [mm] of *Swietenia macrophylla* and *Carapa guianensis* during the period April 1995 until October 1996 in the planatation systems I and III.

Furthermore a reduced xylem production of *Swietenia* grown in the plantation system III compared to system I is of main interest (Fig.5), which is not explained by differences in the soil water supply between the plantation systems I and III. The reduced xylem formation of *Swietenia* grown in the plantation system III compared to the plantation system I is caused by a reduced rate of periclinal cell divisions during the growing season and a reduced period of cambial cell divisions. The period of cambial cell divisions of Swietenia grown in system I lasts from December until Oktober, whereas cambial cell divisions of Swietenia grown in system III only were observed from January until September. The reduced xylem production of *Swietenia* in system III is correlated with the reduced K content of the soil of the 4-year-old plantation system III compared to system I (comp.Fig.4). This is a hint for a high sensitivity of the wood formation of Swietenia to low K supply. This is caused by the high specific K demand of this tree species.

In contrast to that no significant correlation was found between the K content of the soil and the monthly increment of *Carapa* grown in the plantation systems I and III indicating a lower sensitivity of the cambial growth dynamics of *Carapa* to a reduced K supply as well.

Discussion and Conclusion

The investigation of environment-tree growth relationships of plantation grown *Swietenia macrophylla* and *Carapa guianensis* showed that the site factors water supply and K supply are of main importance for sustainable growth in plantation systems on degraded land areas of the Central Amazon.

The water balance of areas without the dense and diverse vegetation of primary forests (comp. Preisinger et al. 1994) is completely different from natural site conditions of the tropical rain forest (comp. Klinge 1976, Whitmore 1993, Junk 1997). Due to shorttime changes between water saturated soil conditions with high water runthrough (comp. Schroth et al. 1998) and periods with high evaporation and transpiration rates (comp. Kramer 1985, Lyr et al. 1992, Müller 1998) in plantation systems, shorttime periods with plant water stress might occur even during the rainy season. This might cause significant alterations of the cambial growth dynamics of plantation grown trees compared to primary growth due to the significance of the water supply for wood formation (comp. Zimmermann 1983, Fritts et al 1991, Kozlowski et al. 1991, Dünisch et al. 1995, Larson 1995, Junk 1997).

The element supply with P and K is a growth limiting factor in many areas of the Central Amazon (Klinge 1976, Sanchez 1982, Lambrecht 1986, Bruenig 1997). The role of the vegetation in primary forests for the element cycling is emphasized in many field studies (Jordan 1982, Whitmore 1993, Fernandes et al. 1997). Especially for the very mobile element K a high absorbance capacity of the vegetation is of main importance as to avoid element loss due to K leaching out of the soil, especially during the first years of plantations (comp. Schmidt 1996) as it was especially shown for a monoculture system in this study. A balanced K input and K output of the plantation systems is also of main importance due to the significance of K for the cambial cell development of trees (comp. Kleinig and Sitte 1992, Dünisch et al. 1998).

The comparison of two different plantation systems (monoculture system, enrichment system) of the same age in this study showed, that the water supply and the K supply of the trees can be stabilized by management practices (comp. Lambrecht 1986, Bruenig 1997). This confirmed that flux measurements of site factors such as the water and mineral element supply are the basis for the evaluation of the sustainabilty of tree growth in plantation systems (comp. Beck et al. 1998, Zech et al. 1998).

The study also showed that the cambial growth dynamics of *Swietenia macrophylla* is strongly influenced by the soil water and mineral element supply of the soil (comp. Coster 1927), whereas wood formation of *Carapa guianensis* reacts less sensitive to changes in the water and K supply (comp. Breitspecher and Bethel 1990). From these findings we conclude that *Carapa guianensis* is more competitive for sustainable growth on this site compared to *Swietenia macrophylla*.

This indicates that the growth dynamics of tree species with a similar wood charateristic (*Swietenia macrophylla/Carapa guianensis*) can significantly differ (comp. Gottwald 1961, Dahms 1989) and the selection of suitable tree species for high quality timber production in plantation systems is of main importance for the sustainability of the plantation. Therefore investigations on the structural dynamics of plantation grown trees (comp.Bendtsen 1978, Zobel 1985, Harzmann and Müller 1987, Bhat et al. 1989, Schuster 1996) have to be carried out in combination with studies on the growth dynamics of the trees (Vetter 1995, Worbes 1995, Junk 1997) as to judge the sustainability of plantation systems from the ecological and economic point of view.

(This study will be published in 1998 in the Proceedings of the 3rd SHIFT-Workshop, Manaus).