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

(SHIFT-project ENV 42)

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Annual report 1995

Introduction

These investigations on growth and wood formation of native tree species of Central Amazonia are part of the development of sustainable landuse systems in this area at the CPAA/EMBRAPA, Manaus. In agricultural systems a small portion of trees for high quality timber production could be of ecological and economic value as well for the landscape development in the Manaus region. Especially for the recultivation of degraded land areas a small portion of longliving trees for high quality timber production might contribute to the stabilization of agroforestry systems. Therefore in recent years the CPAA/EMBRAPA (Dr. L. Gasparotto, C. de Azevedo, R. de Lima, E. Neves) extended its work to studies on growth of forestry tree species on degraded land areas.

For most of the tree species used for timber production in the Manaus region only few informations on growth and site demands for high quality timber production are available. Therefore in this project the influence of site conditions of degraded land areas on growth and wood formation of 8 selected native tree species will be investigated. Due to the specific site conditionns of degraded land areas the investigtions will be carried out with special reference to the mineral element (comp. SHIFT-project Prof. Dr. Lieberei, ENV 23) and water supply (comp. SHIFT-project Prof. Dr. Zech, ENV 45) of the trees. These investigations should give some practical help for the selection of tree species and management practices for high quality timber production in agroforestry systems.

Experimental

The influence of abiotic site conditions on growth and wood formation of up to 8 different native tree species (*Swietenia macrophylla*, *Carapa guianensis*, *Cedrela odorata*, *Dipterix odorata*, *Hymenea courbaril*, *Ceiba pentandra*, *Virola surinamensis*, *Tabebuia heptaphylla*) will be investigated in 3 different plant systems.

System 1: Monocultural system (installed by CPAA/EMBRAPA in January, 1992)
System 2: Enrichment of a 25 years old secondary forest with the species mentioned above (installed by CPAA/EMBBRAPA in January, 1992)
System 3: Mixed agroforestry system (system 4) of the field experiment installed by CPAA/EMRRAPA and Hamburg University in February 1993 (ENV 23)

As to have the chance to compare the results of the project with the investigations carried out on plants for fruit production in agricultural systems (SHIFT-projects ENV 23 and ENV 45), in the subsequent investigations (1)-(3) and (5) partly corresponding methods are used (comp. annual report of the SHIFT projects ENV 23 and ENV 45):

(1) Important abiotic site factors (temperature, air humidity, suction force of the soil, element supply of the soil, wet deposition) will be characterized in all plant systems (comp. methodological approach used by Dr. G. Schroth, ENV 45).

(2) Height growth and stem diameter of the trees are quantified in 6 month intervals by C. de Azevedo and R. de Lima (CPAA/EMBRAPA).

The tree biomass and the biomass of different tree compartments (roots, stem, branches, leaves etc.) will be quantified for all species in one year intervals.

Investigations on the variation of these parameters within different plots are carried out in cooperation with the University of Curitiba (PhD.-thesis E. Neves, Prof. Dr. Reissmann). From these data the net biomass production per year of the trees will be calculated. For all experimental plots litterfall will be quantified in one week intervals.

(3) For corresponding tree compartments the element content and the element distribution within the tissue will be investigated on a subcellular level as to characterize physiological sinks for mineral elements within the tree. From these data and the corresponding biomass of the tree compartments the net element uptake per tree and year will be calculated.

The variation of the element content of the trees between different experimental plots is investigated in cooperation with E. Neves and Prof. Dr. Reissmann (CPAA/EMBRAPA; University of Curitiba).

(4) The influence of the abiotic site factors mentioned above on wood formation will be characterized in one month intervals by time series analysis (Pin-marker technique, correlation analysis). From these data response functions to environmental influences on wood formation will be calculated for different plant systems.

(5) Investigations on the water uptake and water transport of the plants will be carried out under soil culture and field conditions. From these investigations a calibration of the Granier-method (xylem sap flow measurements) for the species investigated will be expected. This offers the chance to quantify xylem sap flow in the field in the future (investigations are carried out in combination with SHIFT project ENV 45, Dr. GG. Schroth).

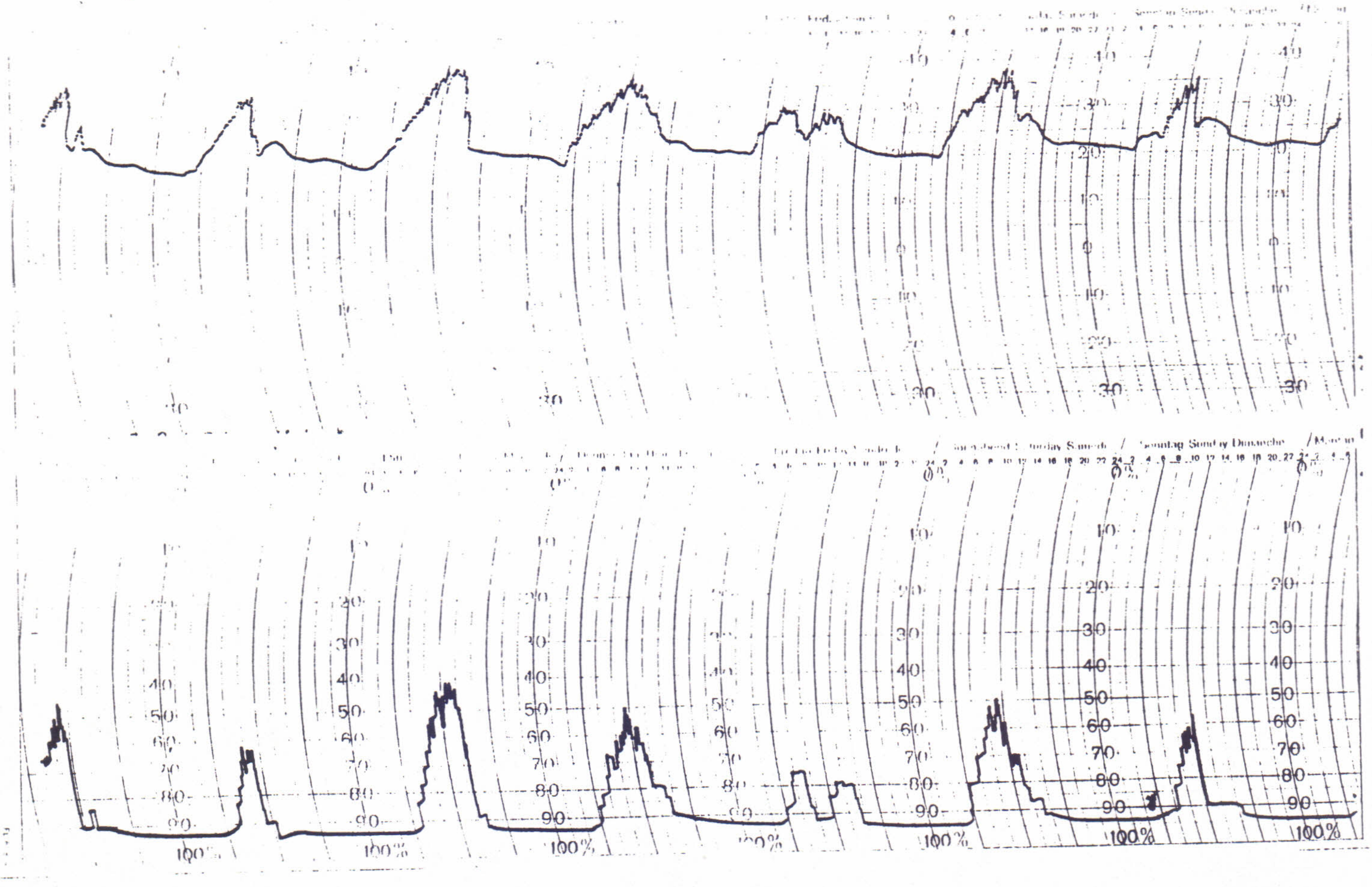
Present state of the investigations

All experimental plots could be used for the investigations mentioned above also in the future. Only a few plants (especially *Swietenia*) died due to fungi and insect attack. Management of the plant systems 1 and 2 is carried out by the CPAA/EMBBRAPA (coordination: Dr. L. Gasparotto, scientists: C. de Azevedo, R. de Lima, field workers: Valdez, Beto) and runs well. Management of the plant system 3 is carried out by the CPAA/EMBRAPA and the SHIFT-projects ENV 23, ENV 45, and ENV 42.

(1) Instruments for the characterization of abiotic site conditions are installed in all 3 plant systems. The last installations of suction cups in a depth of 60cm will be carried out in May 1996. Since July 1995 data are availble for plant system no.1, 2 and 3 in one week intervals.

The meteorological parameters measured in all 3 plant systems indicate strong microclimatical differences between the 3 systems (Fig.1). The diurnal variation of temperature and air humidity is strongly reduced in the plant systems 2 and 3 compared to the monocultural system (system 1). This might be of some evidence for the water and element uptake of the trees as well. The influence of these microclimatical differences on wood formation of the trees will be studied in 1996 and 1997 in more detail.

Plant system 1



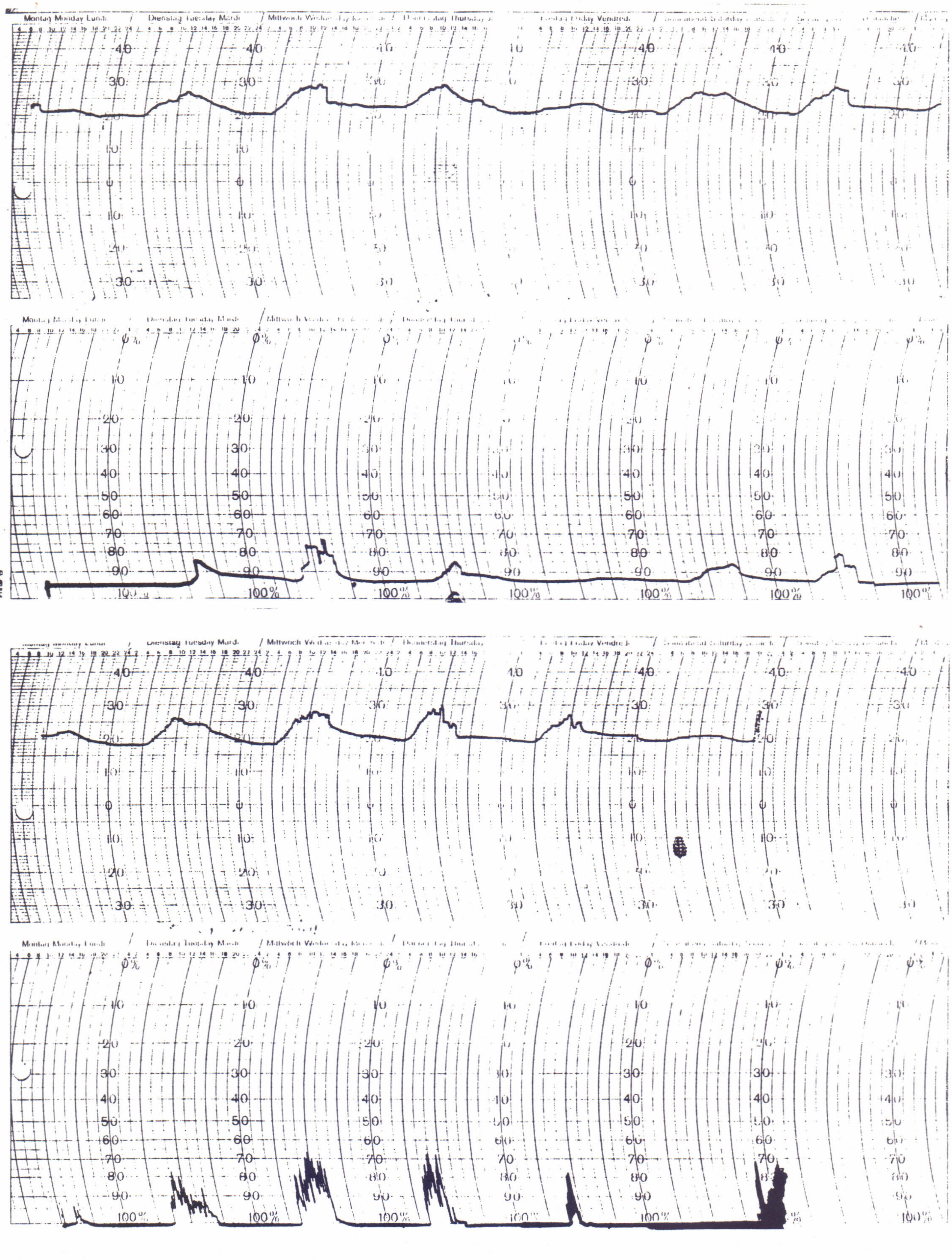


Fig.1: Diurnal variation in air temperature and air humidity in the plant systems 1, 2 and 3 for the experimental period from March 11 to March 17, 1996.

The element content within the soil solution is influenced by the tree species and the plant system as well (comp. Table 1). In all experimental plots the P-, K-, and Mg-supply seems to be of main importance for tree growth. Only small amounts of these macronutrients could be detected in the soil solution. High amounts of nitrate and only small amounts of ammonia could be found in all pant systems, which indicate a strong nitrification within the soil of all experimental plots. Highest N-contents could be registered for *Hymenea* whereas the K-content within the soil solution of all *Hymenea* plots was fairly low. This might be caused by a strong K-uptake of *Hymenea* trees or a stronger leaching effect for K in these plots.

Data on the element content of the litter layer of the soil indicate that only a few amount of K and P are stored in the litter layer, whereas the Ca-content is fairly high (except litter layer of *Dipterix* plots). The element input into the plant systems due to annual rainfall might contribute only to a small amount to the element demand of the plantation systems.

Table 1: Element content of the litter layer, the soil solution (soil depth 20cm) and of rain water of the plant systems 1 and 2 for *Swietenia (Sw), Carapa (Ca), Cedrela (Ce), Dipterix (Di), Hymenea (Hy), Ceiba (Cei), Virola (Vi), Tabebuia (Ta)*, cover crops *Pueraria* and *Homolepis*, and the secondary vegetation of plant system 2 (capoeira).

Litter layer mg/kg	**Art**	**Al**	**Ca**	**Fe**	**K**	**Mg**	**P**	**S**	**C**	**N**	**C/N**
Area I											
1	**Ca**	0,66	56,70	0,15	2,02	8,09	1,08	3,69	44,60	1,24	35,90
1	**Di**	1,20	7,94	0,33	3,22	0,83	0,75	4,18	49,70	1,49	33,30
1	**Hy**	3,27	22,00	0,61		1,73	1,30	3,29	49,20	1,38	35,60
1	**Sw**		85,70	0,31		3,99	0,61	5,19	45,20	1,15	39,30
1	**Pueraria**	1,55	55,30	0,29	0,30	5,96	0,21	6,14	41,70	1,19	35,00
1	**Cei**	6,07	41,80	1,01		8,23	2,00	1,82	45,40	1,44	31,60
1	**Ta**	1,55	28,20	0,41		5,61	0,95	3,44	45,00	1,32	34,00
1	**Vi**	2,20	27,80	0,37		17,00	1,32	3,71	47,70	1,23	38,80
1	**Homol.**	4,08	10,90	0,74	1,80	5,18	1,01	2,71	41,90	1,56	26,90
Area II											
2	**Ca**	0,58	44,60	0,13	3,12	8,18	0,81	5,37	42,10	1,27	33,20
2	**Ce**	2,23	23,90	0,34		4,79	0,67	3,41	45,30	1,41	32,20
2	**Di**	1,78	22,30	0,21	0,37	2,21	1,01	4,54	48,10	1,64	29,30
2	**Capoeira**	4,97	25,60	0,42		5,10	0,82	5,29	46,20	2,05	22,50
Soil solution mg/l		**Al**	**Ca**	**Fe**	**K**	**Mg**	**Cl**	**NO3**	**PO4**	**SO4**	**NH4**
Area I											
1	**Ca**		3,04		1,45	1,27	1,29	4,18		4,17	
1	**Ce**		3,74		1,42	1,46	0,92	11,53	0,32	2,40	0,05
1	**Di**		3,74		1,60	1,35	1,18	6,60	0,30	2,01	
1	**Hy**		5,46		0,91	1,66	1,13	17,30		2,01	
1	**Sw**		3,62		1,03	1,49	0,96	9,60		2,58	0,23
1	**Cei**		2,34		1,22	0,85	1,43	4,52	0,25	1,91	0,31
1	**Ta**		4,40		1,05	1,96	1,18	11,27		2,31	0,11
1	**Vi**		3,47		1,75	1,39	1,06	13,38		2,08	0,07
Area II											
2	**Ca**		4,83		0,95	1,54	1,60	8,68		1,91	0,18
2	**Ce**		4,72		1,58	1,90	1,58	7,16	0,11	3,51	0,21
2	**Di**		2,50		1,31	1,21	1,18	9,24	0,24	2,60	0,47
2	**Hy**		4,17		1,09	1,96	5,48	12,74	0,55	1,08	0,22
2	**Sw**		3,05		0,87	1,03	1,07	3,45		1,31	0,78
Precipitation mg/l			0,26		0,92	0,06		1,60		1,98	0,11

(2) The total tree biomass of a tree was quantified for all tree species investigated in March/April 1995 and in December 1995 (Fig. 2). The biomass production of the trees varied under identical site conditions up to a factor of 1 (*Virola surinamensis*) to 12 (*Ceiba pentandra*). The variation of the biomass production of the trees in the different plant systems was up to a factor of 1 (system 2) to 30 (system 1) for *Hymenea courbaril*. In plant system no.1 only small differences in the rank of the tree biomass of the tree species could be observed between March/April 1995 and December 1995. In contrast to that in plant system no.2 a significant change of the biomass distribution within the tree and the rank of the biomass of the trees could be observed in December 1995 compared to March/April 1995. This indicates a strong interaction between the secondary vegetation and the planted trees in system no.2, whereas the biomass production of the trees is still stronger influenced by genetic factors in system no.1. As to get some informations on the influence of the secondary vegetation on the plant systems, informations on the structure and mineral element supply of selected species of the secondary vegetation are carried out by Ronaldo da Silva (financial support of the work by the CNPq, Brasilia) in cooperation with the SHIFT-project ENV 23 (Dr. H. Preisinger).

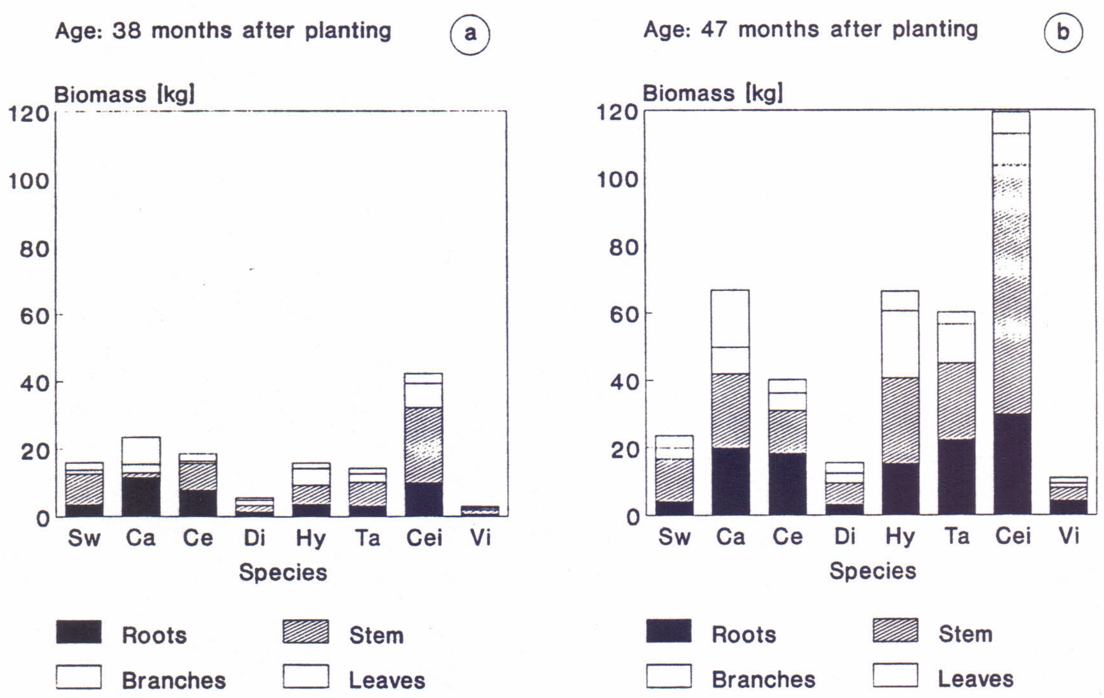


Fig.2: Biomass [kg] of roots, stem, branches and leaves of *Swietenia macrophylla*, *Carapa guianensis*, *Cedrela odorata*, *Dipterix odorata*, *Hymenea courbaril*, *Ceiba pentandra*, *Virola surinamensis*, *Tabebuia heptaphylla* grown in system no.1 38 month (a) and 47 month (b) after plantation.

Significant differences in the biomass distribution within the tree could be observed between the different tree species. A high amount of the total tree biomass of *Swietenia, Dipterix* and *Ceiba* are located in the stem, whereas a higher amount of the tree biomass of *Carapa, Cedrela, Hymenea* and *Virola* is located in the roots and the crown (e.g. 47 month after planting: although the total tree biomass of *Carapa* is twice as much compared to *Swietenia*, Swietenia produced a similar absolute amount of stem biomass compared to *Carapa*). This is of main importance for the economic value of the tree with regard to timber production.

(3) For the mineral element supply of the trees, the element content of leaves (assimilaton) and roots (element uptake) serves as a good indicator (comp. Table 2). First results indicate that in general a high amount of P, K, Ca, and Mg is located in the tree biomass compared to tree species grown in temperate zones. The element content of leaves and fine roots varied between the tree species investigated and for one tree species between the plantation systems as well. First results indicate a high demand for P and K for the tree species *Carapa* and *Cedrela*, whereas the P- and K-content of leaves and roots of *Swietenia* and *Dipterix* were fairly low. The secondary vegetation of plant system no.2 has a strong impact especially on the P- and K-supply of these two species.

Table 2: Element content [mg/kg] of leaves and fine roots of *Swietenia (Sw), Carapa (Ca), Cedrela (Ce), Dipterix (Di), Hymenea (Hy), Ceiba (Cei), Virola (Vi)*, and *Tabebuia (Ta)* grown in plant system 1 and 2. Sample collection March/April 1995.

Leaves mg/kg		**Al**	**Ca**	**Fe**	**K**	**Mg**	**P**	**S**	**C**	**N**	**C/N**
Area I	**Art**										
1	**Ca**		16,10	0,07	28,10	4,45	4,26	8,65	46,80	1,97	23,70
1	**Ce**	4,17	29,40	0,88	41,80	4,24	4,10	6,90	45,00	2,62	17,10
1	**Di**	0,53	14,40	0,16	23,80	3,39	3,61	4,00	47,90	2,08	23,00
1	**Hy**	0,34	20,60	0,18	23,50	3,46	3,56	4,07	48,70	2,43	20,10
1	**Sw**		20,80		37,00	2,99	2,11	4,76	46,20	1,32	35,00
1	**Cei**	2,22	31,40	0,54	33,70	12,10	3,22	4,08	43,60	2,38	18,30
1	**Ta**	0,28	21,40		31,20	4,92	3,57	5,24	45,00	2,23	20,20
1	**Vi**		22,40		0,63	6,62	1,21	2,08	48,10	1,30	36,90
Area II											
2	**Ca**		17,40		35,50	7,00	3,17	7,15	46,50	1,74	26,70
2	**Ce**	2,46	31,70	0,45	33,90	5,68	3,25	7,55	44,50	2,12	21,00
2	**Di**		6,17		8,78	2,66	2,88	6,50	47,80	2,64	18,10
2	**Hy**		14,60	0,06	24,10	3,15	2,90	4,26	49,10	2,46	19,90
2	**Sw**	0,29	42,90	0,14	13,50	6,61	1,73	8,38	46,30	1,59	29,20
Fine roots mg/kg											
Area I											
1	**Ca**	46,10	35,40	7,68	18,90	6,47	3,24	2,63	39,00	0,97	40,20
1	**Ce**	129,00	19,60	22,40	26,10	6,83	2,70	5,07	32,40	1,50	21,70
1	**Di**	51,40	13,00	8,77	2,64	1,51	2,80	0,52	39,80	1,11	35,80
1	**Hy**	16,30	15,90	2,53	9,00	1,29	1,52	4,12	48,60	0,98	49,40
1	**Sw**	68,50	9,00	11,00	19,80	1,83	1,95	2,54	39,10	0,98	39,70
1	**Cei**	24,70	13,70	4,03	13,70	6,22	0,89	2,23	46,30	0,89	52,30
1	**Ta**	43,00	13,50	7,45	33,40	4,61	1,25	2,27	43,90	0,73	60,10
1	**Vi**	50,20	6,74	8,32	32,30	8,43	1,77	3,70	40,00	1,26	31,70
Area II											
2	**Ca**	45,80	20,40	7,22	9,67	4,62	1,24	2,81	40,20	0,96	41,90
2	**Ce**	39,20	8,70	5,91	19,50	6,37	1,35	6,78	42,20	1,32	31,90
2	**Di**	93,30	26,30	12,70	5,90	7,02	1,42	5,06	36,00	1,32	27,20
2	**Hy**	27,50	14,70	4,23	3,00	1,86	0,57	4,46	46,10	0,89	51,70
2	**Sw**	44,40	11,40	6,45	6,23	2,01	1,14	2,97	43,50	1,12	38,80

These results also indicate differences in the uptake and transport within the tree of mineral elements between the tree species investigated. This especially becomes obvious comparing the Al-content of leaves and roots of the trees. Al, which shows a strong antagonism to other mineral elements (e.g. Ca, Mg) is taken up by *Cedrela* and *Ceiba* and is also transported to the leaves, whereas in all other species probably no transport of Al from roots to leaves takes place. Due to the high amount of Al within the soils investigations on differences in the uptake of Al between different plant species are of main importance with regard to the management of mixed plantation systems. These investiations are extended by Ronaldo da Silva (financial support by the CNPq, Brasilia) to important tree species of the secondary vegetation (cooperation SHIFT-project ENV 23, Dr. H. Preisinger).

(4) Since March 1995 wood formation of 4 trees of each species in each plant system is dated in one month intervals by means of pin marker technique. The suitability of the method for the species investigated was proven by light microscopy. The method could be used for all species investigated, but best results were obtained for *Swietenia* and *Ceiba* due to a high sensitive wound reaction. For the study of exogenous influences on wood formation longer time series are necessary. Therefore first results based on correlation analyses could be expected in 1997. Some qualitative observations obtained for *Swietenia* and *Carapa* indicate a strong influence of site conditions to structural dynamics in wood formation.

(5) Under soil culture conditions the water uptake of 7 out of 8 species was quantified under maximum water supply (water saturation of the soil; Table 3). The water uptake of the plants was not strongly correlated with the biomass of the plants. A comparison of the water uptake of the plants under greenhouse conditions and the suction force of the soil in the experimental system no.1 by rank analysis, indicated a similar result for the water consumption of the soil cultured plants and the trees in the field (except *Tabebuia*). In contrast to that the tree species investigated showed a different behaviour in water uptake during the dry season (different rank of the suction force of the soil within the plots during the dry season and the water uptake of the soil cultures), which indicates a different sensitivity of the species to dry seasons. The water uptake of the plants was not correlated with the maximum hight of xylem sap flow (Table 3). This shows, that besides the sap flow velocity the conductive xylem is of main importance for the quantification of the water uptake of the trees. The conductive xylem will be quantified by wood anatomical studies in 1996.

Tab.3: (1.1) Average suction force of the soil [hPa] in a depth of 20cm in the experimental plots of system no.1 during a dry season (20.7.-26.10.1995) and a wet season (27.10.-18.1.1996). (1.2) Maximum hight of xylem sap flow / 1h [cm] of trees of system no.1 cut 17.1./18.1.1996 (48 month after plantation). (2.1) Average water uptake / plant / day [ml] of 6 month old plants under greenhouse conditions.

1. Field experiments								
1.1 Average suction force of the soil in a depth of 20 cm [hPa]								
Period	**Swietenia**	**Carapa**	**Cedrela**	**Dipterix**	**Hymenea**	**Tabebuia**	**Ceiba**	**Virola**
Dry season								
July 20 to Oct.26, 1995	-241	-251	-176	-192	-285	-213	-211	-148
Rank	**3**	**2**	**7**	**6**	**1**	**4**	**5**	**8**
Wet season								
Oct.27 to Jan.18, 1996	-42	-37	-47	-37	-42	-34	-49	-40
Rank	**3/4**	**6/7**	**2**	**6/7**	**3/4**	**8**	**1**	**5**
1.2 Maximum hight of xylem sap flow / 1h [cm]								
Date/time	**Swietenia**	**Carapa**	**Cedrela**	**Dipterix**	**Hymenea**	**Tabebuia**	**Ceiba**	**Virola**
Jan.17 / Jan.18, 1996								
9:30-10:30 AM	129	78	210	81	57	39	186	42
Rank	**3**	**5**	**1**	**4**	**6**	**8**	**2**	**7**
2. Soil cultures								
2.1 Average water uptake / day / plant of 6-month-old plants under greenhouse conditions [ml]								
Period	**Swietenia**	**Carapa**	**Cedrela**	**Dipterix**	**Hymenea**	**Tabebuia**	**Ceiba**	**Virola**
June 6 to June 23, 1995								
Nov.29 to Dec.19, 1995	99	44	153	51	113	58	151	
Rank	**4**	**7**	**1**	**6**	**3**	**5**	**2**	

These preliminary results indicate, that growth and wood formation are strongly influenced by genetic factors. Nevertheless the strong variation of tree growth of the same tree species in different plantation systems indicates, that side conditions have a strong influence on tree growth as well. This offers the chance to improve tree growth and wood quality by management practices.

Appendix

Investigations on parameters suitable for predicting wood quality of plantation grown Andiroba trees

Within the SHIFT-project ENV 42 the influence of different site conditions on tree growth and wood formation of 8 native tree species (*Swietenia macrophylla, Carapa guianensis, Cedrela odorata, Dipterix odorata, Hymenea courbaril, Ceiba pentandra, Virola surinamensis, Tabebuia heptaphylla*) is studied since January 1995. The aim of these investigations is to get informations about growth patterns of the trees as to include promissing native tree species for high quality timber production within agroforestry systems.

Besides the ecological stability of plantation systems the economic success of plantations is of main importance in the long run. Especially for longliving trees the quality of the timber is important for the selection of tree species included in agroforestry systems from the economic point of view. Therefore a prediction of wood quality of younger plantations for the future would be an interesting tool for plantation management. Therefore in a first attempt Florian Schuster (Master student at the Institute of Wood Biology, Hamburg University) tried to evaluate parameters suitable for predicting wood quality of plantation grown Andiroba trees.

During a 5 week stay at the CPAA/EMBRAPA in November/December 1995 he collected wood samples of eight 4 year old planted Andiroba trees from the SHIFT experimental field of CPAA/EMBRAPA, 2 older plantations 40 km north of Manaus and 2 trees from old growth Andiroba from a primary forest.

At our Institute of Wood Biology, Hamburg University, he compared wood anatomical parameters (formation of growth rings, fiber length, distribution of cell types within the xylem, vessel size etc.) and technological parameters (density profiles from pith to bark, modulus of elasticity) of these trees. First results indicate that structural parameters of plantation grown Andiroba from the SHIFT experimental field after a couple of years reach a similar level as it could be observed at old growth Andiroba. This gives some hints, that wood quality of planted Andiroba trees expected for the future might be similar to wood quality of natural stands from the structural point of view. From these investigations no informations about the chemical durabilty of the timber are available. Nevertheless these are promissing results for the growth of Andiroba in planted systems. Florian Schuster will finish his thesis in September 1996. We hope we can extend these work to other tree species mentioned above (Celso de Azevedo will continue this work with Ceiba trees in September 1996 during his stay at Hamburg University).