Der Tropenlandwirt, Beiträge zur tropischen Landwirtschaft und Veterinärmedizin,
96. Jahrgang, Oktober 95, S. 225 - 239.

Shoot Biomass of Natural Stump Regrowth in Cropping Systems in the Subhumid Forest Savanna Mosaic Zone of West Africa.

Andreas Böhringer*, Dietrich E. Leihner* and Reinhard Böcker**

Key words: site restoration, bush-fallowing, natural stump species, stump regrowth.

Abstract

A rapidly growing population calls for intensified cropping in the region, endangering the ecological and economic success of traditional bush fallowing which depends on a site specific balance of crop and fallow components in space and time. Research has hence given trees and shrubs a key role in ecosystem conservation as well as in increasing crop yields, yet the contribution of naturally occurring stumps to shoot biomass turn-over in farmers' fields has not been evaluated with respect to its agroforestry potential. The regrowth and productivity of natural stump species was therefore studied in different cropping systems and environments in southern Bénin and compared to exotic agroforestry trees. In fields where negative impacts of land-use on natural vegetation, such as burning and weeding, was still moderate, 32 stump species with densities of 0.0315 m^2 were recorded contributing a total of 14.2 g m^2 shoot dry matter after 285 days of regrowth. By renouncing burning and selective weeding, number of stump species increased to 36 in the subsequent year, producing 98.8 g m^2 total shoot dry matter at densities of 0.086 individuals m^2. In particular, species of the mature forest such as *Albizia* species, *Baphia nitida*, *Lecaniodiscus cupanoides*, *Morinda lucida*, and *Rauvolfia vomitoria* responded favorably to protection, contributing not only significant amounts to shoot biomass turnover, but also being much more efficient in accumulating biomass than exotic agroforestry species such as *Gliricidia sepium*. Neither NPK-fertilization nor planting of fast growing exotic tree species influenced natural stump growth and productivity in any significant way. The preservation and management of natural stumps between crops represents therefore an economic agroforestry option worth consideration in the future. This would simultaneously help to conserve the mul-

* Institute of Plant Production in the Tropics and Subtropics and Institute of Plant and Landscape Ecology, University of Hohenheim, PF 700562, D-70593 Stuttgart, Germany

** Institute of Plant and Landscape Ecology, University of Hohenheim, PF 700562, D-70593 Stuttgart, Germany

Correspondance Address: Dr. A. Böhringer, Universitas Bangkalan, Jl. Telang Raya, P.O. Box 2 Kamal, Bangkalan- Madura, Indonesia; Tel.: 031-91146, Fax: 031-91506

tiple products and services of these stump species to man as well as preserve the functioning of the natural ecosystem in the region.

1 Introduction

Bush-fallow rotations are still the predominant land-use system in West Africa, and are traditionally managed in such fashion that the transition from cultivation to fallow is indistinct and gradual, with plant populations oscillating between peak densities of crops and trees (AWETO, 1981; BROWN & LUGO, 1990; CLAYTON, 1958; HALL & OKALI, 1979; HART, 1980; MOSS & MORGAN, 1991). Crop and tree populations rarely reach zero at any time in the cycle, because crop volunteers and useful trees are always protected (FLOQUET & AGLI, 1993; MOSS & MORGAN, 1977; UNRUH, 1988). Even when bush fallows mature to become sizeable secondary forests they are managed by man to provide a multitude of products and benefits for the livelihood of the farming family (BRAND, 1976; FLOQUET & AGLI, 1991; HUTCHINSON & DALZIEL, 1954-1972; JOHNSON & JOHNSON, 1976; OKIBO, 1977; SOFOWORA 1982). Farmers in West Africa today reduce the tree component in time and space with increasing demographic pressure, offsetting the precarious balance between trees and crops in traditional bush-fallowing which has been instrumental to the ecological and economic stability of the system (EWEL, 1986; KANG et al., 1990; LEIHNER et al., 1993; MOSS & MORGAN, 1977). This process currently degrades secondary forests to savanna, owing to intensified burning, weeding, tree cutting and destumping in fields (CLAYTON, 1958; KELLMANN, 1980; SANFORD & ISICHEI, 1986; UHL et al. 1982; UNRUH, 1988). With the progressive disappearance of secondary forests, their products and services to man are also lost, exacerbating in turn human pressure on few remaining primary forests (BROWN & LUGO, 1990). Nutrient restoration during fallowing depends on a rapid re-establishment of woody vegetation, and soil degradation under intensified cropping on derived savanna-sites is common and develops often rapidly (AWETO, 1981; MOSS & MORGAN, 1977; SANFORD & ISICHEI, 1986). Derived savanna may revert quickly to secondary forest, providing protection from fire and tree cutting (LAMOTTE, 1975; MACGREGOR, 1937 after CLAYTON, 1958; MENAUT & CESAR, 1982), and a sufficient seed bank for recolonization (UHL et al., 1982). The efficiency of site restoration has been shown to rely on the rapid establishment of a dense root system in fallow vegetation and on promoting forest over savanna species to increase the biomass productivity of the agroecosystem (MOSS & MORGAN, 1977). Unruh (1988), proposed the early establishment of woody, successional species in farmers' fields to be an effective mechanism in site recovery which, according to Clayton (1958), can be fostered by conserving ample stumps, suckers and woody seedlings between crops. Trees and shrubs are thus given a key role in site recovery and ecosystem conservation as well as in the development of more productive, yet ecologically sound, cropping systems of the future (EWEL, 1986; HART, 1980; KANG et al., 1990; LEIHNER et al., 1993). As mentioned in the beginning, farmers in West Africa do protect certain tree species during times of more intensive cropping, but their numbers and composition are not based on the biomass productivity of tree species but rather on social, cultural and economic preferences of individual land owners (BRAND, 1976; JOHNSON & JOHNSON, 1976; OKIBO, 1977). Yet, in regions where land pressure is exceptionally high, trees in crop land have already been noted for reasons of faster site recovery and soil fertility maintenance (BÖHRINGER et al., in print; FLOQUET & AGLI, 1991; KANG et al., 1990). Current agricultural research in the region focusses also on the development of highly productive agroforestry systems that combine crops and trees in space and time. Most research, however, evaluated only fast-growing, exotic tree species, and the contribution of natural stump regrowth to shoot biomass turn-over in farmer's fields has not been looked at from an agroforestry perspective (KANG et al., 1990; LEIHNER et al., 1993).

Since mixed cropping is predominant in West Africa (LEIHNER et al., 1993), it was hypothesized that after the harvest of one crop, considerable space often remains unused in farmers' fields which could be quickly taken up by regrowth of natural stumps, if they are protected at subsequent weedings. This could not only recycle considerable amounts of shoot biomass to the system, but should also help in conserving woody fallow vegetation per se. Yet, species composition of natural stumps and their biomass contribution from shoot regrowth has not been quantified in agricultural ecosystems. The objectives of this study were therefore: (1) to identify natural woody species with good regrowth and their occurrence in mixed cropping; (2) to quantify their contribution to shoot biomass in different cropping systems and (3) to compare their productivity to fast-growing, exotic tree species. Three typical bush-fallows were cleared in 1991 and large-scale experiments with a cassava-maize intercrop were planted. The regrowth of natural stumps was studied from maize to cassava harvest in five different cropping systems and in three agrosystems in southern Bénin.

2 Site description

The study was conducted at three village locations, situated between longitude 2° and 3° E in the provinces of Atlantique and Zou in the south of the Republic of Bénin/Westafrica. Houeto has a latitude 6°27'N and an altitude of 20 m a.s.l., Attotinga 6°41'N and 82 m, and Aguagon 7°58'N and 190 m, respectively.

Total annual rainfall and mean monthly temperature for nearby weather stations of the three sites, averaged over the last 20 years ranged from 1099 to 1244 mm and from 28.4 to 28,6°C, respectively. Rainfall distribution changes from a bimodal at Houeto and Attotinga, with significant precipitation from March to July and from September to November, to a unimodal at Aguagon (March to October).

Soils at Houeto and Attotinga derived from late eocene clayey sandstones and are classified as Ferrali-Haplic Acrisols, locally known as "terre de barre". Due to overcropping, values of pH, K+ex, Ca_2+ex, CEC and C/N were much lower in the top soil at Houeto in comparison to the less depleted Acrisol at Attotinga. Soils at Aguagon developed from precambrian crystalline rocks and belong to Ferric Lixisols.

More detailed descriptions of climate and soils at the three sites were provided by Leihner et al. (1993).

The potential vegetation at Houeto and Attotinga is a subhumid semi-deciduous forest of the so-called forest-savanna mosaic zone (CLAYTON, 1958; HALL & OKALI, 1979; LAMOTTE, 1975; MENAUT & CESAR, 1982; SANFORD & ISICHEI, 1986). Elements of the savanna belong to the southern guinea-type and are favored by anthropogenic changes such as fire, land preparation and weedings (LAMOTTE, 1975; MACGREGOR, 1937 after CLAYTON, 1958; MENAUT & CESAR, 1982). Remaining primary vegetation is largely confined to regularly scattered islets, protected as sacred forests, and gallery forests, difficult to reach, dominated by species of the mature forest such as *Antiaris africana* LESCHENAULT, *Cola spp.*, *Albizia spp.*, *Diospyros monbuttensis* GÜRKE, *Triplochiton scleroxylon* K.SCHUM., *Lecaniodiscus cupanoides* PLANCH EX BENTH. and *Chlorophora excelsa* (WELW.) BENTH. The southern guinea savanna extends to latitude 7°15'N in Bénin, and Aguagon thus belongs to the northern guinea savanna dominated by tree species *Daniellia oliverii* (ROLFE) HUTCH. & DALZ., *Burkea africana* HOOK., *Vitex doniana* SWEET and *Parkia biglobosa* (JAQ.)BENTH. Prevalent grasses are *Loudetia spp.*, *Andropogon spp.* and *Hyparrhenia spp.* (MENAUT & CESAR, 1982; SANFORD & ISICHEI, 1986).

Most of the natural vegetation has been changed today into secondary regrowth by bush-fallowing (MOSS & MORGAN, 1977). The fallow vegetation, with sufficient time, may turn into a secondary forest playing an important role in serving the people with food, firewood, construction materials, feed, medicines and in restoring soil fertility, to mention just the most important functions (BRAND, 1976; FLOQUET & AGLI, 1993; JOHNSON & JOHNSON, 1976; OKIBO, 1977; SOWOFORA, 1982). In the forest-savanna mosaic zone, *Elaeis guineensis* JACQ. palms (uses: oil, alcohol & materials) are regular fallow elements, being often planted and protected during years of cropping (CLAYTON, 1958; FLOQUET and AGLI, 1991; HALL and OKALI, 1979). Other commonly protected species are *Albizia spp.* (construction), *Chlorophora excelsa* (timber), *Cola spp.* (drug), *Diospyros monbuttensis* (timber), *Dialium guineense* WILLD. (fruit & branches for aquaculture), *Parkia biglobosa* (food), and *Spondias mombin* LINN. (fruit) to mention just a few and their main uses. After several years of fallowing, fields are cleared by hand and burned. Mixed cropping is predominant in farmers' fields with main crops cultivated being maize, cassava, cowpeas, peanuts and yams (*Dioscorea spp.*).

3 Materials and methods

Approximately one hectare of uniform bush fallow land was initially selected at each site. At Houeto, the fallow vegetation was four years old, at Attotinga six and at Aguagon five years of age. All vegetation was cut at land clearing, large stems (diameters > 5 cm) and logs were removed, but all other biomass was left in the field unburned as mulch.

The land at each site was divided into 20 plots of sizes ranging between 400 m2 and 576 m2 for an agronomic experiment laid out as a randomized complete block with five treatments and four replications. Three alternative agroforestry systems were compared to annual cassava-maize intercrops without fertilizer (check) and with fertilizer applications of 9.0 N, 7.8 P and 7.4 K g m-2 every year. Agroforestry systems were: alleycropping (KANG et al, 1990) with mixed hedges of *Gliricidia sepium* JACQ.(WALP.) and *Flemingia macrophylla* (WILLD.)MERR.; a cut and carry system using zonal tree blocks and the same tree species as in former alleycropping; alleycropping with annual hedges of *Cajanus cajan* (L.)MILLSP. For a more detailed description on the five evaluated cropping systems see Leihner et al. (1993).

A mixed crop of maize and cassava was planted in rows with identical plant populations of 2.5 plants m^2 for maize and 0.8 plants m^2 for cassava in all plots. Both crops were planted together conditional to rainfall between late March and early May. Maize was weeded first at 22 days after planting (DAP) and a second time at 45 DAP. Weeding was carried out by cutting forbs and grasses at ground level with hoes and by slashing lianes and stump regrowth with cutlass. Maize was harvested by hand at 126 DAP. In 1991/92, two more weedings followed (146 and 241 DAP), whereas in 1992/93 one more weeding at 150 DAP was carried out for cassava. At all weedings after maize harvest, only grasses, forbs and lianes were cut, but all natural stumps were allowed to regrow freely. Regrowth periods for stumps from last weeding up to cassava harvest were thus 285 days in both years. Stump regrowth in the first cropping year was only measured at Attotinga, due to its natural highest species diversity in the fallow (LEIHNER et al., 1993), but also due to logistical constraints and the length of field work involved. In the following season, the study could be extended to all three sites. After cassava harvest, only natural stumps having attained plant heights above 1 m from ground were considered for the study, because the inclusion of all stumps would have been unmanageable with the available work force and also because planted agroforestry species were cut at 1 m height, too (LEIHNER et al., 1993). The underlying assumption was thus that natural stump species that reached plant heights above 1 m after regrowth would be particularly valuable from an agroforestry standpoint. Stump species were identified according to Hutchinson and Dalziell (1954-72) using the current taxonomy.

Measurements on each individual were: (1) plant height from ground [cm]; (2) number of stumps; (3) diameters of all stumps [mm]; (5) total number of resprouting shoots; (6) diameters of ten random shoots [mm]; (7) fresh matter (FM) in leaves and stems of resprouted shoots [g]. One sub-sample for each species at each site was taken: leaves and stems of several individuals were collected and combined to give 500 g fresh leaves and 800 g fresh stems. Sub-samples were later dried in the oven at 75°C for dry matter (DM) determination. Shoot DM of each individual was calculated by matching its weighed leaf and stem FM with DM fractions from the species' sub-sample.

Data were analyzed with SAS (release 6.03) using general linear models (GLM; SAS Institute Inc., 1988). For the ANOVA, all stump parameters within an agronomic plot were summed, with the exception of plant height, being averaged for all stumps. The effect of year, cropping system and interaction was analyzed in a combined ANOVA for Attotinga; for 1993, environments, cropping systems and interaction variances were analyzed by combining results from all three sites. Mean separation was carried out by using Fisher's least significant difference test (LSD; SAS Institue Inc., 1988).

4 Results

4.1 Species composition of stumps

A list of recorded species at Attotinga in both years is given in Table 1. In 1992, 32 species including three unidentified, were found, whereas 36 species were listed in 1993.

The following four species attained heights below 1 m in and were not considered again in 1993: *Cassia sieberiana* DC., *Combretum hispidum* LAWS., *Combretum paniculatum* VENT., and *Raphiostylis beninense* (HOOK f.ex. PLANCH) ex BENTH. (Tab. 1).On the opposite, nine species could be added to the list of stumps with plant heights above 1 m in 1993: *Anthocleista vogelii* PLANCH ex HOOK, *Clausena anisata* (WILLD.) HOOK f.ex BENTH., *Lonchocarpus cyanescens* (SCHUM.& THONN.) BENTH., *Millettia thonningii*, *Monodora tenuifolia* (GAERTN.)DUNAL, *Moringa oleifera* LAM., *Psidium gujava* LINN., and *Usteria guineensis* WILLD. A total of 288 individuals was counted in 1992 and 681 in 1993 (Tab. 1). In 1993, 17 species were recorded at Houeto and 8 at Aguagon (Tab. 1)

4.2 Shoot biomass contribution of stumps

The effect of the year was profound (1% level) at Attotinga for all parameters and mean separation is given in Table 2. Neither cropping systems nor interactions influenced stump growth and productivity across years. Parameters were higher throughout in the second year (Tab. 2).

In 1993, all stump parameters responded profoundly to environment (1% level), but failed to respond to cropping systems and interactions. Results at Attotinga were higher for all parameters with differences between Houeto and Aguagon being marginal in most cases (Tab. 3).

highest in shoot DM among all species, with 1610 and 1576 g plant^{-1}, respectively. But, *Dialium guineense*, *Albizia zygia* (Dc.) J.F.MACBR., *Albizia adianthifolia* (SCHUMACH.) W.F.WRIGHT, and *Baphia nitida* contributed most to total shoot biomass produced by all stumps, amounting to 24.6, 16.6, 14.0 and 11.7 % of total, respectively. In 1993, sixteen species yielded higher than 1000 g plant^{-1} in shoot DM, with *Baphia nitida* leading with 2267 g plant^{-1}, followed by *Usteria guineensis* with 2014 g. The contribution of most species to total shoot biomass was less than 5 %, but DM of *Albizia zygia*, *Albizia adianthifolia*, *Lecaniodiscus cupanoides*, *Rauvolfia vomitoria* AFZEL. and *Morinda lucida* BENTH. amounted to 17.8, 10.4, 9.9, 9.6 and 5.3 % of total, respectively.

Table 1: List of stump species with plant heights above 1 m after regrowth at Attotinga in southern Bénin in 1992 and 1993.

Site	Attotinga			Houeto	Aguagon
Species / **Year**	**1992**	**1993**	**Δ**	**1993**	**1993**
Agelaea obliqua	6	5	- 1	0	0
Albizia adianthifolia	43	73	+30	27	0
Albizia ferruginea	2	3	+ 1	0	0
Albizia zygia	59	128	+69	1	0
Allophyllus africanus	7	51	+44	0	0
Anthocleista vogelii	0	3	+ 3	0	0
Antiaris africana	5	15	+10	0	0
Azadirachta indica	3	6	- 3	2	4
Baphia nitida	9	8	- 1	0	0
Blighia sapida	7	9	+ 2	0	0
Blighia unijugata	4	5	+ 1	0	0
Bridelia ferruginea	1	10	+ 9	10	3
Byrsocarpus coccineaus	5	4	- 1	2	0
Cassia sieberiana	1	0	- 1	0	0
Chlorophora excelsa	5	5	+-0	0	0
Clausena anisata	0	1	+ 1	0	0
Combretum hispidum	1	0	- 1	0	0
Combretum paniculatum	3	0	- 3	0	0
Dialium guineense	38	61	+23	8	0
Dichapetalum guineense	5	8	+ 3	0	0
Ehrezia zymosa	0	1	+ 1	0	0
Ficus exasperata	6	19	+13	0	0
Lecaniodiscus cupanoides	16	50	+34	2	0
Lonchocarpus cyanescens	0	5	+ 5	0	0
Malacantha alnifolia	2	5	+ 3	9	0
Millettia thonningii	0	1	+ 1	0	0
Monodora tenuifolia	0	3	+ 3	0	0
Morinda lucida	14	31	+17	5	0
Moringa oleifera	0	1	+ 1	0	0
Newbouldia laevis	0	1	+ 1	0	0
Parinari polyandra	4	5	+ 1	0	1
Phyllanthus discoideus	4	6	+ 2	1	0
Psidium gujava	0	4	+ 4	1	0
Raphiostylis beninensis	1	0	- 1	0	0
Rauvolfia vomitoria	7	62	+55	0	0
Rytigynia senegalensis	0	0	+-0	1	0
Securinega virosa	0	0	+-0	0	1
Spathodea campanulata	7	29	+22		
Trichilia emetica	0	0	+- 0	0	1
Usteria guineensis	0	1	+ 1	0	0
Uvaria chamae	8	24	+16	1	0
Vitex doniana	0	0	+-0	2	0
Voacanga africana	12	28	+16	0	0
Zanthoxylum zanthoxyloides	0	10	+10	37	0
XY (unidentified)	3	0	- 3	0	0
TOTAL	**288**	**681**	**379**	**126**	**14**

Table 2: The effect of year on seven growth and productivity parameters of stump species at Attotinga.

Stump Parameter	1992 [1]	1993	$LSD_{0.05}$
Number of individuals [m^{-2}]	0.0315^{B}	0.0860^{A}	0.0194
Average plant height [cm] [2]	163.7^{B}	205.2^{A}	11.6
Number of stumps [m^{-2}]	0.1128^{B}	0.2691^{A}	0.0677
Total stump basal area [cm^2 m^{-2}]	1.839^{B}	4.972^{A}	1.521
Number of shoots [m^{-2}]	0.3417^{B}	0.4934^{A}	1.484
Total shoot basal area [cm^2 m^{-2}]	0.257^{B}	1.374^{A}	0.442
Total shoot dry matter [g m^{-2}]	14.2^{B}	98.8^{A}	20.4

Table 3: The effect of environment on seven growth and productivity parameters of stump species at Attotinga (AT), Houeto (HU) and Aguagon (AG) in 1993.

Stump Parameter	AT [3]	HU	AG	$LSD_{0.05}$
Number of individuals [m^{-2}]	0.0859^{A}	0.0150^{B}	0.0019^{A}	0,0146
Average plant height [cm] [4]	205.2^{A}	206.2^{A}	205.2^{B}	33.3
Number of stumps [m^{-2}]	0.2691^{A}	0.0383^{B}	0.0081^{B}	0.0433
Total stump basal area [cm^2 m^{-2}]	4.972^{A}	0.935^{B}	0.013^{B}	1.157
Number of shoots [m^{-2}]	0.4934^{A}	0.0555^{B}	0.0307^{B}	0.0879
Total shoot basal area [cm^2 m^{-2}]	1.374^{A}	0.105^{B}	0.011^{B}	0.355
Total shoot dry matter [g m^{-2}]	98.8^{A}	13.1^{B}	2.5^{B}	16.8

At Attotinga in 1992, *Bridelia ferruginea* BENTH. and *Baphia nitida* LODD. yielded

1means of years followed by same letter are not different according to Fisher's least significant difference test with alpha=0.05

2mean plant height of stumps > 1 m within one agronomic plot (cropping system)

3 means of years followed by same letter are not different according to Fisher's least significant difference test with alpha=0.05

4 mean plant height of stumps > 1 m within one agronomic plot (cropping system)

The contribution of selected species to total shoot biomass and leaf biomass at Attotinga is given in Table 4 for both years, and is compared to total cut DM from Gliricidia sepium and Flemingia macrophylla across both agroforestry treatments. Mean growth and productivity parameters of selected species and both exotic species at Attotinga in 1993 are further summarized in Table 5.

At Houeto in 1993, eight species produced more than 1000 g shoot DM plant-1. Highest yielding was *Ficus capensis* THUNB. with 3038 g $plant^{-1}$, followed by *introduced Azadirachta indica* A.JUSS. with 2274 g, *Phyllanthus discoideus* (BAILL.) MUELL.ARG. with 2120 g and *Parkia biglobosa* with 1805 g $plant^{-1}$. Total shoot DM produced was 10.7 g m^{-2} with most of species contributing less than 5 %, but shoot DM of *Zanthoxylum zanthoxyloides* Lam. amounted to 27.3 %, *Parkia biglobosa* to 19.7 %, Albizia adianthifolia to 15.9 %, Dialium guineense to 10.0 % and Bridelia ferruginea to 8.7 % of total.

Table 4: Shoot biomass DM of natural stump regrowth and cut DM of two planted exotic species on an Acrisol in southern Bénin over two years of cropping (1991-93).

	Year 91/92		Year 92/93	
Shoot Biomass Source	**Total DM [g m^{-2}]**	**Leaf DM [g m^{-2}]**	**Total DM [g m^{-2}]**	**Leaf DM [g m^{-2}]**
Gliricidia	-	-	622	384
Flemingia	-	-	595	354
Planted trees Total	**0.0** [5]	-	**1217**	**738**
Albizia adianthifolia	21	6	79	32
Abizia zygia	25	12	135	36
Dialium	37	23	4	2
Lecaniodiscus	7	4	75	41
Morinda	3	2	40	11
Rauvolfia	2	1	73	17
Uvaria	5	2	34	13
Baphia	17	8	22	94
Allophyllus	1	-	47	17
Stump regrowth Total	**14.9** [6]	**73**	**76.3** [7]	**261**

At Aguagon in 1993, highest shoot DM was produced by introduced Anacardium occi-

5 trees were sown directly and established in the first year without being cut

6 total of 32 species and 1006 stumps

7 total of 36 species and 2514 stumps

dentale Linn. with 4896 g $plant^{-1}$, followed by *Ficus capensis* with 2364 g, *Bridelia ferruginea* with 872 g and *Nauclea latifolia* Sm. with 854 g $plant^{-1}$. Total shoot DM produced was 2.1 g m^{-2} to which the first two species contributed 29.8 and 28.8 %, respectively.

Table 5: Mean growth and productivity parameters of planted exotic trees and important natural stump species on an Acrisol in the second year of cropping (1992/93).

Species	Sample size	Total DM	Leaf DM	Stump efficiency parameters	
	n	[g $plant^{-1}$]	[g $plant^{-1}$]	[g DM Leaf cm^{2} BSA [8]]	[Number Stumps kg^{-1} Leaf DM]
Gliricidia [9]	223	140	89	56	739
Flemingia	112	347	212	367	717
Albizia adianthifolia [10]	73	888	282	144	70
Abizia zygia	128	863	301	162	62
Dialium	61	49	25	3	2917
Lecaniodiscus	50	1230	657	137	73
Morinda	31	1057	283	145	69
Rauvolfia	62	962	222	87	114
Uvaria	24	1153	465	145	69
Baphia	8	2267	1143	71	140
Allophyllus	51	751	265	134	75

5 Discussion

Differences in biomass contribution of natural stump species was especially meaningful in comparing both Acrisol sites in the second year. Attotinga and Hoeuto have the same potential vegetation, but species diversity, stump density and biomass productivity was drastically reduced at Houeto, owing to more frequent burnings and weedings during the last 17 years of its recorded land history (own observation). Similar effects have been confirmed by other authors (Clayton, 1958; Kellmann, 1980; Sanford & Isichei, 1986; Uhl et al., 1982), causing a seven-fold reduction of shoot DM from stump regrowth at Houeto. On the pure savanna site Aguagon, tree density is naturally much lower (Lamotte, 1975; Menaut & Cesar, 1982; Sanford & Isichei, 1986), but was reduced further by the more destructive local land preparation technique of ridging

8 basal stump area [cm^2]

9 values for planted trees Gliricidia and Flemingia are totals/means of six cuts and 370 days of growth in the second year

10 values for natural stump species are for 285 days of regrowth (from 2nd hand-weeding to land preparation of subsequent cropping year)

(Leihner et al., 1993), rendering stump biomass contribution insignificant there with 2.1 g DM m^{-2}.

On the species level, the very high productivity of *Ficus capensis* at Houeto and Aguagon stands out, but needs verification with larger sample numbers. Increases in total DM of individual species at Attotinga between 1992 and 1993, was due to much increased numbers in individuals with most species, but the productivity of Baphia nitida was an exception to this pattern: its DM productivity per plant was exceptionally high in both seasons, contributing significant amounts to total stump DM each season with only few individuals (Tab. 4 & 5). *Albizia spp., Lecaniodiscus cupanoides, Morinda lucida, Uvaria chamae*, and *Allophyllus africanus* P.BEAUV. were very efficient in producing shoot biomass, all yielding above 100 g in leaf DM per c basal stump area or, in other terms, needing less than ten stumps in the mean to produce 1000 g leaf DM (Tab. 5). In comparison, exotic *Gliricidia sepium* produced only 56 g leaf DM cm^{-2} basal stump area and needed as many as 739 stumps to produce 1000 g of leaf DM. In comparing DM productivity of natural stump species and planted, fast growing, exotic tree species, the value of stumps becomes even more important considering the fact that appreciable amounts of shoot biomass were recycled already from the first year of cropping onwards (Tab. 4) and this at no additional cost to the farmer. Overall, this distinguished native stump species as a very efficient life form in accumulating biomass and suggested their protection between crops to be an economic agroforestry option worth consideration.

Species richness and stump density increased substantially at Attotinga within two years of cropping (Tab. 1 & 2), and this could be attributed to renouncing burning at land clearing as well as to subsequent selective weedings (BROWN & LUGO, 1990; HEDBERG, 1986; CLAYTON, 1958, UNRUH et al., 1988). The latter largely had the effect of releasing cutting stress on stumps, so that losses in stored assimilates of roots and stumps were minimized. In general, this may have also helped stumps to withstand environmental stresses such as drought better increasing again their regrowth productivity (CONNOR, 1983). Total shoot DM was boosted between both years by a factor ranging from five to seven (Tab. 2 & 4). Stumps in 1993, reaching heights above 1 m after 285 days of regrowth, were all natives of West Africa, with the exception of introduced *Azadirachta indica* and *Psidium gujava*. Further, species with highest increases in individuals over both years (Tab. 1) all belonged to the mature forest (HUTCHINSON & DALZIEL, 1954-1972). A similar trend was observed by Clayton (1958) in Nigeria, who observed that neglected weedings favored *Cnestis ferruginea, Baphia nitida* and *Ficus exasperata* among other native species. The reappearance of *Newbouldia laevis* in 1993, together with the prominence of *Morinda lucida* and *Rauvolfia vomitoria* indicated a similar vegetation type at Attotinga to the ones described by Hall and Okali (1979) in Nigeria. The loss of both *Combretum spp.* on the list of 1993 stumps (Tab. 1) was conspicuous, but this could have been due to erroneous cuttings, because villagers may have counted them as lianes at weeding.

Both ANOVA's (Tab.2 & 3), revealed that cropping systems had no meaningful effect on growth, distribution, density and shoot DM productivity of stumps, meaning their was neither response of natural species to applications of mineral NPK-fertilizer nor to the inter-planting of different exotic and fast growing species such as *F. macrophylla*, *G. sepium*, or *C. cajan*. This was surprising, since it was expected that at least fertilization with NPK would show some impact on species composition and their DM productivity. But, Harcombe (1977), observed a similar phenomenon in Costa Rica, in that biomass and nutrient stocks in early successional vegetation were not enhanced by fertilization, but natural succession was rather retarded in favor of forbs. This observation was not corroborated in this study, at least in terms of significantly reduced numbers of stumps in fertilized plots. At the same time, no significant increase in forbs and grasses was observed, but this could not be substantiated since both were weeded off without being measured. The indifferent response of natural stump species to fast-growing leguminous species such as *Gliricidia*, *Flemingia* and *Cajanus* could be explained by their localized presence in plots, either in hedges or tree blocks, leaving enough space to stumps where competition was lower. The presence and productivity of natural stump species within-tree rows was measured in another study separately, but no difference was found between tree hedges and blocks, too (BÖHRINGER, unpubl. results). Kellmann (1980), in support, showed the choice of crops and their spatial arrangement to have the least influence on natural succession. Mechanisms of interactions between fallow vegetation and crops in farmers fields are yet poorly understood and this deserves future attention at the species level in order to pass out recommendations to farmers on optimum mixtures of crops and natural stump species in their fields. It appeared, as if a minimum number of useful stump species would be generally required in order to warrant full and efficient site restoration after years of cropping. Yet, it is unknown, how many individuals per area would be needed in different environments and what mixtures of crops and natural stump species would be best to maximize crop yields and value of fallows?

The selection of natural species within a field should also take into consideration values of their products. The pharmacologic value of many fallow species, both in traditional medicine and also for export, could be an important selection criterion. Naming a few stump species among many others may suffice to highlight this potential: Bridelia ferruginea in treating diabetics, Rauvolfia vomitoria in psychotherapy as a sedative, and Zanthoxylum zanthoxyloides as a therapeutic for sickle-cell anaemia (HEDBERG, 1986; SOFOWORA, 1982). But, few useful plants have been studied systematically in order to establish their usefulness in a wider context (Hedberg, 1986). The indigenous knowledge that accompanies products from natural species is a resource deserving conservation as much as the species themselves.

6 Conclusions

The diversity of natural stump species and their contribution to shoot biomass in cropping systems depended on land-use practices, such as burning, weeding, tree cutting and destumping. Species richness and stump density increased substantially by renouncing burning and selective weedings later in the season. In particular species of the mature forest responded favorably to this protection, with *Albizia spp.*, *Baphia ni-*

tida, *Lecaniodiscus cupanoides*, *Morinda lucida*, and *Rauvolfia vomitoria* being also extremely efficient in accumulating shoot biomass. Their contribution to shoot dry matter turnover was equally high in the five contrasting cropping systems being evaluated, making agroforestry with these and probably many other potential native species an economic and ecologically sound cropping system innovation worth consideration. The multiple uses of natural stump species can not be conserved in isolation from the species themselves, and their promotion within fields represents, therefore, the most immediate means of preserving the functioning of the natural ecosystem. The conservation of natural stump species with their multiple products and services to man has a global dimension, too, since it will help to release human pressure on rapidly declining primary forests in the region and should therefore be included as priority in national environmental action plans. However, a huge information gap still exists on native tree and shrub species and their agroforestry potential. This represents currently the primary obstacle in formulating extension messages on "good" management of natural vegetation, aiming to maximize crop yields and value of fallows, while helping to preserve the functioning of the natural ecosystem.

Biomasseproduktion der natürlichen Stockausschläge in Anbausystemen der subhumiden Waldsavanne Westafrikas

Zusammenfassung

Die aufgrund des Bevölkerungswachstums notwendige Intensivierung des Pflanzenbaus in Westafrikas geht momentan zu Lasten der ökologischen wie ökonomischen Nachhaltigkeit von traditionellen Buschbrachesystemen. Die landwirtschaftliche Forschung in der Region gibt deshalb Bäumen und Büschen eine Schlüsselfunktion zum Schutz der lokalen Ökosysteme und zur Steigerung der landwirtschaftlichen Ernteerträge. Trotzdem wurden dem agroforstwirtschaftlichen Potential und saisonalem Biomasseeintrag der natürlich vorkommenden Stockausschläge bislang keine Aufmerksamkeit geschenkt. Deshalb wurde der Wiederaufwuchs von natürlich vorkommenden Baumstümpfen in verschiedenen Anbausystemen und -orten im Süden Bénins gemessen und deren Biomasseproduktivität mit der von exotischen Agroforstspezies verglichen. In Feldern mit mäßigen negativen Einflüßen durch Abbrennen und Unkrauthacke wurden 32 Baumspezies identifiziert mit einer Dichte von 0,0315 Stümpfen pro m^2 und einer Trockenbiomasseproduktivität durch Stockausschläge von 14,2 g m^{-2} nach 285 Tagen Wiederaufwuchs. Mit einem Verzicht auf Abbrennen zur Landvorbereitung und einer selektiven Unkrauthacke während der folgenden Anbauzeit konnte die Anzahl der Baumspezies auf 36 gesteigert werden, bei einem gleichzeitigen Anstieg deren Dichte auf 0,086 Stümpfe pro m^2 und Trockenbiomasseproduktivität auf 98,8 gm^{-2}. Insbesonders Baumspezies, die dem natürlichen Waldökosystem zuzuordenen sind wie *Albizia spp.*, *Baphia nitida*, *Lecaniodiscus cupanoides*, *Morinda lucida*, und *Rauvolfia vomitoria*, reagierten positiv auf diese schonende Behandlung während der Kultivierung. Bedeutende Mengen an Biomasse konnten so durch den Schnitt der Stockausschläge den Feldern als Mulch zurückgeführt werden. Diese natürlich vorkommenden Baumstümpfe waren auch viel effizienter in der Biomasseakkumulierung als angepflanzte, exotische Agroforstspezies wie *Gliricidia sepi-*

um. Der Schutz und die Berücksichtigung von natürlich vorkommenden Stümpfen während des Anbaus von Feldkulturen stellt deshalb eine wirtschaftlich interessante Agroforstalternative dar, der in Zukunft mehr Aufmerksamkeit geschenkt werden sollte. Gleichzeitig würden die vielfachen Produkte und Dienstleistungen dieser Baumspezies für die Menschen der Region gesichert.

La biomasse produite par les repousses des souches dans le système d'agriculture an Sud du Bénin

Resumé

L'augmentation rapide de la population entraîne une intensification des cultures en Afrique de l'Ouest, mettant en péril la capacité de reproduction économique et écologique des systèmes culture itinérante de défriche brûlis capacité dependant d'un etat d'equilibre dans le temps et l'espace entre culture et jachère sur un site donné. Il a été prouvé par la recherche que les arbres et arbustes jouent un rôle primordial dans la conservation de l'écosytème aussi bien que dans l'acroissement des rendements; cependant la contribution de la biomasse produite par les repousses des souches des espèces indigènes dans le champs des paysans n'a pas encore été évaluée dans le cadre de leur potentiel agroforestier. Ainsi, la repousse et la productivité des souches des espèces indigènes a été étudiée dans différents systèmes culturaux et environnements au Sud du Bénin et comparées aux espèces introduites agroforestières. La recherche fut exécutée sur differnts champs où les effet négatifs du système d'exploitation de la végétation naturelle, tels que les brûlis et la sarclage, furent modérés. Trente deux espèces de souches avec des densités d'un individu par 0.0315 m^2 furent collectées, conribuant ainsi à un total de 14.2 g m^2 de matière sèche végétale après 285 jours de croissance. En évitant le brûlis et en faisant des sarclages sélectifs, le nombre des espèces de souches augmenta jusqu'à 36 au cours de l'année suivante, produisant 98.8 g m^2 de matière sèche vegétale grâce aux repousses de leur tronc avec une densité de 0.086 individu par m^2. En particulier, les espèces de la grande forêt tels que *Albizzia spp.*, *Baphia nitida*, *Lecaniodiscus cupanoides*, *Morinda lucida*, et *Rauvolfia vomitoria* ont répondu favorablement à la protection, contribuant non seulement à des quantités significatives de biomasse provenant des repousses (tronc), mais aussi elles sont plus efficaces en accumulant plus de biomasse que les espèces introduites agroforestières à croissance rapide tel que le *Gliricidia sepium*. Ni la fertilisation, ni la plantation d'espèces introduites à croissance rapide n'ont infuencé la repousse des souches indigènes et leur productivité. La préservation et la gestion des souches indigènes entre les cultures représentent une option économique qui devrait demander beaucoup plus de consideration dans le futur. Ceci aiderait à la fois à conserver les multiples services et produits que l'homme tire des souches de ces espèces indigènes aussi bien que le maintien du fonctionnement de l'écosystème naturel dans la région.

7 References

1. AWETO, A.O., 1981. Secondary succession and soil fertility in south-western Nigeria. II. Soil fertility restoration. Journal of Ecology, 69:609-614.

2. BÖHRINGER A., GEMMILL B., LEIHNER, D.E. & KANG, B.T., in print. Selecting indigenous species with potential for agroforestry from native bush-fallow vegetation in the subhumid forest- savanna mosaic zone of West Africa. Agroforestry Systems (special edition).
3. BRAND, R.B., 1976. Les hommes et les plantes. L'usage du plantes chez les Wemenou du Sud- Dahomey. Genève-Afrique Genf, 15:15-44.
4. BROWN, S. and LUGO, A.E., 1990. Tropical secondary forests. Journal of Tropical Ecology, 6:1-32.
5. CLAYTON, W.D., 1958. Secondary vegetation and the transition to savanna near Ibadan, Nigeria. Journal of Ecology, 46(2):217-238.
6. CONNOR, D.J., 1983. Plant stress factors and their influence on production of agroforestry plant associations. Pp. 407-426 in Huxley, P. [ed.]. Plant research and agroforestry. ICRAF, Nairobi, Kenya.
7. EWEL, J.J., 1986. Designing agricultural ecosystems for the humid tropics. Ann. Rev. Ecol. Syst., 17:245-271.
8. FLOQUET, A. and AGLI, C., 1993. Les pratiques paysannes sont elles performantes? Document de travail no. 3. Projet UNIHO-DRA G1; DRA, B.P. 884, Cotonou, Republique du Bénin.
9. HALL, J.B. and OKALI, D.U.U., 1979. A structural and floristic analysis of woody fallow vegetation near Ibadan, Nigeria. Journal of Ecology, 67:321-346.
10. HARCOMBE, P.A., 1977. The influence of fertilization on some aspects of succession in a humid tropical forest. Ecology, 58:1375-1383.
11. HART, R.D., 1980. A natural ecosystem analog approach to the design of a successional crop system for tropical forest environments. Biotropica (special supplement), 12:73-82.
12. HEDBERG, I., 1986. Conservation and land use. Pp. 309-326 in Lawson, G.W. [ed.]. Plant ecology in West Africa. J. Wiley & Sons Ltd..
13. HUTCHINSON, J. and DALZIEL, J.M., 1954-1972. Flora of West Tropical Africa. 2nd edn. Crown Agents, London, England.
14. JOHNSON, E.J. and JOHNSON, T.J., 1976. Economic plants in a rural Nigerian market. Economic Botany, 30:375-381.
15. KANG, B.T., REYNOLDS, L. and ATTA-KRAH, A.N., 1990. Alley farming. Advances in Agronomy, 43:315-359.
16. KELLMANN, M., 1980. Geographic patterning in tropical weed communities and early secondary successions. Tropical Succession, 80:34-39.
17. LAMOTTE, M., 1975. The structure and function of a tropical savannah ecosystem. Pp. 179-222 in Golley, F.B. [ed.]. Tropical ecological systems. Ecological studies volume 11. Springer Verlag, New York, U.S.A..
18. LEIHNER, D.E., BERNARD, M., AKONDE, P., BÖHRINGER, A. and ERNST-KARLE, R., 1993. Development of improved cropping systems for the West African savanna eco-systems. Pp. 237-278 in Universität Hohenheim [ed.]. Standortgemässe Landwirtschaft in Westafrika, Zwischenbericht 1990-93, SFB 308, Stuttgart, Germany.
19. MENAUT, J.C. and CESAR, J., 1982. The structure and dynamics of a West-African savanna. Pp. 80-100 in Huntley, B.J. & Walker, B.H. [eds.]. Ecology of tropical savannas. Ecological studies volume 42. Springer Verlag, Berlin-Heidelberg, Germany.
20. MOSS, R.P. and MORGAN, W.B., 1977. Soils, plants and farmers in West Africa. Pp. 1-31 in Garlick, J.P. & Keay, R.W. [eds.]. Human ecology in the tropics, Vol. IX. Pergamon Press, New York, U.S.A..
21. OKIBO, B.N., 1977. Neglected plants of horticultural and nutritional importance in traditional farming systems of tropical Africa. Acta Horticulturae, 53:131-150.
22. SANFORD, W.W. and ISICHEI, A.O., 1986. Savanna. Pp. 95-149 in Lawson, G.W. [ed.]. Plant ecology in West Africa. J. Wiley & Sons Ltd..
23. SAS Institute Inc., 1988. SAS/STATIM user's guide, release 6.03 edition. Cary, NC, U.S.A.
24. SOFOWORA, A., 1982. Medicinal plants and traditional medicine in Africa. J. Wiley & Sons Ltd..
25. UHL, C., CLARK, H., CLARK, K. and MAQUIRINO, P., 1982. Successional patterns associated with slash-and-burn agriculture in the upper Rio Negro region of the Amazon Basin. Biotropica, 14(4):249-254.
25. UNRUH, J.D., 1988. Ecological aspects of site recovery under swidden-fallow management in the Peruvian Amazon. Agroforestry Systems, 7:161-184.