TRADITIONAL TARO (*COLOCASIA ESCULENTA)* CULTIVATION IN THE SWAMP FOREST OF GUADELOUPE (F.W.I.) : IMPACT ON FOREST STRUCTURE AND PLANT BIODIVERSITY

Daniel IMBERT[1], Etienne SAUR[1, 2], Ingrid BONHÊME[1] & Valérie ROSEAU[1]

RÉSUMÉ

En Guadeloupe, le taro (*Colocasia esculenta*) est cultivé traditionellement dans la forêt marécageuse à *Pterocarpus* sous couvert partiel. L'impact de cette pratique agroforestière originale sur la structure, le sol et la flore de la forêt a été étudié dans la Baie du Grand Cul-de-sac Marin, au sein de la réserve MAB, dans des parcelles d'inventaire totalisant 4000 m^2. Il s'avère que la culture du taro entraîne d'importantes modifications qualitatives et quantitatives de la végétation et, dans une moindre mesure, du sol. Dans les peuplements cultivés, la densité de tiges était réduite de 80 % et de nombreuses espèces herbacées opportunistes apparaissaient alors que plusieurs espèces sciaphiles du sous-bois, elles, disparaissaient. Cependant, ces perturbations étaient localisées à la frange amont de la forêt, et le couvert forestier semblait se reconstituer sans difficulté dans les peuplements anciennement cultivés. Nous croyons que, dans le cadre de la mise en place d'une stratégie de conservation de la forêt marécageuse à *Pterocarpus* et dans la mesure où des études complémentaires sur des espèces particulièrement menacées pourront être menées, ce type d'agroforesterie durable constitue un intéressant outil pour la mise en œuvre effective du concept de « zone tampon ».

SUMMARY

In Guadeloupe, traditional taro monoculture (*Colocasia esculenta*) is conducted under partial, natural shade in the *Pterocarpus* swamp forest. The impact of this original agroforestry practice on forest structure, soil and flora was investigated on inventory plots totalling 4000 m^2 within the MAB reserve, in the Bay of the Grand Cul-de-sac Marin. Taro cultivation was responsible for important qualitative and quantitative changes of vegetation and, to a lesser extent, soil characteristics. Stem density decreased by 80 %, and a number of weeds invaded cultivated stands while several shade-tolerant understorey species were eliminated. However, such disturbances were confined to the landward forest edge, and forest recovery appeared to be efficient on formerly cultivated stands. Regarding the development of conservation strategies applicable to the *Pterocarpus* swamp forest, and providing that complementary studies on especially endangered species be conducted, we believe that this sustainable agroforestry system could be a useful tool in the building of effective "buffer zones".

---

[1] Université des Antilles et de la Guyane, Laboratoire de Biologie et Physiologie Végétales, Campus de Fouillole, F-97159 Pointe-à-Pitre Cedex, Guadeloupe. E-mail : daniel.imbert@univ-ag.fr

[2] Present address: École Nationale des Ingénieurs des Travaux Agricoles de Bordeaux, BP 201, F-33175 Gradignan Cedex. E-mail : e-saur@enitab.fr

Rev. Écol. (Terre Vie), vol. 59, 2004.

INTRODUCTION

The taro *Colocasia esculenta* Schott (*Araceae, Colocasioideae*) is an ancient crop, native of South-East Asia which is grown today throughout all the humid tropics for its edible corms and leaves. Taro was clearly mentioned by R.P. Duss (1897) but probably introduced in Guadeloupe for agricultural purposes earlier in colonial times. R.P. Du Tertre (1667) alluded to « *fausse racine de Chine* », but without giving enough details to be able to relate it surely to taro. Since historical times, the knowledge of its cultivation seems to have been perpetuated through family tradition. Although taro culture occurs in two other types of farming systems in Guadeloupe (homegarden and upland monoculture), monoculture under swamp forest is the dominant system in total yield. In fact, local farmers consider that since suitable hydrological conditions are met (waterlogged soils fed by upland seepage, with some superficial drainage), the peaty soils of the swamp forest are good for taro cultivation (*terre à madère*). In this environment, taro does not exhibit major problem of disease or pest damages in contrast to upland taro and *Xanthosoma* cultivation. When traditionally conducted, this culture needs no soil preparation (except some shallow, hand-made ditches enhancing natural drainage), no fertilizer or organic amendments, and no phytosanitary chemicals.

The swamp forest covers about 2 600 ha of coastal wetlands in Guadeloupe. It occurs mostly at the landward edge of the mangrove forest when the soil is flooded by freshwater. *Pterocarpus officinalis* Jacq. (*Papilionoideae, Dalbergieae*) is the dominant tree species of the forest, forming a dense, almost evenly flat canopy. It represents 76% of the tree stems with girth at breast height (GBH) $\geq$ 10 cm (Imbert *et al.,* 2000). However, with 107 vascular plant species over 6800 m^2 (Imbert *et al., op. cit*.), the flora of the swamp forest is far richer than that of the nearby mangrove forest. The *P. officinalis* swamp forest is unique to the Caribbean region, and especially to the Antilles (Bacon, 1989). During the last three centuries, swamp forest areas have dramatically decreased in Caribbean islands due to land reclamation for agriculture and urban expansion. In Guadeloupe, however, large patches of swamp forest still remain fairly undisturbed around the Bay of the Grand Cul-de-sac Marin (GCSM): 460 ha have been included in a specially protected area, the GCSM Natural Reserve, which belongs to the core zone of the Man and Biosphere (MAB) reserve of Guadeloupe archipelago (Mège & Anselme, 1997). The rest of the swamp forest surrounding the Bay is part of the buffer zone of the MAB reserve and is managed by the French National Forest Office which may deliver administrative authorizations for taro cultivation.

Despite the special consideration devoted to the conservation of coastal resources in the Caribbean islands (e. g. Knausenberger & Fleming, 1989; Lugo & Bayle 1992; Maul, 1993; Parkinson *et al*., 1994; Snedaker 1995) investigations on Caribbean swamp forest biodiversity and its fate are scarce (Bacon, 1989; Alvarez-Lopez, 1990; Imbert *et al*., 2000; Saur *et al*., 2000). Traditional taro cultivation requires partial clearing of the native forest (Fig. 1); furthermore, control of forest structure on a long-term basis is insured by hand-cutting (herbs and young trees) and burning (large trees). Among the questions raised by the authorities in charge of the conservation of this ecosystem are: i) to what extent does such a traditional exploitation of the ecosystem by local communities affect biodiversity? and ii) is this agroforestry practice sustainable and relevant to ecosystem conservation strategies? In this study we have tried to address such questions by evaluating the impact of taro cultivation on forest structure, soil characteristics and plant biodiversity.

Figure 1. — Taro plantation in the *Pterocarpus* swamp forest of Guadeloupe *(photo. D. Imbert).*

MATERIAL AND METHODS

STUDY SITE

The study site was located within the MAB Reserve on the West side of the GCSM Bay, on the calcareous Grande-Terre island, astride the Belle-Plaine Canal. This area hosted extensive wetlands that develop in a large coastal plain. The contrasted pattern of rainfall resulted in seasonal variations of the water-table level that might fluctuate from 10 cm above to 40 cm below ground level. However, depending on the topography and the proximity of karstic resurgences, the soil might be locally submitted to permanent flooding. Climatic data from Météo France's regional office indicated that for the considered area mean monthly rainfall ranges from 60 to 220 mm (annual mean 1700 mm), whereas monthly mean of extreme temperatures varies between 19 and 31 °C (annual mean 25 °C).

On its landward edge, the swamp forest was surrounded by herbaceous swamps and water meadows developing on organic, clayey soils. Seawards, as ground-water salinity increased, mangrove forest or brackish marshes occurred. In the inner part of the swamp forest, organic soils (peat) might reach 7 m depth (Feller *et al.,* 1992).

INVENTORIES

Taro plantations were mainly restricted to the landward edge of the forest and, according to the estimate given by Braux (1981), affected *ca.* 10% of the whole swamp forest area. On aerial photographs, these plantations were difficult to distinguish from natural gaps and spontaneous forest understorey. We therefore used a set of transects perpendicular to the landward edge of the forest in order to characterize the outer part of the forest submitted to cultivation, and another set of plots in the inner, undisturbed part of the forest to serve as control.

Four 5 x 100 m transects were established along the forest edge at *ca.* 600 m intervals. Inventory of vascular plants was implemented in each transect within 40 m^2 contiguous subplots. Stems ≥ 10 cm GBH were numbered and measured. Girth of *Pterocarpus* stems was measured 20 cm above buttresses. When the top of buttresses was impossible to climb (sometimes over 4 meters high) stem girth was assessed by eye. Each vegetation layer was characterized by the dominant species, canopy height and vegetation cover (using a semi-quantitative index ranging from 1 to 8). The same measurements and observations were made in five 10 x 40 m control plots sampled at random, away from any visible influence of anthropic disturbances.

Soil characteristics were investigated during the dry season along the transects and in the control plots. Water-table level was measured and soil profile up to 1 m depth was described from soil cores extracted by means of a peat auger. Soil texture (clay, peat, muck) and consistency (1: firm, 2: soft, 3: very soft to fluid) were assessed empirically. Redox potential and pH were measured in the field along the cores at 20 cm intervals. Stand micro-topography and indices of human activities were also noticed.

Statistics

Statistics were performed using Statview® software. Mann-Whitney U-test was applied on quantitative and semi-quantitative data sets, whereas the χ^2 Goodness of Fit was computed on a contingency table for qualitative observations. For each test, decision was taken at a level of confidence ≥ 0.95.

RESULTS

Forest structure

Four types of stand were defined according to the degree of anthropic disturbance. The inner forest stands, where no evidence of past or present human disturbance was found, were regarded as control plots. Subplots from the forest edge (transects) were split into three groups according to the contribution of *Colocasia* to the understorey: non cultivated stands (no *Colocasia*), formerly cultivated stands (*Colocasia* cover < 25%) and stands under cultivation during the study period (*Colocasia* cover ≥ 25%).

The inner forest stands exhibited higher average stem density (25 stems ≥ 10 cm GBH / 100 m^2), basal area (61 dm^2/100 m^2) and tree cover as well (Tab. I). However, these stands did not significantly differ from the non cultivated stands of the forest edge as regarding these descriptors. Average forest canopy height was significantly lower in the control plots (15 m) than in any other type of stand (17 to 19 m). This may be due to the inner position of the control plots within the forest, being farther from nutrient-rich upland runoff. No significant difference was found between forest structure of current *vs.* former cultivated stands.

These stands were characterized by few scattered, large *Pterocarpus* and lower tree-layer cover.

TABLE I

Soil and vegetation characteristics in four types of stand in the swamp forest of Guadeloupe

Stand descriptor	Inner forest stands	Outer forest stands		
		Non cultivated	Formerly cultivated	Under cultivation
Total area (m^2)	2000	800	850	350
pH	6,66 [a]	6,58 [a]	6,89 [b]	6,88 [b]
Redox (mV)	-182	-106 [a]	-138 [b]	-117
Water-table level (cm)	-8 [b]	-18 [a]	-9 [b]	-6 [b]
Soil texture	P [a]	P [a]	M [b]	M [b]
Soil consistency	1,8	2,0	2,0	2,0
Stem density (/100m^2)	25 [a]	21 [a]	6 [b]	3 [b]
Basal area (dm^2/100m^2)	61 [a]	48	41	36 [b]
Forest canopy hight (m)	15 [a]	9 [b]	19 [b]	17 [b]
Tree-layer cover	2,0 [a]	2,4 [a]	3,3 [b]	3,4 [b]
No. of plant species:				
Total	62	63	86	66
Mean (/50 m^2)		12[a]	22	21 [b]
Mean (/400 m^2)	24	-	-	-

Soil texture and consistency were each appreciated though 3 modalities; respectively: peat (P), muck (M), clay (C), and firm (1), soft (2), fluid (3). Percent of cover for the tree layer was assessed using semi-quantitative scale: 100-90 (1), 75-90 (2), 50-75 (3), 25-50 (4), < 25% (5). For each descriptor, the values quoted with different letters indicate significant differences (p>0.05). Mann-Whitney U-test was applied on quantitative and semi-quantitative data sets, and a χ^2 Goodness of Fit was computed on a contingency table for qualitative observations (soil texture).

FLORA

The mean number of species of vascular plants encountered on 50 m^2 subplots in both current and former cultivated stands was twice greater than in the non cultivated stands of the forest edge. Furthermore, the subplots of stands submitted to current or recent cultivation exhibited, on average, nearly as many species as the control plots which were 8 times larger. As a result, plots from the forest edge totalled 134 plant species on a 2 000 m^2 area compared to 62 species for the control plots, over a same area. Only 45 species were shared by the two sets of plots.

Pterocarpus was the dominant species in all stands, except in those under current cultivation of *Colocasia* where this species was co-dominant or even dominant. The most frequent species in both inner and outer non cultivated forest stands were *Pterocarpus officinalis* (tree), *Polypodium latum* (epiphitic fern), *Hippocratea volubilis* (liana), and *Tabernaemontana citrifolia* (small tree). In former cultivated stands, a number of other common vascular plants co-existed with these species, whereas the two last species were far less frequent in cultivated stands (Tab. II).

TABLE II

Life form and occurrence of the most frequent species (frequency ≥ 0,5) in the three types of stand of the swamp forest edge

Species	**Life form**	**Occurrence in stands**		
		Non cultivated	**Formerly cultivated**	**Under cultivation**
Acrostichum danaefolium	Ter. fern		x	
Anthurium grandifolium	Epi. herb		x	x
Colocasia esculenta	Ter. herb		x	x
Commelina diffusa	Ter. herb		x	x
Hippocratea volubilis	Liana	x	x	
Nephrolepis biserrata	Epi. fern		x	
Piper dilatatum	Ter. herb		x	
Polypodium latum	Epi. fern	x	x	x
Pterocarpus officinalis	Tree	x	x	x
Scleria mitis	Ter. herb		x	
Struchium sparganophorum	Ter. herb		x	x
Tabernaemontana citrifolia	Tree	x	x	
Tectaria incisa	Ter. fern		x	
Thelypteris cf extensa	Ter. fern		x	x
Thelypteris reticulata	Ter. fern		x	x

Relative contribution of the main life-forms to the flora of the four studied types of stand is shown in figure 2. A higher proportion of epiphytes and trees was found in both inner and outer non cultivated stands. Conversely, recent and current cultivated stands hosted many more herbaceous ground species. Furthermore, life-form spectra from all forest-edge stands differ from that of inner forest stands due to their lower contribution of lianas and shrubs.

SOILS

In both inner and outer non cultivated forest stands, soil was most often peaty, with slightly, but significantly, lower pH values than in cultivated stands where soil texture was essentially mucky (*cf.* Tab. I). Water-table level was significantly higher in the cultivated than in the non cultivated stands from the forest edge. Accordingly, redox values were higher in non cultivated outer forest stands. No significant difference was found between stands as regarding soil consistency.

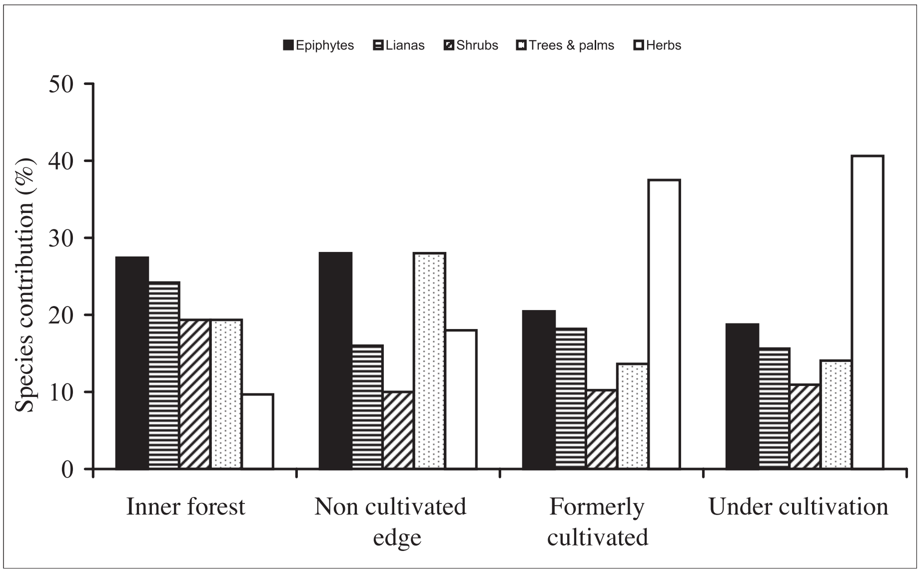

Figure 2. — Life-form spectra of four types of stand in relation with taro cultivation in the swamp forest of Guadeloupe. Epiphytes include here hemi-epiphytes and hemi-parasites; shrubs include small trees < 8 m high.

DISCUSSION

Traditional taro cultivation in the swamp forest causes considerable changes in forest structure. Basal area is reduced by 40% and stem density by 80%. The empirical knowledge of Guadeloupean farmers thus consists in maintaining a few large *Pterocarpus* trees so that taro culture may benefit the optimum level of light interception (*ca.* 50% of initial forest cover). In fact, taro leaves have higher chlorophyll content and stable chlorophyll a : b ratio when submitted to moderate shade, suggesting that their light-harvesting system may be normally adapted to shade conditions (Johnston & Onwueme, 1998). As a result of forest canopy opening, a number of weed species invade cultivated stands and some individuals escape from manual weeding, especially at the edge of planted units and close to the remaining *Pterocarpus* stumps. Conversely, some forest species among the most shade-tolerant disappear. Maintaining the presence of a certain amount of *Pterocarpus* biomass may also improve taro production in another way: *Pterocarpus* trees very likely have a positive impact on the mineral budget (specially N) of the tree / crop association through their efficient symbiotic N-fixing (Saur *et al.*, 1998).

Regarding soil and forest structure, formerly cultivated stands are quite similar to those which are still under cultivation. However, as cultivation is abandoned, qualitative changes occur in floristic composition: the contribution of *Colocasia* to the herbaceous layer dramatically falls off whereas floristic diversity increases, and understorey species progressively replace light-demanding weeds. Although a number of non cultivated stands along the forest edge have exhibited rather unsuitable hydrological conditions for taro cultivation (lower water-table level), some others have shown signs of ancient cultivation: cut stems, long-lived cultivated species often associated to taro plantations such as *Cocos nucifera,* or *Musa sp.* Such stands do not significantly differ from inner forest stands (control plots) regarding the main descriptors of soil and forest structure. However, their life-form spectrum and floristic composition indicate that they should be regarded as late successional stands. It is thus possible to view the three types of forest stands which have been identified at the forest edge as distinct successional stages of the swamp forest dynamics in relation to agricultural practices. As related to other wetlands (Lugo *et al.*, 1990), changes in soil texture and pH could be directly related to anthropic activities *via* reversible processes: drainage ditches and surface digging improve aerobic decay of organic matter and thus lead to higher pH values and mucky texture, as compared with the peaty soils of closed-forest stands.

It may be argued therefore that traditional taro cultivation under swamp forest as conducted in Guadeloupe for about three centuries can be regarded as an example of sustainable agroforestry practice, in divergence with other flooded taro culture around the tropical world (Onwueme, 1978; Wang, 1983). Furthermore, we believe that this system has to be preserved as a social and agricultural heritage, and that it could constitute a new perspective for flooded agriculture by the use of N-fixing trees in association with flood-tolerant crops. Owing to its sustainability and its socio-economical value for local communities (Braux, 1981), traditional taro cultivation in clearly delineated "buffer zones" (UNESCO, 1984) could be viewed as a tool for swamp forest preservation, helping to increase public awareness of the natural resources and the ecological functions of this Caribbean unique ecosystem. However, to insure the conservation of plant biodiversity over the whole swamp forest ecosystem, large areas of the forest should remain undisturbed, especially (but not only) in the presently specially protected areas. Moreover, further studies on the fate of endemic, rare or endangered swamp forest species (Bonhême *et al.*, 1998) are desirable before developing a comprehensive management programme of the *Pterocarpus* swamp forest.

ACKNOWLEDGEMENTS

We are grateful to Philippe Julianus and Régis Tournebize for agronomical survey and field assistance, and to Kim Lacoste for improving the English language. The French National Forestry Office contributed to support the financial cost of this study.

REFERENCES

ALVAREZ-LOPEZ, M. (1990). — Ecology of *Pterocarpus officinalis* forested wetlands in Puerto-Rico. Pp. 251-265, *in*: A.E. Lugo, M. Brinson & S. Brown (eds*). Ecosystems of the world 15; forested wetlands*. Elsevier.

BACON, P.R. (1989). — Ecology and management of swamp forests in the Guianas and Caribbean region. Pp. 213-250, *in*: A.E. Lugo, M. Brinson & S. Brown (eds*). Ecosystems of the world 15; forested wetlands*. Elsevier.

BONHÊME, I., IMBERT, D., ROUSTEAU, A. & SAUR, E. (1998). — La forêt marécageuse à *Pterocarpus officinalis* - Sa situation en Guadeloupe. *Bois et Forêts des Tropiques,* 258: 59-68.

BRAUX, M. (1981). — Système d'occupation des sols en arrière mangrove. Pp. 157-180, *in*: A. Kermarec (ed.). *Etude de la mangrove et de sa zone côtière en Guadeloupe.* INRA – DGRST, Pointe-à-Pitre, Guadeloupe.

DUSS, R.P. (1897). — *Flore phanérogamique des Antilles françaises, tomes I et II.* Réédité en 1972 par la Société de Distribution et de Culture, Fort-de-France, Martinique.

DU TERTRE, R.P. (1667). — *Histoire générale des Antilles habitées par les François.*

FELLER, C., FOURNIER, M., IMBERT, D., CARANTINI, C. & MARTIN, L. (1992). — Datations ^{14}C et palynologie d'un sédiment tourbeux continu (0-7m) dans la mangrove de Guadeloupe (F.W.I.). Résultats préliminaires. Pp. 193-202, *in*: M.T. Prost (ed.). *Evolution des littoraux de Guyane et de la zone Caraïbe méridionale pendant le quaternaire.* Editions de l'ORSTOM, France.

IMBERT, D., BONHÊME, I., SAUR, E. & BOUCHON, C. (2000). — Floristics and structure of *Pterocarpus officinalis* swamp forest in Guadeloupe, Lesser Antilles. *J. Trop. Ecol.,* 16: 55-68.

JOHNSTON, M. & ONWUEME, I.C. (1998). — Effect of shade on photosynthesis pigments in the tropical root crops: yam, taro, tannia, cassava and sweet potato. *Expl. Agric*., 34: 301-312.

KNAUSENBERGER, W.I. & FLEMING, C.B. (1989). — *Proceedings of the workshop on coastal protected areas in the lesser Antilles.* University of the Virgin Islands, St Thomas, U. S. Virgin Islands.

LUGO, A.E., BROWN, S. & BRINSON, M.M. (1990). — Concepts in wetland ecology. Pp. 53-86, *in*: A.E. Lugo, M. Brinson & S. Brown (eds*). Ecosystems of the world 15; forested wetlands*. Elsevier.

LUGO, A.E. & BAYLE, B. (1992). — Wetlands management in the Caribbean and the role of forestry and wetlands in the economy. *Proceedings of the fifth meeting of Caribbean foresters at Trinidad and the first meeting of Ministers of Agriculture to consider the economic role of forestry at St Lucia*. USDA Forest Service, Rio Piedras, Puerto Rico.

MAUL, G.A. (1993). — Implications of future climate on the ecosystems and socio-economic structure in the marine and coastal regions of the Intra-Americas Sea. Pp. 3-28, *in*: G.A. Maul (ed.*). Climatic change in the Intra-Americas Sea*. Edward Arnold (Hodder & Stoughton).

MÈGE, S. & ANSELME, M. (1997). — *Plan de gestion de la Réserve Naturelle du Grand Cul-de-sac Marin, Guadeloupe, 1998-2002*. Parc National de la Guadeloupe, St Claude, Guadeloupe.

ONWUEME, I.C. 1978. — *The tropical tuber crops*. John Wiley and Sons.

PARKINSON, R.W., DE LAUNE, R.D. & WHITE, J. R. (1994). — Holocene sea-level rise and the fate of mangrove forests whithin the Wider Caribbean region. *J. Coastal Res*., 10: 1077-1086.

RISÈDE, J.-M. (1984). — *Observations préliminaires sur la situation du madère* (Colocasia esculenta) *et du malanga* (Xanthosoma sagittifolium) *en Guadeloupe*. Mémoire de fin d'étude. Institut Supérieur Technique d'Outre-Mer.

SAUR, E., BONHÊME, I., NYGREN, P. & IMBERT, D. (1998). — Nodulation of *Pterocarpus officinalis* in the swamp forest of Guadeloupe (Lesser Antilles). *J. Trop. Ecol*., 14: 761-770.

SAUR, E., CARCELLE, S., GUEZENNEC, S. & ROUSTEAU, A. (2000). — Nodulation of Legume species in wetlands of Guadeloupe (Lesser Antilles). *Wetlands*, 20: 730-734.

SNEDACKER, S.C. (1995). — Mangroves and climate change in the Florida and Caribbean region: scenarios and hypotheses. *Hydrobiologia*, 295: 43-49.

UNESCO (1984). — Plan d'action pour les réserves de la biosphère. *Nature et Ressources,* 20: 1-12.

WANG, J.-K. (1983). — *Taro. A review of* Colocasia esculenta *and its potentials*. University of Hawaii Press.