WOOD BIOMASS OF ONE GALLERY FOREST[1]

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ABSTRACT - On a study in a gallery forest at the small stream Dos Macacos situated at Santo Antônio do Descoberto, GO, Brazil, an area of one hectare was analysed. On 1.741 trees the wood volume with bark and the dry wood biomass of stems and branches was determined for trees with a DBH greater than 5 cm. 117 species were identified. The total volume was 181,996 m³/ha corresponding to 132 tons of dry wood. The results could form a base for management plans, utilizing these resources on a sustainable yield basis.

Index terms: forest inventory, forest productivity, natural forest.

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RESUMO - Analisou-se um hectare da mata ciliar do córrego dos Macacos situada no Município de Santo Antônio do Descoberto, GO. Determinou-se o volume com casca e o peso da madeira seca do fuste e dos galhos de 1.741 árvores com DAP igual ou superior a 5 cm. Foram identificadas 117 espécies. O volume total de madeira em metros cúbicos foi de 181,996/ha, e o correspondente peso seco dessa madeira, de 132 toneladas. Os resultados apresentam bases para os correspondentes planos de manejo sustentado.

Termos para indexação: inventário florestal, produtividade florestal, florestas nativas.

INTRODUCTION

Gallery forest are woody vegetation types which grow along the riversides in savanna regions, as in the Brazilian cerrado. In the middle-west region of Brazil the gallery forests consist of the typical species composition as can be found in the Amazon region. One of the theories is that these forest types originate from former tropical moist forests. The human activities lead to a considerable reduction of the areas of the gallery forests in the Brazilian cerrado region. Not much is known about the biology, ecology and silviculture of these forest types, so that it is not possible to create management plans on a sound base of knowledge. There exist a great diversity of species in these forests so that one can assume that there must be a possibility to utilize them, e.g. as energy forests or for multiple use.

There is only little literature with a focus on the dynamics and the species composition of these forests. The most relevant studies in this context are, Camargo et al. (1971), Troppmair & Machado (1974), Gibbs & Leitão Filho (1978), Bertoni & Martins (1987), Heringer & Paula (1989) and Paula et al. (1990, 1993).

Paula et al. (1990, 1993) emphasize the necessity for ecological and dendrometrical studies. Parameters like the species distribution, basal area per hectare and natural regeneration are a first step to know the dynamics and the silvicultural and economical potencial.

It is generally recognized that a management on a sustainable yield basis is one of the best ways to protect forest areas, to protect habitats for wildlife and to guarantee water supply on a long term basis. This study is a case study, carried out in a one-hectare study area in a gallery forest at the small stream Dos Macacos situated at Santo Antônio do Descoberto, GO, Brazil. The objective is to contribute to the

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knowledge of the composition of gallery forests, which is one of the evidences needed to establish management plans. Special emphasis is here on the wood biomass and the lignine contents of the wood; evidences that are necessary to judge the commercial potential of these type of forests.

MATERIALS AND METHODS

The forest selected is located at the small stream Dos Macacos in the middle-west region of Brazil, in the county of Santo Antônio do Descoberto in the state of Goiás. The geographical coordinates are 48° 21' longitude (east of Greenwich) and 15° 48' latitude (south). The distance to the capital Brasília is about 65 km. The entire gallery forest there covers an area of about 5 hectares. For the study, an area of one hectare was selected, partitioned in ten subplots of 1.000 m² each.

All trees with a DBH greater or equal to 5 cm were registered and measured. Variables measured on the stem were the DBH, the diameter at stump height (0,2 m), the upper diameter below the first branch of the stems bifurcation; the height of this diameter was measured as well. For all branches the diameters at the lower and upper end were measured, and the distance between these measurements. The minimum diameter was 5 cm in this case as well. The species identification was made in the forest. In the case that an immediate identification was not possible, samples were carried to the Herbario da Universidade de Brasília for a proper identification. From one tree per species a wood sample was taken to the laboratory. With these samples the specific weight of the species was determined to make biomass calculations possible and the lignine content was analysed to determine the total amount of lignine. All the processing of these samples took place at the laboratory of Wood Anatomy at the University of Brasília.

The parameters derived in this paper are the woody volume outside bark of the stems and branches. The Smalian formula was used to calculate the corresponding volumes, utilizing the upper and lower diameter and the length of the piece. The specific weight (s.w.) was determined as the ratio of the samples dry weight to its volume.

The dry wood biomass was calculated with the volume, calculated in the manner described above, and the corresponding specific weight.

The amount of lignine in the wood samples was determined with the analysis method presented by Correa et al. (1970), Barrichelo & Brito (1976) and Paula (1989).

RESULTS AND DISCUSSION

The survey showed that in the study area there were 1.741 trees with DBH greater than 5 cm, representing 117 species and 47 taxonomical families.

A comprehensive listing of the main frequency species encountered and its mayor characteristics is given in Table 1.

Analysing the mean DBH, 27 species (23% of all species) had individuals with diameters greater than 15 cm. The bigger mean diameters concentrate on the following species: *Qualea dichotoma* with 76,00 cm (1 tree), *Copaifera langsdorffii* with 38,10 cm (5 trees), *Vochysia pyramidalis* with 35,04 cm (11 trees), *Piptadenia peregrina* with 25,67 cm (3 trees), *Licania apetala* with 26,65 cm (11 trees), *Maytenus alaternoides* with 23,00 cm (1 tree) and *Callisthene mayor* with 22,33 cm (6 trees).

The diameter distribution of the 1.741 trees has a negative exponencial form which is typical for natural forest types. The highest concentration is in the minor classes; about 72% of the trees have diameters between 5 cm and 13 cm. Only about 0,6% of the trees have diameters bigger than 50 cm. The mean diameter therefore is 11,77 cm. According to a silvicultural and production oriented classification used in Brazil, this type of forest can be put into the class "fire wood production", when only the diameter dimensions are considered. The biggest trees are of the species *Copaifera langsdorffii*, *Vochysia pyramidalis*, *Licania apetala* and *Callisthene mayor*, formed the upper layer (Table 2).

The basal area of the 1.741 trees with a DBH of 5 cm and more was 26,44 m². The mean basal area is therefore 0,015 m². The species which contributed significantly to the basal area were: *Protium brasiliense* 2,0945 m²/ha (7,9% with 159 trees), *Vochysia pyramidalis* 1,2451 m²/ha (4,7% with 11 trees), *Hirtella glandulosa* 1,2196 m²/ha (4,6% with 102 trees), *Sideroxylon venulosum* 1,1152 m²/ha (4,2% with 50 trees), *Tapira guianensis* 1,0530 m²/ha (4,0% with 63 trees), *Emmotum nitens* 1,0115 m²/ha (3,8% with 37 trees), *Sclerolobium paniculatum* 1,0192 m²/ha (3,8% with 38 trees), *Copaifera langsdorffii* 0,8899 m²/ha (3,4% with 5 trees), *Matayba guianensis* 0,7892 m²/ha (3,0% with

TABLE 1. Results of the woody biomass calculation, species with more than 10 trees.

Species	Family	n	Mean DBH cm	Spec. weight g/cm³	Total vol. m³/ha	Total biomass kg	Total lignine kg
Andira fraxinifolia Benth.	Leguminosae	27	8,98	0,76	0,76	580,72	461,67
Apuleia molaris Spruce ex. Benth.	Leguminosae	20	14,40	1,.00	2,57	2.574,82	2.028,96
Aspidosperma olivaceum M. Arg.	Apocynaceae	14	13,95	0,76	2,45	1.861,75	1.486,43
Astronium fraxinifolium Schott.	Anacardiaceae	43	10,42	0,95	2,65	2.519,49	2.013,02
Bauhinia rufa R. Grah.	Leguminosae	26	9,36	0,73	0,82	603,43	479,24
Byrsonima laxiflora Griseb	Malpighiaceae	36	10,67	0,72	1,82	1.314,56	1.048,13
Cabralea cangerana Saldanha	Meliaceae	67	10,56	0,67	4,41	2.951,79	2.360,36
Callisthene fasciculata Mart.	Vochysiaceae	35	9,81	0,76	1,36	1.034,77	825,99
Calophyllum brasiliense Camb.	Guttiferae	11	19,59	0,65	6,08	3.954,55	3.159,96
Cheiloclinium cognatum A.C. Smith.	Hippocrateaceae	19	12,38	0,82	1,18	966,32	770,85
Cupania vernalis Camb.	Sapindaceae	34	9,60	0,65	1,29	840,51	670,22
Emmotum nitens (Benth.)Miers.	Icacinaceae	37	15,33	0,72	6,76	4.868,01	3.890,88
Erythroxylum amplifolium E.O.Sch.	Erythroxylaceae	13	8,88	0,61	0,34	205,16	159,10
Gomidesia regneliana Berg.	Myrtaceae	49	10,89	0,86	2,61	2.242,74	1.790,99
Guettarda viburnoides Cham. & Schl.	Rubiaceae	13	9,00	0,76	0,26	202,10	158,68
Hirtella glandulosa Sprenger	Rosaceae	102	11,98	0,95	6,64	6.304,35	5.038,98
Inga fagifolia (L.) Willd.	Leguminosae	27	11,42	0,65	1,77	1.152,61	918,99
Licania apetala Fritsch	Rosaceae	11	26,65	0,61	7,63	4.655,82	3.719,75
Licania octandra Runtze	Rosaceae	58	8,91	0,81	1,81	1.465,72	1.168,77
Luehea divaricata Mart.	Tiliaceae	24	11,48	0,56	1,13	663.65	502,90
Maprounea guianensis Aublet	Euphorbiaceae	14	14,68	0,70	1,83	1.283,25	1.023,21
Matayba guianensis Aublet	Sapindaceae	121	8,82	0,76	3,31	2.519,82	2.012,88
Micropholis grandiflora Piers	Sapotaceae	24	17,99	0,75	5,69	4.272,89	3.416,01
Myrcia tomentosa (Vell.) Arrab.	Myrtaceae	10	8,50	0,72	0,24	172,22	134,79
Ocotea densiflora Meissn.	Lauraceae	14	15,32	0,63	2,94	1.854.92	1.483,21
Ocotea pomoderoides (Meissn.) Mez.	Lauraceae	10	15,35	0,83	1,43	1.186,07	945,25
Ocotea spixiana (Nees.) Mez.	Lauraceae	12	13,04	0,83	2,00	1.661,10	1.322,87
Ouratea castaneaefolia Engl.	Ochnaceae	36	9,92	0,74	1,13	836,42	665,22
Pera glabrata Poep.	Euphorbiaceae	24	16,27	0,70	4,85	3.392,03	2.709,09
Piptadenia macrocarpa Benth.	Leguminosae	10	17,95	0,86	2,72	2.338,72	1.866,07
Protium brasiliense Engl.	Burseraceae	159	12,08	0,60	16,83	10.100,08	8.072,28
Prunus chamisseiana Koehne	Rosaceae	17	10,71	0,57	1,01	576,72	458,08
Rustia formosa Klotsch	Rubiaceae	32	9,44	0,52	1,17	611,43	485,20
Salacea amigdalina Peyr.	Hippocrateaceae	19	14,74	0,60	4,24	2.542,22	2.028,75
Sclerolobium paniculatum Vog.	Leguminosae	38	17,14	0,83	7,92	6.573,52	5.252,21
Sideroxylon venulosum Mart.	Sapotaceae	50	14,85	0,81	8,10	6.563,44	5.250,75
Simaruba versicolor A.St.Hil	Simarubaceae	10	12,50	0,55	0,75	414,04	327,98
Siphoneugena densiflora Berg.	Myrtaceaea	41	10,43	0,93	2,57	2.387,04	1.903,62
Taluma ovata St.Hil.	Magnoliaceae	10	12,40	0,40	0,94	376,11	294,81
Tapira guianensis Aubl.	Anacardiaceae	63	13,62	0,65	6,35	4.129,26	3.299,07
Tapura amazonica Poepp. et Engl.	Dichapetalaceae	19	10,29	0,66	0,88	582,82	462,96
Terminalia glabecens Mart.	Combretaceae	10	14,74	0,73	2,63	1.922,29	1.535,54
Virola sebifera Aublet	Miristicaceae	14	9,07	0,73	0,59	434,01	342,81
Vochysia pyramidalis Mart.	Vochysiaceae	11	35,04	0,64	10,84	6.935,63	5.543,98
Xylopia emarginata Mart.	Annonaceae	12	12,29	0,52	1,44	748,17	597,11
Xylopia sericea St.Hil.	Annonaceae	19	8,70	0,63	0,74	464,94	369,85

121 trees), *Cabralea cangerana* 0,7301 m²/ha (2,8% with 67 trees) and *Micropholis grandiflora* 0,7263 m²/ha (2,7% with 24 trees).

Analysing the diameter classes one sees that there is a great growth potential as the lower diameter classes have 72% of all trees, as generally can be

TABLE 2. Indicator species for the main layers.

Species	n	mean DBH cm	total vol. m^3/ha	Biomass total ton	Biomass indiv. kg
Dominant layer:					
Vochysia pyramidalis	11	35,04	10,84	6,9	630,5
Copaifera langsdorffii	5	38,10	8,27	6,4	1.289,7
Licania apetala	11	26,65	7,63	4,6	423,2
Callisthe major	6	22,33	3,44	1,8	305,0
Intermediate layer:					
Protium brasiliense	159	12,08	16,83	10,1	63,5
Sideroxylon venulosum	50	14,85	8,10	6,6	131,2
Sclerolobium paniculatum	38	17,14	7,92	6,6	172,9
Emmotum nitens	37	15,33	6,76	4,9	131,5
Hirtella glandulosa	102	11,98	6,64	6,3	61,8
Tapira guianensis	63	13,62	6,35	4,1	65,5
Calophyllum brasiliense	11	19,59	6,08	3,9	359,4
Micropholis grandiflora	24	17,99	5,70	4,3	179,5

observed in gallery forest types. Only few trees with a diameter of 45 cm and more can be found.

The two species *Vochysia pyramidalis* and *Copaifera langsdorffii* are the most significant in terms of basal area and in terms of their spatial distribution. Theoretically, one could calculate from the number of trees per hectare that the mean spacing is 8 m x 8 m for *Protium brasiliense*, while the overall mean spacing for the 1.741 trees would be 2,4 m x 2,4 m.

The most frequent species are *Protium brasiliense* with 159 trees, *Matayba guianensis* with 121 trees, *Hirtella glandulosa* with 102 trees, *Cabralea cangerana* with 67 trees and *Tapira guianensis* with 63 trees. These species represent 30% of the entire population, while only *Protium brasiliense* and *Tapira guianensis* are part of the intermediate layer (Table 2).

The volume outside bark was calculated separately for stem and crown (branches). The total volume of the 1.741 trees is 181,996 m^3/ha, where 158,055 m^3/ha (86,8%) are from the stems and 23,941 m^3/ha (13,2%) from the crowns. All together, 1.672 branches were registered and measured. The species with the greatest contribution to the volume were *Protium brasiliense* 16,833 m^3/ha (159 trees), *Vochysia pyramidalis* 10,836 m^3/ha (11 trees), *Copaifera langsdorffii* 8,267 m^3/ha (5 trees), *Sideroxylon venulosum* 8,103 m^3/ha (50 trees), *Sclerolobium paniculatum* 7,919 m^3/ha (38 trees), *Licania apetala* 7,632 m^3/ha (11 trees), *Emmotum nitens* 6,761 m^3/ha (37 trees), *Hirtella glandulosa* 6,636 m^3/ha (102 trees), *Tapira guianensis* 6,352 m^3/ha (63 trees), *Calophyllum brasiliense* 6,083 m^3/ha (11 trees). The highest mean volume per individual is with *Copaifera langsdorffii* (1,653 m^3) and *Vochysia pyramidalis* (0,985 m^3).

The species with considerable proportion of woody volume in the crown are *Apeiba tibourbou, Copaifera langsdorffii, Didymopanax macrocarpum, Myrcia velutina* and *Sclerolobium paniculatum.*

With respect to the specific weight, the following results were found: 21 species (1,2%) had a specific weight of less than 0,60 g/cm^3, 63 species (3,6%) were between 61 and 80 g/cm^3, 21 species (1,2%) between 81 and 90 g/cm^3, 11 species (0,6%) between 91 and 100 g/cm^3 and 1 species (0,1%) with more than 100 g/cm^3. This analysis shows that most of the species found are usable for the production of charcoal (specific weight more than 60 g/cm^3).

The natural regeneration comprises 2.361 individuals of woody species. An interesting observation could be made with respect to the ratio between number of adult and regeneration trees of the same species. There were 100 individuals in the regeneration of *Aspidosperma olivaceum* but only nine adult trees. Similar observations could be made for *Cabralea cangerana* (210 and 67 trees), *Xylopia emarginata* (80 and 12 trees). This situation gives the precise insight in the reproduction intensity and the survival rate of these species.

The total biomass was 132,019 tons of dry wood, consisting of 114,12 tons (86,4%) in the stem sections and 17,89 tons (13,6%) in the tree crowns.

The species with the highest dry wood biomass are: *Protium brasiliense* (10.100,083 kg), *Vochysia pyramidalis* (6.935,628 kg), *Sclerolobium paniculatum* (6.573,521 kg), *Sideroxylon venulosum* (6.563,436 kg), *Copaifera langsdorffii* (6.448,007 kg), *Hirtella glandulosa* (6.304,354 kg), *Emmotum nitens* (4.868,007 kg) and *Licania apetala* (4.655,818 kg).

The ratio between lignine content (in kg) and biomass (in kg) of the trees is very constant. The frequency distribution of this ratio is given in Fig. 1 and the corresponding plot of lignine against biomass is shown in Fig. 2, where one can see the strong relationship.

If one observes the lignine content against the volume of the individual trees, the variation is bigger; this variation corresponds to the variation of the specific weight. The frequency distribution of the ratio between lignine content (in kg) and the volume (in dm^3) of the trees is shown in Fig. 3 and the corresponding plot of lignine against volume in Fig. 4.

The highest biomass production per tree can be found with the following species: *Qualea dichotoma* with 2.272,10 kg, *Copaifera langsdorffii* with 1.289,77 kg, *Vochysia pyramidalis* with 630,51 kg, *Licania apetala* with 423,26 kg, *Calophyllum brasiliense* with 359,46 kg, *Terminalia phaeocarpa* with 329,41 kg, *Callisthene major* 304,97 kg and *Maytenus alaternoides* with 294,07 kg. The biomass production in kilogram dry wood per tree can be considered as quite low. Only *Copaifera langsdorffii* and *Qualea dichotoma* exceed the biomass value of 1.000 kg.

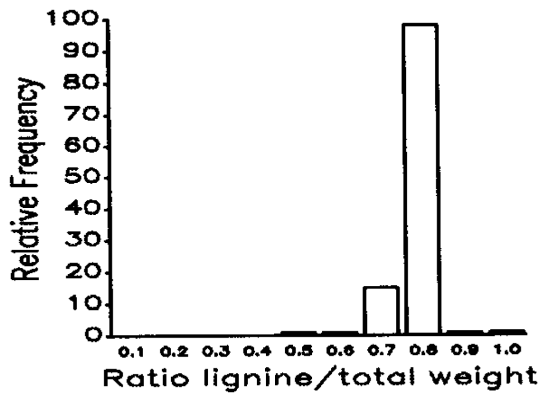

FIG. 1. Frequency distribution of ratio between lignine content (kg) and biomass (kg) of the individual trees.

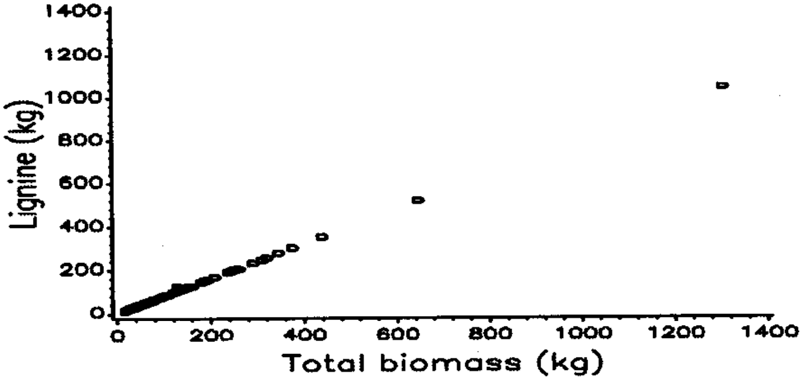

FIG. 2. Plot of lignine (kg) against biomass (kg).

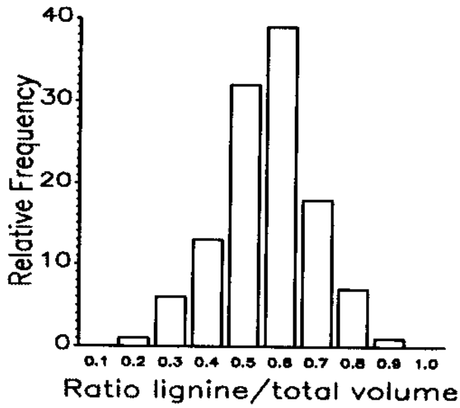

FIG. 3. Frequency distribution of ratio between lignine content (kg) and volume (dm^3) of the trees.

Species with a specific weight of 0,60 g/cm^3 and more are considered as appropriate for charcoal production. There are many species to be considered important for this purpose and that should be investigated more closely.

For a possible oil production *Copaifera langsdorffii* might be considered which also is part of the species appropriate for charcoal production.

Twelve species have a specific weight greater than 90 g/cm^3. Two of them, *Astronium urundeuva* and *Astronium fraxinifolium* have very hard wood with a high natural resistancy against fungi and insects; larger dimensions of this species could be used for construction, smaller individuals for e.g. fence poles.

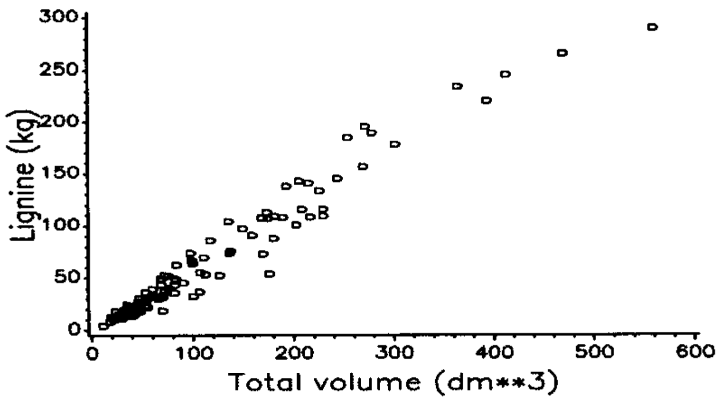

FIG. 4. Plot of lignine (kg) against volume (dm^3).

A comparison with the findings of Paula et al. (1990, 1993) in a study of the gallery forest of the Rio São Bartolomeu and stream Capãozinho (Federal District), shows some differences with respect to the density (1.741 here, 649 and 568, respectively in their sudies), while the total wood biomass is about no more different (132 tons against 144 and 127 tons respectively).

According to the socioeconomic situation in the region and in many parts of Brazil, it appaers important to state that this type of gallery forest could be used as energy forest (charcoal) or as forest for multiple use, assumed that this management is carried out under the regime of sustainable yield.

Sawtimber of intermediate dimensions could be produced from the following species: *Amaioua guianensis, Apuleia molaris, Aspidosperma australe, Faramea cyanea, Hirtella glandulosa, Hirtella martiana, Mouriria glazioviana, Myrcia acutata, Pouteria gardneriana, Pouteria rivicoa* and *Siphoneugena densiflora.*

The following species can be considered of multiple use because of their producing eatable fruits and seeds: *Alibertia macrophylla, Apuleia molaris, Byrsonima fagifolia, Calophyllum brasiliense, Cardiopetalum calophyllum, Cheiloclinium cognatum, Copaifera langsdorffii, Didymopanax morototoni, Emmotum nitens, Eugenia bracteata,* *Faramea cyanea, Faramea warmingiana, Gomidesia regneliana, Guarea trichilioides, Hirtella gracilipes, Inga alba, Protium brasiliense, Siparuna guianensis, Virola sebifera* and *Xylopia sericea.*

The cellulose and lignine production was quantified in this study to get an idea on the production potencial for alcohol and charcoal from the wood. The demand for this raw material in huge and the forests of the type investigated here are at the moment certainly not ready to be used for that purpose. However, there are various species appropriate for this utilization.

CONCLUSIONS

1. About 65% of the trees in the study area could enter into a charcoal production process. A management of gallery forests, however, has to integrate several silvicultural treatments like enrichment planting to assure sustainable yield.

2. The main issue, however, is the long term preservation of these forests and their diversity and ecological equilibrium. Therefore it can be stated that gallery forests of the type investigated can contribute to a certain extent to the wood production but that they are far away from being highly productive.

3. Their importance could be seen on a local level where the wood demand is quite high; so the even limited wood production from gallery forests may help improve the local socioeconomic situation. Protection and preservation, however, is the main issue.

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