LITTER PRODUCTION IN AREAS OF BRAZILIAN "CERRADOS"[1]

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ABSTRACT - Litter production was measured in Brazilian Cerrado and Cerradão during three successive years. The average yearly production of total litter is 7,800 kg/ha^{-1} and 2,100 kg/ha^{-1} in Cerradão and Cerrado, respectively. The leaf-litter (including grasses) represents 76.7% of the total litter in Cerradão and 84% in Cerrado. The rates of litter decomposition determined by direct litter-bag technique are very slow on surface in both ecosystems. The litters from Cerrado and Cerradão have almost the same nutrient storage ability. Samples of litter composed of the parts of predominant plants contain 0.82%-0.85% of N, 0.06% P, 0.16% K, 0.32%-0,34% Ca and 0.12%-0.14%Mg.

Index terms: savanna.

PRODUÇÃO DE RESÍDUOS VEGETAIS EM ÁREAS DE CERRADOS DO BRASIL

RESUMO - Foram efetuadas avaliações de produção de resíduos vegetais de Cerrado e Cerradão, durante três anos consecutivos. A produção média anual de resíduos vegetais foi de 7.800 e 2.100 kg/ha no Cerradão e Cerrado, respectivamente. As folhas senescentes (incluindo gramíneas) representam 76,7% da produção total de resíduos de biomassa no Cerradão, e 84% no Cerrado. A taxa de decomposição deste material foi determinada diretamente em sacos de tela de nylon, sendo considerada muito baixa em ambos os ecosistemas. Os resíduos vegetais coletados no Cerrado e no Cerradão apresentaram semelhante composições de nutrientes: 0,82-0,85% de N; 0,06% de P; 0,16% de K; 0,32%-0,34% de Ca e 0,12-0,14% de Mg.

Termos para indexação: savana.

INTRODUCTION

Litter is one of the most important means of transferring materials and energy for the maintenance of ecosystem process. Several studies have been carried out on the litter production in various ecosystems, but no research has dealt with the Brazilian Cerrado. Cerrado (savanna) is the principal vegetation of most of Central Brazil. It covers 25 per cent of Brazilian territory. Stands of this vegetation vary mainly in the size and density of trees. They are arbitrarily divided into four intergrading categories: "campo sujo", "campo cerrado", "cerrado" *sensu strictu* ("orchard-like vegetation") and "cerradão" ("woodland-like vegetation") (Goodland 1971). Considerable data on Cerrado vegetation, soil chemistry and fertility, crops, etc. can be found in materials from the IV Symposium on Cerrado held in 1976 (Ferri 1977). The economic importance and agricultural potential of Cerrado were discussed by Silva (1978). Some studies have also been conducted on the microbiology of Cerrado soils (Dantas & Drozdowicz 1972, Linhares & Drozdowicz 1972, Drozdowicz 1977, Coelho & Drozdowicz 1978, Coelho et al. 1979, Oliveira & Drozdowicz 1980). The purpose of this study was to determine quantitatively the litter production in two typical virgin Cerrado areas.

MATERIAL AND METHODS

Litter is defined here as leaves, twigs, stems, flowers and fruits which have been naturally shed by the plants and rest on the soil surface. The "standing" dead plant matter is not included.

The study area

The research area is situated in the Planalto Central (Central Plateau) of Brazil, close to the capital, Brasília, at an altitude of 965 m. The climate here is strictly seasonal, with a rainy summer from October to April and a dry winter from May to September. Rainfall is 1,200-2,000 mm per year. The mean temperature is 20°-26°C. The soil in the Cerrado area examined is classified as Red-Yellow Latosol in the Acrustox group, and the soil in the Cerradão area as Dark Red Latosol in the Haplustox group. The terms Cerrado and Cerradão are used here according to the physiognomic gradients suggested by Goodland (1971). There is significant difference in the density and distribution

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of vegetation between the two ecosystems examined, as described by Ribeiro et al. (1981). In cerrado, the herbaceous vegetation creates a continuous stratum, while the discontinuous stratum is composed of scattered trees and shrubs, representing about 18% of the covered area. The arevage height of the trees is 3.3 m, with the most prevalents species being *Qualea grandiflora* and *Q. parviflora* (family Vochysiaceae) and *Kielmeyera coriaceae* (family Guttiferae). In Cerradão, Ribeiro et al. (1981) described the vegetation as a woodland with a dense canopy creating a continuous stratum of trees covering about 93% of the soil. The mean height of the trees was 6.6 m, with the most prevalent species being *Emmotum nitens* (family Icacinaceae) and *Siparuna guianensis* (family Morimiaceae).

In the areas examined, as well as in other cerrado territories, most of the trees and shrubs produce and retain greenish leaves throughout the year, even during the dry season. Some herbaceous plants also retain green leaves and even blossom during the drought.

The dimension of each study area, Cerrado and Cerradão, was one hectare. The sites have been surrounded by a wire fence to prevent invasion by animals. No fire occurred during the studies.

Sampling procedure

On each area, 30 randomly distributed circular plots (60 cm diameter each) were located. Each plot was encircled by a metallic fence fixed in the soil. In Cerradão, all plots were located under the canopy. In Cerrado, most of the plots were located close to the trees and shrubs and some of them covered only the herbaceous vegetation. At the start of the research, all plant material lying on the floor of each plot was collected and discarded, and then the plots were emptied by hand sampling at monthly intervals. The collected material comprised the litter lying on the floor shed by trees, shrubs and herbaceous vegetation. The standing herbaceous plants were not removed from the plots during the sampling. The collected litter was separated into three categories:

a. leaves, (including herbaceous leaves);
b. twigs and stems, and
c. flowers and fruits.

In the laboratory the material was oven-dried at 60°C and weighed.

Decomposition measurements

Outside of some randomly selected plots, the rate of litter decomposition was measured by a technique essentialy similar to that described by Sniffling & Smith (1974). Samples of undecomposed leaf litter and herbaceous litter were dried at 60°C, weighed and packed separately in nylon bags (2 mm mesh), forming a thin layer of plant material. The herbaceous samples were composed of grasses in both ecosystems. The leaf litter samples were mixed: *Annonaceae* and *Leguminosae* leaves in Cerradão, and *Leguminosae* and *Vochysiaceae* leaves in Cerrado.

In January 1977, several of such bags were placed close to the fence of the plots on the soil surface. The bags were fixed with pins so that a firm contact was made with the soil. Seven to nine bags were collected at monthly intervals. In the laboratory the litter was dried and weighed, and the rate of disappearance was calculated from differences in mass. Corrections were made for spillage when necessary (Sniffling & Smith 1974). Then the bags were returned to the field, fixed as before, and reused.

Analysis procedure

Samples composed of a mixture of predominant litter components, in proportions corresponding to data presented in Table 1, were prepared. Samples were wet-ashed with H_2SO_4-H_2O_2 digestion and analyzed. Phosphorus in the ash was determined by a technique suggested by Murphey & Riley (1962), Ca and Mg by atomic absorption spectrophotometry and K by flame photometry. Micro-Kjeldahl procedure was used for N analysis.

RESULTS

Litter production

The study began in July 1976 and the samples were collected up to the end of 1979. During five months of 1976 (August-December) the total litter fall was 3,634 kg/ha^{-1} and 926 kg/ha^{-1} in Cerradão and Cerrado, respectively. The yearly litter production found in Cerradão was 8,523 kg/ha^{-1}, 7,079 kg/ha^{-1} and 7,848 kg/ha^{-1} during 1977, 1978 and 1979, respectively. The corresponding data for Cerrado were: 2,847 kg/ha^{-1}, 1,377 kg/ha^{-1} and 2,056 kg/ha^{-1} (Fig. 1).

Fig. 2 shows the differences in average monthly litter production as influenced by climatic conditions. The parts of the plants have been shed during the whole year; however, maximum litter production occurs during the dry season. The only exception was the rainy period 1976/1977, when litter production was higher than in the dry season in the Cerrado area. In this case the moribund plant parts probably remained fixed to the standing plants during the dry season and then were shed by rainfall in the rainy period.

Litter composition

The leaves (including those of herbaceous

TABLE 1. Litter composition.

	Cerradão			Cerrado		
	1977	1978	1979	1977	1978	1979
			Percent of total litter			
Leaves	87.0	76.0	67.3	93.0	82.7	78.3
Stems and twigs	13.0	22.5	30.6	7.0	14.6	18.5
Flowers and fruits	ns	1.5	2.1	ns	2.7	3.2

ns: Flowers and fruits were not measured separately in 1977.

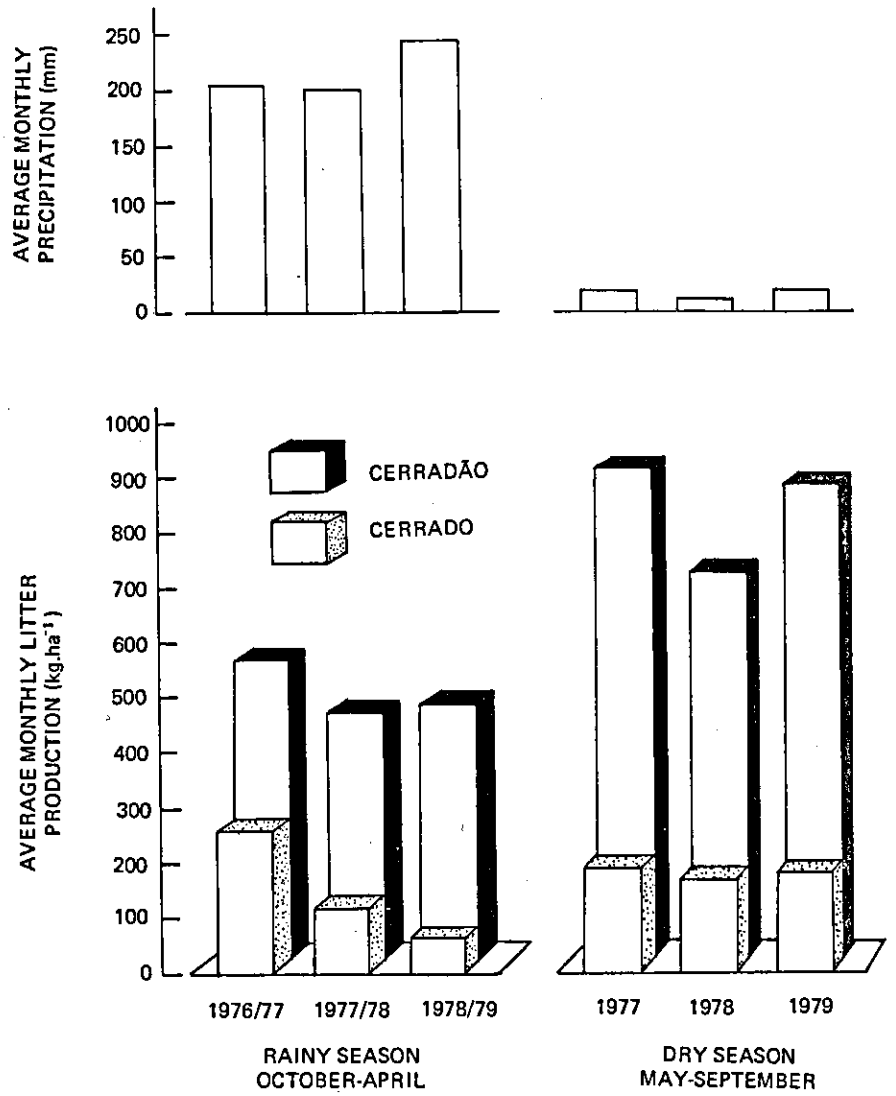

FIG. 1. Yearly litter production.

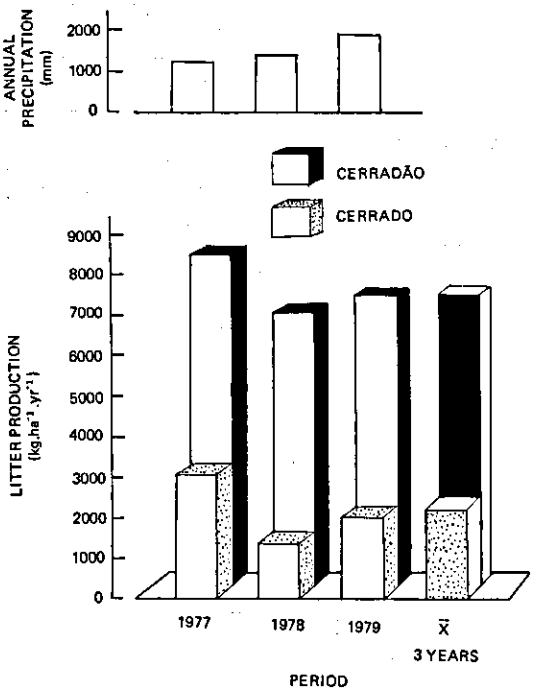

FIG. 2. Average monthly litter production in rainy and dry season.

plants) were the main component of total litter, followed by twigs and stems, in both ecosystems examined (Table 1), independently of the season. Some details about the composition of litter as influenced by season are given in Table 2.

In order to get a preliminary idea about the function of litter as a storage of plant nutrients, subsamples composed of a mixture of predominant litter components were prepared and analyzed for percent nitrogen, phosphorus, potassium, calcium and magnesium content. The results are presented in Table 3.

Litter disappearance rate

The decomposition measurements were carried out during 1977, when total precipitation was 1,270 mm. For each determination the contents of 7-9 bags were weighed and then the means calculated. The yearly decomposition rate of grasses was 7.2% and that of Annonaceae and Leguminosae leaves was 3.3% in Cerradão. The highest monthly rate of litter disappearance occurred in the rainy season (0.7%-1.2% for grasses and 0.5%-0.8% for other plants) and the lowest in the dry months (0%-0.2% for grasses and 0.1%-0.3% for other plants). In Cerrado the rate

TABLE 2. Litter composition as influenced by season. *

Month	Cerradão				Cerrado			
	Total litter kg/ha^{-1}	Leaves	Stems	Flowers and fruits	Total litter kg/ha^{-1}	Leaves	Stems	Flowers and fruits
		Percent of total litter				Percent of total litter		
January	306.1	68.4	30.2	1.4	47.3	67.3	20.3	12.5
February	362.4	53.7	44.9	1.4	51.3	83.5	12.4	4.1
March	559.6	36.6	62.5	0.9	66.2	85.5	7.0	7.5
April	362.0	57.3	40.9	1.8	110.0	87.1	12.1	0.8
May	335.7	67.2	31.6	1.2	135.6	79.8	17.6	2.6
June	455.4	58.9	40.4	0.7	112.2	84.8	12.6	2.6
July	914.6	59.9	39.6	0.5	156.0	87.1	11.1	1.8
August	1,257.1	86.1	13.1	0.8	272.3	89.3	8.7	2.0
September	1,470.0	77.1	21.6	1.3	225.1	82.1	15.1	2.8
October	1,031.5	70.5	27.8	1.7	277.0	69.2	26.1	4.7
November	227.9	64.2	26.7	9.1	478.1	68.0	28.2	3.8
December	568.0	59.9	29.0	11.1	125.0	78.4	20.7	0.9

Data from 1979
* Rainy season: October/April
Dry season: May/September

TABLE 3. Nutrient concentration in litter.

	Nutrient				
	N	P	K	Ca	Mg
			Percent of dry matter		
Cerradão	0.82 (0.58-1.18)	0.06 (0.05-0.07)	0.16 (0.08-0.28)	0.34 (0.19-0.44)	0.14 (0.08-0.21)
Cerrado	0.85 (0.58-1.06)	0.06 (0.05-0.07)	0.16 (0.06-0.28)	0.32 (0.21-0.44)	0.12 (0.07-0.19)

Means from 30 subsamples prepared at monthly intervals from May 1977 through November 1979. In parenthesis, minimum and maximum percent content.

of decomposition was higher: the yearly decomposition of grasses was 16%, and that of the Leguminosae and Vochysiaceae leaves was 14.8%. The highest decomposition rate also was in the rainy season and the lowest in the dry one (1.9%-4.8% for grasses in the rainy months and 0.3%-1.1% in the dry season; the other plants disappeared at a monthly rate of 1.1%-3.2% in the rainy season and 0.7%-0.8% during the dry months) in the Cerrado ecosystem.

DISCUSSION

Circular traps fixed on the soil surface were employed in this work to assess both tree-litter and ground-plant litter production. Among several techniques used by different authors in various ecosystems, this one seems to be well adapted to the structure and phenology of the vegetation in Cerrado areas. No attempt was made to correct the results either for weight losses caused by litter decay between sampling intervals or for litter which was blown out of or into the traps by wind. The slow monthly rate of litter disappearance and the relief of the area, which reduced the effect of wind, made the correction unnecessary. One of the methods to check the reliability of a technique used for the estimation of litter production is to repeat the measurements two or more years in succession (Wiegert & McGinnis 1975). This study was performed for more than three successive years. The yearly results seem to be in good agreement, and suggest reliability of the technique employed.

The mean yearly litter production found in Cerradão during 1977, 1978 and 1979 was 7,800 kg/ha^{-1}. This is a high production, similar to the 7,900 kg/ha^{-1} found in Cerradão - like area in Venezuela (Medina 1966); 7,200 kg/ha^{-1}/yr^{-1} in the Olokemeji forest reserve, Nigeria (Hopkins 1966); 7,400 kg/ha^{-1}/yr^{-1} found in Amazonian "terra firme" forest (Klinge & Rodrigues 1968a, b); 7,000 kg/ha^{-1}/yr^{-1} in Trinidad tropical rain forest (Cornforth 1970); 9,000 kg/ha^{-1}/yr^{-1} in a teak stand in Nigeria (Egunjobi 1974); and 5,900-9,900 kg/ha^{-1}/yr^{-1} in Ivory Coast savanna (Menaut & Cesar 1979). It is higher than the 1,570 kg/ha^{-1}/yr^{-1} found by Singh & Ambasht (1980) in teak plantations at Varanassi (India). Low litter production was found in the Cerrado area: mean 2,100 kg/ha^{-1}/yr^{-1}. There are few data available on litter production in ecosystems similar to Cerrado. Hopkins (1966) found in a savanna site in Nigeria a leaf-litter fall of 900 kg/ha^{-1}/yr^{-1}. However, the data from African savannas - in spite of the physiognomic similarities - are hardly comparable with these from Cerrado, because the Cerrado situation seems fundamentally different from that of the African savannas, mostly because of differences in the moisture status (Goodland & Pollard 1973).

The use of nets made from material resistant to biodegradation to confine litter has become a common practice in the measurements of litter disappearance. According to the dimension of the mesh, different biological agents participate in litter degradation. The application of 2 mm-mesh

bags protects the litter from spillage. However, the small dimension of the mesh restricts the variety of organisms which may participate in litter decomposition to microorganisms and some representatives of meiofauna. This is one of the reasons why the litter bag technique provides an estimate based toward the low side (Wiegert & Evans 1964). Wiegert & McGinnis (1975) compared the litter-bag technique with the paired-plots technique and found that the rate of litter disappearance from the bags was 28%-55% lower than that determined by the paired-plots technique. However, even if a correction based on this estimate is applied, it can be concluded that the monthly rates of litter disappearance were slow in the areas examined. There are very few comparable data on litter decomposition in ecosystems similar to Cerrado areas. Madge (1969) reports that the leaves placed in terrylene bags and buried in the soil remained intact during nine months in Nigeria savanna. Hopkins (1966) found that more leaf-litter was destroyed by fire than by decay in the savanna.

Notwithstanding the slow disappearance rates, litter decomposition returns to the soil considerable amounts of nutrients. The data summarized in Table 3 show that, in spite of physiognomic differences, Cerrado and Cerradão vegetations have almost the same storage ability for different nutrients. Compared with some data on litter composition in other tropical ecosystems it can be concluded that Cerrado and Cerradão litter contain less nitrogen (0.82%-0.85% vs. 1.4%) and slightly more phosphorus (0.06% vs. 0.03%) and calcium (0.32%-0.34% vs. 0.25%) than the litter produced in Amazonian forest (Klinge & Rodrigues 1968a, b). The litter from Trinidad tropical rain forest contains more calcium (0.92% vs. 0.32%-0.34%) and magnesium (0.21% vs. 0.12%-0.14%) than Cerrado and Cerradão litter (Cornforth 1970).

A botanical evaluation suggests that both Cerrado *sensu strictu* and Cerradão have to be classified as components of one big group of Cerrado ecosystems (Ferri 1977). Several families, genera and species found in Cerradão are also commonly present in other categories of Cerrado, but rarely in other woodland-like plant communities. Most of the trees and shrubs growing in different categories of Cerrado have similar characteristic features such as sclerophylly and deep root system; the trees in Cerrado communities are short and their trunks and branches are tortuous. However, notwithstanding the botanical similarities, there is a considerable physiognomic difference between the dense Cerradão vegetation and the scattered Cerrado vegetation, and this difference is obviously reflected by the differences in litter production. The causes of this significant difference are not clear. The distance between the two areas examined is about two kilometers and the climatic conditions are very similar in Cerrado and Cerradão; these factors can not be responsible for the differences in productivity.

Goodland & Pollard (1973) compared the nutrient levels in soils (fertility gradients) with the physiognomic gradients (density of trees = = , basal area of trees in cm^2/ha^{-1}) in different categories of Cerrado. They found a strong correlation between the basal area of trees and N, P and K content in soil, but not with pH, % C, Ca + Mg, Al and % clay. The authors suggested that the physiognomic gradients of Cerrado vegetation parallel the fertility gradients. The results obtained in this work using not density of trees but litter production as an indicator seem to support this suggestion.

Little is known about the origin, state and transformation of Cerrado ecosystems. There are some hypotheses but they are based rather on suppositions than on experimental data. Some authors suggest that measurements of litter production can be helpful to characterize the state of a given ecosystem. According to Wiegert & Evans (1964), in an ecosystem approximating a steady state there are practically no year-to-year changes in litter production. The percent difference found in this work between the amounts of litter produced in 1977 vs. 1978 is 17%, 1977/1979 - 8% and 1978/1979 - 10%, in Cerradão. In Cerrado, the differences are 52%, 28% and 33% for 1977/1978, 1977/1979 and 1978/1979, respectively.

The differences in yearly litter production and the observed transformation of vegetation suggest that the Cerrado ecosystems are still far from a steady state and that a significant difference exists

between the state of Cerrado and that of Cerradão.

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