



## Nutrient stock and litter decomposition in riparian forests on Cerrado biome in Coxim municipality - MS, Brazil<sup>1</sup>

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**Abstract:** Litter is considered as one main key component in functioning process of forest ecosystems. Based on this, the objective of this study was to evaluate whether leaf litter decomposition dynamics correlate with environmental variables and can be used as an environmental indicator of nutrient cycling in two riparian forest sites (“Córrego Criminoso” site and “Rio Taquari” site), located in Cerrado biome, in Coxim municipality – MS, Brazil. For decomposition rates and nutrient content evaluation in litter, freshly fallen leaves were collected and submitted to weighed and stored in 30 litterbags (25 cm x 25 cm) for each site, which were later randomly distributed in soil surface. Nutrient chemical evaluation was performed from litter in sites to analyze Cu, Ca, Fe, Mg, Mn, K nutrients. The remaining leaf mass in both sites was equivalent at the end of 150 days of study, with a percentage of 74.4%. Leaf fraction decomposition showed higher correlations with air temperature than with pluviometric precipitation. The “Rio Taquari” site presented lower nutrient concentration for Cu, K and Fe when compared to “Córrego Criminoso” site. Litter correlated with climatic variable (air temperature) and was an environmental indicator of nutrient cycling in riparian areas in Cerrado.

**Keywords:** Nutrients; Remnant mass; Environmental variables

### Estoque de nutrientes e decomposição de serapilheira em matas ciliares do bioma Cerrado em Coxim - MS, Brasil

**Resumo:** A serapilheira é considerada como um dos principais componentes-chave no processo de funcionamento dos ecossistemas florestais. Com base nisso, o objetivo deste estudo foi avaliar se a dinâmica de decomposição de serapilheira foliar se correlaciona com variáveis ambientais e pode ser empregada como indicadora ambiental da ciclagem de nutrientes em duas áreas de matas ciliares (Área Córrego Criminoso e Área do Rio Taquari), localizadas no bioma Cerrado, no município de Coxim – MS, Brasil. Para a avaliação das taxas de decomposição e teores de nutrientes na serapilheira, foram coletadas folhas recém-caídas, posteriormente submetidas à secagem, pesagem e acondicionamento em 30 *litterbags* (25 cm x 25 cm), distribuídos aleatoriamente na superfície do solo em cada área de estudo. Da serapilheira acumulada em cada área, realizou-se a análise química dos nutrientes Cu, Ca, Fe, Mg, Mn, K. A massa remanescente foliar foi equivalente em ambas às áreas, ao final dos 150 dias de estudo, detendo de um percentual de 74,4%. A decomposição da fração foliar teve maior correlação com a temperatura do ar do que com a precipitação pluviométrica. Na serapilheira na Área Rio Taquari houve menores concentrações de nutrientes Cu, K e Fe quando comparada à Área Córrego Criminoso. De modo geral, a serapilheira se correlacionou com variável ambiental (temperatura do ar) e pode ser considerada uma indicadora de ciclagem de nutrientes em áreas de matas ciliares no Cerrado.

**Palavras - chave:** Nutrientes; Massa Remanescente; Variáveis ambientais

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## Introducion

The human activities development has brought problems with forest resources, mainly how to keep them ecologically balanced (ARAÚJO, FARIAS and LEAL, 2008). Any anthropic activity, in its general aspects, causes an environmental impact that directly or indirectly affects the health, safety, well-being of the population, biota, economic and social activities (CUNHA and SUARTE, 2017).

Front environmental degradation, it is necessary to adopt techniques aimed at ecosystem restoring, so that it may have resiliency to regain his balance, and eventually be restore itself without additional incentives. Restoration is defined by Law 9,985, in its art. 2, as “degraded ecosystem restoration or wild population as close as possible to its original condition” (BRASIL, 2000). For restoration process are used some techniques to recover degraded areas, such as natural regeneration, direct planting of forest seedlings or direct seeding of forest native species (Souza, 2014), aimed at environmental and forest succession restoration. Independent of technique employed, in degraded areas it is necessary to restoration process monitoring, for observed positive or negative results about the environment restoration. This monitoring can be carried out using environmental indicators.

Litter is a possible environmental indicator (ARATO, FERRARI and MARTINS, 2003), because it consists in layer of residues on the soil, where material deposition and accumulation occurs that will be transformed into organic matter. The litter is formed mainly by leaves, seeds, branches, fruits, reproductive structures, bark, among other residues that contribute to nutrient reservoir, with fundamental function in ecosystem sustaining by nutrient cycling (SOUZA, 2014; GARCIA et al., 2011).

Nutrient cycling has already been categorized by “Millennium Ecosystem Assessment” as an ecosystem support service that is, related to natural mechanisms necessary for other services existence (provision,

regulatory and cultural services). Litter represents an important link in organic production-decomposition cycle, regulator acting on soil surface of mineral input and output processes, receiving carbon and nutrients via vegetation (input), and supplying the soil and roots with nutrients and organic matter (output) (SOARES and FROUFE, 2015).

The decomposition of litter has a fundamental role in ecosystem process, since it provides nutrients for biota, contributing to soil fertility and productivity, in addition to part promoting the carbon dioxide dissipation (SHEER, 2008). The dynamics of decomposition comes from decomposing microorganisms action, biochemical aspects and environmental conditions. These processes promote progress in succession actions, as they create adaptation conditions for other plant species.

The nutrient cycling provides subsidy to preservation the forest ecosystems conditions and the objective of this study was to evaluate whether the dynamics of leaf litter decomposition correlates with climatic variables and can be used as an environmental indicator of nutrient cycling in two forest sites (“Córrego Criminoso” and “Rio Taquari”) of Cerrado biome, in Coxim municipality - MS, Brazil.

## Material and methods

### *Study sites*

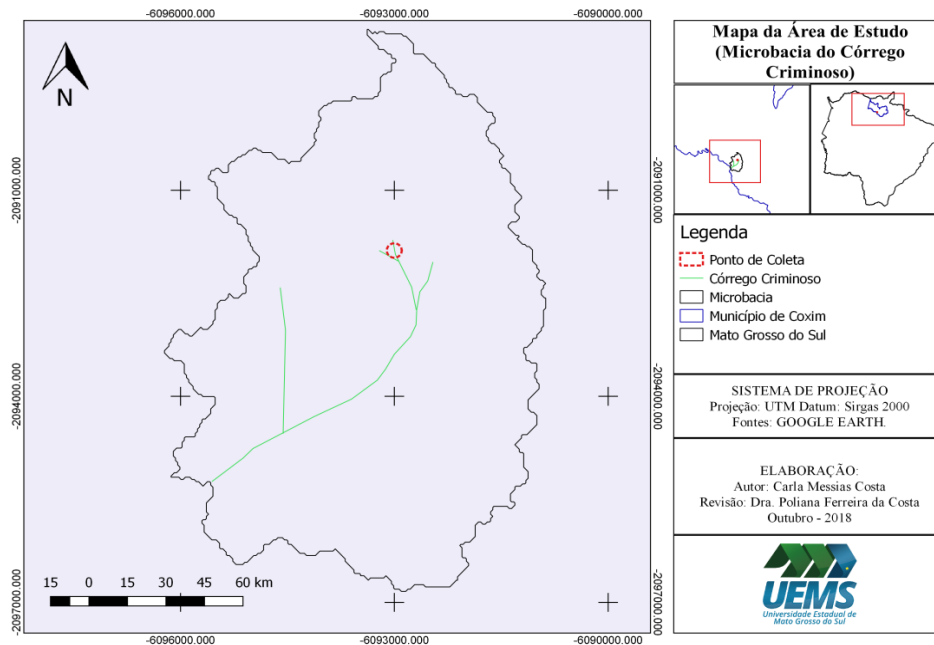
The first study site is nominated “Córrego Criminoso” (CC) and is located in rural area of Coxim municipality – MS, Brazil (Figure 1), in a watershed that has an extension of 28,815 km<sup>2</sup>. The site is located between the central geographic coordinates of 20°57'37''S and 55°52'28''O (BROCH, MEDEIROS and SOUZA, 2008). The stream is a right margin of Taquari river affluent.

The second study site is nominated “Rio Taquari” (RT) comprises the area belonging to the 47th Infantry Battalion (47° BI), the

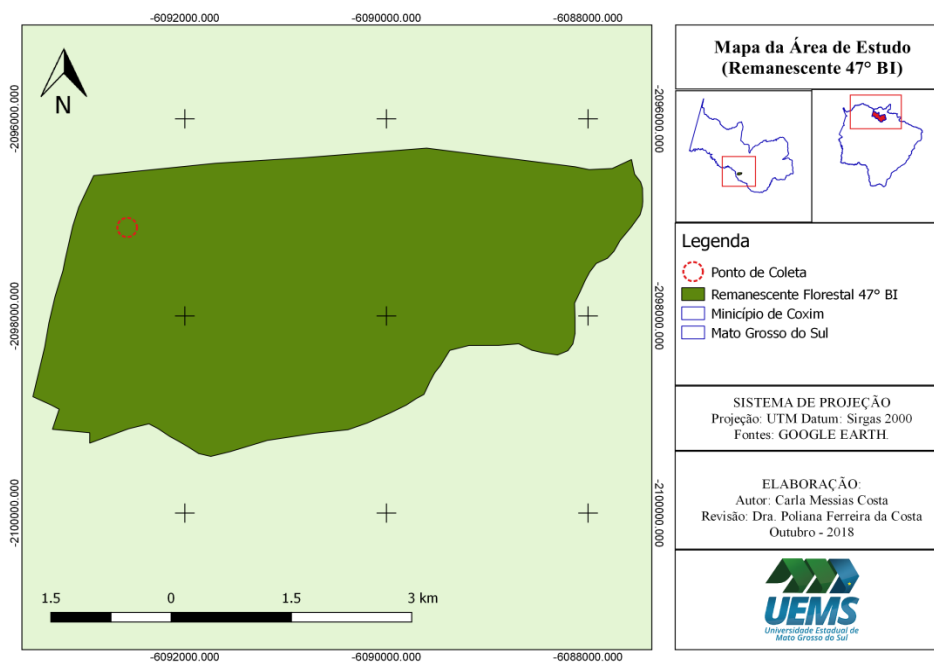


Sertanist Battalion Domingos Gomes Beliago (Figure 2), also located in Coxim municipality-MS, Brazil, on urban perimeter, in southern

region, close to principal Taquari river course margins, being under the central geographic coordinates of  $18^{\circ}30'48''S$   $54^{\circ}44'03''O$ .



**Figure 1.** Location map of “Córrego Criminoso” site.  
**Figura 1.** Mapa de localização da área Córrego Criminoso.



**Figure 2.** Location map of “Rio Taquari” site.  
**Figura 2.** Mapa de localização da área Rio Taquari.

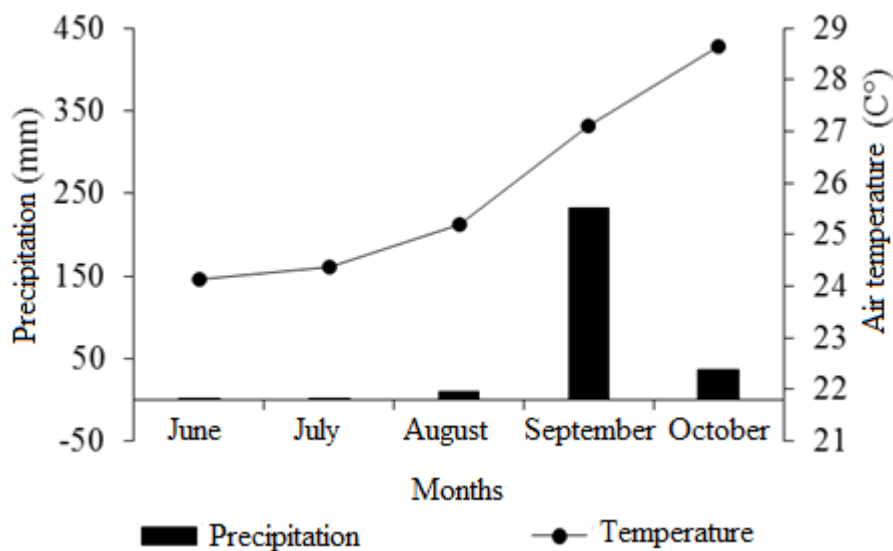
The study sites are in direct contact with urban perimeter of Coxim municipality and, with urbanization advance, they are increasingly pressured by anthropization. However, they constitute an ecological corridor for fauna, linking two phytogeographic domains, Pantanal and Cerrado, since they are areas located in Cerrado, but this is a transition region between two biomes.

The CC site is a riparian forest of “Córrego Criminoso”, right margin affluent of Taquari river. The RT site corresponds to riparian forest of Taquari river itself, but 5.0 km upstream of CC site. These water courses are part of Paraguay river watershed.

The soil texture aspects in sites are predominantly sandy, typical of Cerrado biome soils (GALDINO, 2012). The air temperature

variation observed during the study period reached a maximum of 28.6 °C in October and a minimum in June with 25.1 °C. It was also noted that there was an exponential rise in air temperature over the study period (Figure 3).

Precipitation was abundant in September, reaching rainfall levels of 232.86 mm, followed by October with considerable 37.19 mm; the lowest rainfall indexes were recorded in July (0.88 mm), June (1.72 mm) and August (9.34 mm) (Figure 3). According to data obtained from IBGE (1990), the region climate is sub-humid to semi-arid, characterized by two months of water surplus, usually between November to January, and six months of water deficiency that occurs from May to September (IBGE, 1990).



**Figure 3.** Precipitation and air temperature in Coxim municipality – MS, Brazil, referring to experimental period, 2018. Source: Agritempo, 2018.

**Figura 3.** Precipitação pluviométrica e temperatura do ar do município de Coxim – MS, Brasil, durante a condução do estudo, no ano de 2018. Fonte: Agritempo, 2018.

### *Analysis of nutrient stock in litter*

The litter samples collection was carried out in March 2018, with a 0.5 m x 0.5 m. All organic material was collected and stored in paper bags. Ten litter samples were collected in each site. All litter samples were oven-dried at 65 °C to constant weight and leaves, branches,

residues were triturated (SCORIZA et al., 2012; PAULA, PEREIRA and MENEZES, 2009) for nutrients analysis.

Amount of 0.5 g of each sample went through the digestion process, in *OneTouch “Plant material”* microwave digester. Then was added 10 mL of HNO<sub>3</sub> (65% v/v). After acid adding, pre-digestion was performed in water



bath at 60 °C, for 20 min, with open tubes. After water bath, tubes were properly capped and shelf placed inside the digester. Then *OneTouch* “*Plant material*” method was selected (CEM Corporation, USA). The heating method program keeps the samples on a ramp for 15 minutes until reaching of 210 °C temperature, using 900 W of power, followed by 15 minutes waiting time at 200 °C temperature and a pressure of, approximately, 800 psi and, finally, 15 minutes of cooling.

After cooling, samples were filtered and measured with ultrapure water in 25 mL volumetric flask. The nutrients copper (Cu) calcium (Ca), iron (Fe), magnesium (Mg), manganese (Mn) and potassium (K) were determined using an atomic absorption spectrometer equipped with flame atomizer and hollow cathode lamp.

#### *Litter decomposition analysis*

Litter decomposition evaluation rate was carried out between March and October 2018. The litter recently fallen on forest floor, inside the sites was collected and sent to laboratory for leaf fractions separate (VIERA, SCHUMACHER and ARAÚJO, 2014). Consequently, the material was a drying in oven at 65 °C, until constant weight was reached and later placed in decomposition bags (litterbags). Were considered 10 g of leaf fraction stored in each litterbag (LIMA et al., 2015), weighed on a precision semi-analytical balance (0.01 g).

In each site, 30 litterbags were randomly distributed (PEREIRA et al. 2012). Litterbags were made of polyvinyl mesh with 2 mm and 25 cm of side, distributed in area of 200 m<sup>2</sup> approximately, placed in soil level for simulate the natural fall of material that litter composes. The litterbags were tied with nylon lines on tree trunks and experiment nameplates, in order to prevent their displacement by animal action, rain and/or wind.

To decomposition rate estimate in two study sites, the litterbags were installed on 18 March 2018, in collections carried out at regular

intervals of 30, 60, 90, 120 and 150 days (LIMA et al., 2015), with six repetitions in each site.

In each period samples collected were carefully removed, in order to avoid material loss, packed in plastic bags and identified for forwarding to laboratory. Subsequently, the samples were submitted to cleaning process, with help of brush to remove soil particles and adhered residues that did not correspond to leaf fraction. Subsequently, materials contained in each litterbags were transferred to identified paper bags for drying in an oven at 65 °C, for a period of 72 hours, or until a constant mass.

Leaf fraction was weighed on a precision semi-analytical balance (0.01 g), to remaining dry matter mass obtain and, from it, decomposition rate was estimated (SCORIZA et al., 2012). Remaining litter mass was quantified using the Equation 1:

$$\text{Remaining mass (\%)} = \frac{\text{final mass}}{\text{initial mass}} \times 100 \quad (1)$$

After calculating the remaining mass, decomposition constant *k* was calculated, according to adjusted exponential model proposed by Olson (1963) (Equation 2).

$$X = X_0 \times e^{-kt} \quad (2)$$

Where *k* = constant of decomposition; *X* = amount of dry matter remaining after a *t* time period (days); *X*<sub>0</sub> = initial dry material weight.

Half-life (*t* ½) corresponds to time required for litter half initial fraction contained in litterbag to be completely decomposed, estimated by the formula (Equation 3):

$$t \frac{1}{2} = \ln(2)/k \quad (3)$$

Where *k* is a constant calculated by Equation 2.

The data were submitted to variance analysis (ANOVA) and when *F* test was significant, Tukey test was applied at 5% error probability level. Analyzes were used in order to detect differences between nutrients concentrations contained of litter in the two study sites.

Correlations for constant of decomposition ( $k$ ) and half-life ( $t_{1/2}$ ) were performed, in addition to litter decomposition and environmental variables (rainfall and air temperature), based on Pearson's simple linear coefficient ( $r$ ), using R software. Pearson's correlation test can have values ranging from -1, 0 and 1, being cataloged according to Callegari-Jacques (2003), as follows: 0.00 to 0.30: weak correlation; 0.30 to 0.60: moderate correlation; 0.60 to 0.90: strong correlation; 0.90 to 1: very strong correlation and perfect negative linear correlation ( $r = -1$ ).

Environmental variables data come from Agritempo meteorological monitoring system

in Coxim municipality – MS, Brazil, collected during the study period.

## Results

### *Nutrients concentrations in litter*

Nutrients concentrated in litter follows magnitude increasing order of Cu, K, Mg, Fe, Ca and Mn (Table 1). There were significant differences in nutrients concentration between the sites, especially for Cu, K, Fe and Ca elements. Only Mg and Mn concentrations do not differ between sites.

**Table 1.** Means nutrients concentrations in litter in two riparian forests of Cerrado biome, Coxim municipality, MS, Brazil.  
**Tabela 1.** Concentrações médias de nutrientes na serapilheira acumulada em duas matas ciliares no bioma Cerrado, Coxim, MS, Brasil.

Site	Cu	K	Mg	Fe	Ca	Mn
	g kg <sup>-1</sup>					
CC	3,51 b	74,47 a	51,62 a	473,05 a	748,66 a	606,53 a
RT	7,46 a	10,97 b	42,77 a	294,22 b	241,21 b	626,59 a
C.V (%)	18,24	46,37	15,43	13,25	49,90	23,38

\*Means followed by same letters in column do not differ by Tukey's test ( $p < 0.05$ ). CC = "Córrego Criminoso" site; RT = "Rio Taquari" site; C.V. = coefficient of variation.

The nutrients in litter with lower concentrations were Cu, K, and Mg. The latter (Mg) still showed statistically similar results between sites ( $p < 0.05$ ), with 51.62 g kg<sup>-1</sup> for CC and 42.77 g kg<sup>-1</sup> in RT, with low value coefficient of variation, about 15.43%, indicating low data variability in relation to samples means. In litter the nutrient Fe was found in high concentrations, showing a statistical difference between CC (473.05 g kg<sup>-1</sup>) and RT (294.22 g kg<sup>-1</sup>) sites. The Ca contents, in relation to other evaluated nutrients, showed high concentrations and were statistically different between sites, with higher concentrations in litter of CC site (748.66 g kg<sup>-1</sup>).

As for Mn content in litter of two riparian forests, it was noted that values are statistically similar ( $p < 0.05$ ) between sites and are in higher concentrations when compared to other

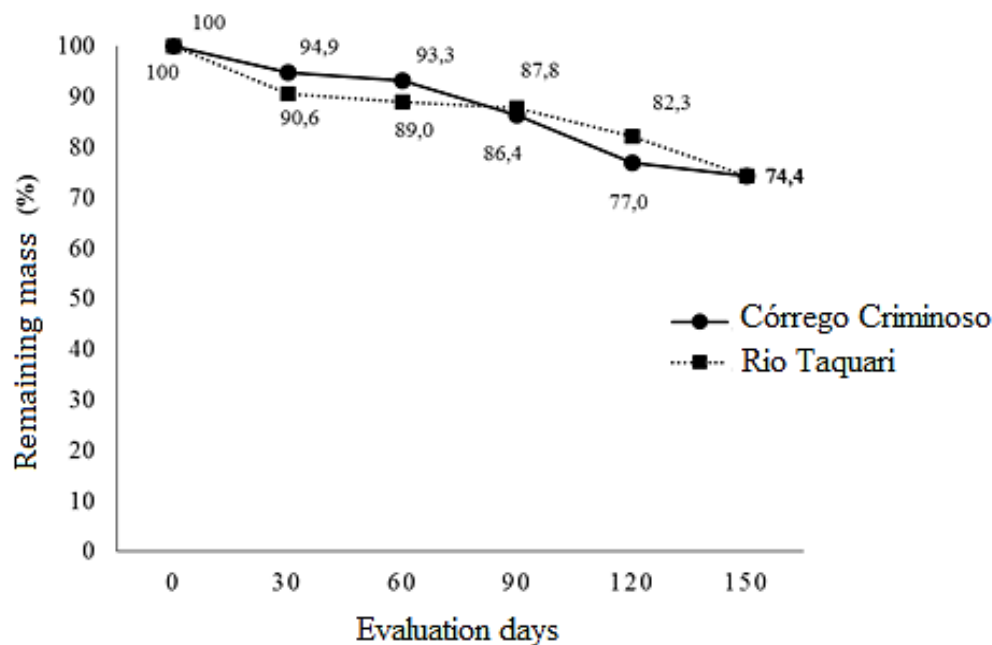
elements, where for "Córrego Criminoso" site a Mn concentration was 606.53 g kg<sup>-1</sup> and for "Rio Taquari" site it was 626.59 g kg<sup>-1</sup>.

Generally, litter of "Córrego Criminoso" riparian forest was highest concentrations of four (K, Mg, Fe and Ca) in six (Cu, K, Mg, Fe, Ca and Mn) nutrients evaluated in relation to "Rio Taquari" site.

### *Litter decomposition*

The leaf mass decomposition rate, in both sites, showed similar results at 150 days end, that is 74.4% of remaining material. However, it was observed that in period from 0 to 30 days, decomposition speed was faster and higher in Rio Taquari site, with 9.4% fall of remaining mass, while in CC site was 5.1% of material reduction (Figure 4).





**Figure 4.** Remaining leaf mass after 150 days, in two riparian forests in Cerrado biome, Coxim municipality, MS, Brazil.  
**Figura 4.** Massa foliar remanescente após 150 dias, em duas matas ciliares no bioma Cerrado, Coxim, MS, Brasil.

From 30 to 60 days, in both sites, decomposition speed was lower, reducing 1.55% in CC and 1.57% in RT. From 60 to 90 days, decomposition was more effective in “Córrego Criminoso” site and, in both sites, decomposition speed increased in period from 90 to 120 days, corresponding to 9.40% for CC site and 5.58% for RT. At 150 days the decomposition speed stabilized, with 74.40% remaining for both sites, which corresponded to 25.65% of total litter decomposition.

It is noted that there is a similar behavior between sites with respect to constant of decomposition ( $k$ ) values, where in “Córrego Criminoso” site the rate was  $0.0023 \text{ g g}^{-1} \text{ day}^{-1}$ , a value slightly higher than that observed in “Rio Taquari” site ( $0.0020 \text{ g g}^{-1} \text{ day}^{-1}$ ) (Table 2). However, when half-life analyzing in each riparian forest, it is possible to significant difference verify, where time to litter

decompose in CC site is greater, that is, the material was more decomposition resistant (592.30 days) when compared to RT.

When Pearson correlation ( $r^2$ ) considering for each site, it is noted that there is a satisfactory correlation between two variables (constant of decomposition  $k$  and half-life), that is, when one variable increases the other tends to decrease, this correlation being stronger in CC (-0.98539), in detriment to RT (-0.89256).

It is noted that remaining mass showed a strong correlation, mainly with air temperature in both sites, and for “Rio Taquari” there was - 9.861 of perfect negative linear relationship, and for “Córrego Criminoso” the -0.9734 correlation was also perfect negative linear (Table 3). Therefore, when air temperature is higher as found in region during study period, remaining mass rates lower.

**Table 2.** Constant of decomposition ( $k$ ) and half-life ( $t_{1/2}$ ) of litter after 150 days, in two riparian forests in Cerrado biome, Coxim municipality, MS, Brazil.

**Tabela 2.** Constante de decomposição ( $k$ ) e tempo de meia-vida ( $t_{1/2}$ ) da serapilheira após 150 dias, em duas matas ciliares no bioma Cerrado, Coxim, MS, Brasil.

Sites	Constant of decomposition ( $k$ ) ( $g\ g^{-1}\ day^{-1}$ )	Half-life time ( $t_{1/2}$ ) (days)	Pearson correlations ( $r^2$ )
CC	0.0023	592.30	-0.89256
RT	0.0020	362.86	-0.98539

Where: CC= "Córrego Criminoso" site; RT = "Rio Taquari" site.

**Table 3.** Pearson correlations ( $r^2$ ) between environmental variables in relation to litter remaining mass in two riparian forests in Cerrado biome, Coxim municipality, MS, Brazil

**Tabela 3.** Correlação de Pearson ( $r^2$ ) entre as variáveis ambientais em relação à massa de serapilheira remanescente em duas matas ciliares no bioma Cerrado, Coxim, MS, Brasil.

Site	Precipitation (mm)	Air temperature ( $^{\circ}C$ )
CC	-0.6135*	-0.9734*
RT	-0.3578*	-0.9861*

\*Perfect negative linear of Pearson correlation ( $r = -1$ ); CC= "Córrego Criminoso" site; RT = "Rio Taquari" site.

## Discussion

### *Nutrients amount in litter*

In relation to nutrients concentrations in litter (Table 1), Sheer (2008) also evidenced in his studies with litter, in an Atlantic Alluvial Dense Rainforest in natural regeneration, K and Mg lower contents. These macronutrients can have low concentrations in litter due to rapid cycling characteristics.

The low values of K and Mg, found in relation to other elements of the litter, can also be explained due to the lower concentrations available in the soil, which are the result of the high pH that directly influence the disposition of nutrients in the absorbed plants (VIERA and SCHUMACHER, 2010). These authors also point out that these nutrients are leaching susceptible, which can also contribute to low levels in litter.

The significant levels of Fe concentrations in litter, when compared to other nutrients, can occur because that nutrient has a considerable concentrations present in leaves, when compared to other plant components

(CALDEIRA et al., 2007). High Fe concentration in litter is also result of high soil Fe concentrations, as samples can be contaminated with soil particles by adhering to plant material (VIERA and SCHUMACHER 2010; CALDEIRA et al., 2008).

Calcium also showed high concentrations in litter, in the two riparian forests of Cerrado. According to Borém and Ramos (2002), this occurs due to slower liberation of this element from newly fallen material, due to other elements retranslocation before abscission and, or as a consequence of calcium retention contained in throughfall.

Values of Manganese have a most expressive contribution in both sites (Table 1). The high levels of Mn in litter can be justified by trees age. When the plant age advance, Mn concentration in leaves is higher, there is a small portion of element translocated from old to new leaves in growth, where nutrient is in smaller proportions concentrated (HEENAN and CAMPBELL, 1980). In addition, Mn can present in high levels when subjected to interaction with acidic soil, possibly due to higher solubility characteristic of compounds,





facilitating the Mn absorption by the plant (MALAVOLTA, VITTI and OLIVEIRA, 1997).

As mentioned in results, four of the six nutrients evaluated in this study were more concentrated in litter of “Córrego Criminoso”. Although the riparian forests evaluated were disturbed, degraded and are currently in being restored process, higher levels of nutrients in litter may be due to alluvial forest and palm swamp areas characteristics. These factors possibly performance influenced and soil organic matter supply, consequently, express the nutrients concentrations in litter.

### *Litter decomposition*

In 30 days of initial evaluation, there was an increase in litter decomposition speed (Figure 4). Silva et al. (2014) observed that there was a litter loss of 17% in native forest after two months, and at the end of 180 days there was a 66.01% remaining leaf mass loss. High decomposition in first 30 - 60 days is generally associated with less resilience of nutrients, which are leached out more easily.

Although this rapid decomposition occurred in first 30 days, it was also found that speed at which litter mass remaining is slow decomposed in riparian forests of Cerrado, as over 50 days 50% of leaf fraction has not yet been decomposed. Decomposition processes are limited by microorganisms action and these, in turn, are also limited by nutrients presence such as P and N. The slow litter decomposition in Cerrado forests may be due to soil characteristics, such as lower P concentrations, which limit microorganisms presence that decomposition process responsible (SILVA, 2009).

Paula, Pereira and Menezes (2009) in their study of three forest fragments periodically awash in “Ilha da Marambaia”, Rio de Janeiro state, found constant of decomposition (k) values of  $0.0028 \text{ g g}^{-1} \text{ day}$ ,  $0.0032 \text{ g g}^{-1} \text{ day}$  and  $0.0031 \text{ g g}^{-1} \text{ day}$ , time being  $t \frac{1}{2}$ , of 247 days, 217 days and 223 days, respectively, showing a

faster and shorter decomposition and half-life, respectively, than those found in this study (Table 2).

The lowest decomposition rates found in two riparian forests in this study are possibly due to anthropic interference processes, caused by past use and these areas occupation. These factors may have conditioned lower litter decomposition rates, as they interfere with forest conservation degree and, consequently, in microorganisms action, given that they need some basic factors to process optimize.

As for Pearson's correlation considering air temperature and rainfall variables (Table 3), there may be perfect negative linear correlation ( $r = -1$ ) or perfect positive correlation ( $r = 1$ ) or, even, linear relationship absence ( $r = 0$ ) (CALLEGARI-JACQUES, 2003). In this study, Pearson's correlation indicated values for two sites close to -1, mainly for air temperature, which showed greater proximity to -1 in its correlation with decomposition. That is, when air temperature was higher, there was less leftover litter mass. Schumacher (1992) argues that high temperatures positively influence the decomposition, admitting that greater this variable, greater the mass loss of remaining material.

According to Luizão and Shubart (1987), pluviometric precipitation directly influences the process and speed decomposition, considering that this environmental variable stimulates the decomposing organisms action. During conduct of this study, there were considerable rainfall volumes, being higher in September (232.86 mm) and October (37.19 mm), which may have contributed to this positive interaction with decomposition.

The nutrients concentrations analyze in litter, as well as remaining material decomposition rates, in different riparian forests demonstrated the different behaviors in “Córrego Criminoso” and “Rio Taquari” sites. The sites have distinct characteristics, considering that RT suffers greater edge effects compared to CC, which may have contributed to different responses. In “Córrego Criminoso” site, despite suffering interference with anthropic activities and being



degraded, it is still possible to find a better nutritional litter quality compared to “Rio Taquari” site, possibly due to alluvial characteristic and developed of anthropic activities in area, such as livestock that may be contributing, through animal waste to considerable nutrients concentrations.

## Conclusions

The leaf litter decomposition dynamics correlates with environmental variables and can be used as nutrient cycling environmental indicator in riparian forest areas of Cerrado biome.

The leaf fraction decomposition showed greater correlations with air temperature than with rainfall, due to high temperatures in some times of the year in region, which favors the decomposition process by microbiological activity stimulating.

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