CARBON CONTENT ESTIMATION IN AN AQUATIC ECOSYSTEM CASE STUDY THROUGH THE PROCESS OF LEAF LITTER DECOMPOSITION

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Plant litter decomposition varies depending on species and environmental conditions. The decomposition rates of plant litter were monitored for two common types of vegetation (Phragmites australis and Cattails) in the Dambovita River to determine the proportion of labile and recalcitrant fractions of the decomposition. Biological control of decomposition was witnessed through home-field advantage, in which decomposition in aquatic environments was applied through the litter bags that were submerged in-situ. The study showed that the magnitude of fraction-specific from decomposition rates was considerably higher in the first stage, followed by a decreasing trend of the labile fraction for both species.

Keywords: litter bags, wetland, vegetation, carbon

1. Introduction

Scientific community recognized the proofs demonstrating that greenhouse gases are responsible for the increase of mean global temperature, also causing effects of climate changes. The actions to mitigate the effects of climate changes are related to diminishing the emissions and to absorb greenhouse gases from atmosphere [1]. Land use land use change and forestry are one of the National Greenhouse Gases Inventory Sectors with potential to balance the anthropological emissions as is targeted by Paris Agreement [2,3].

Rivers are the landscape's arteries, connecting and sustaining a varied range of freshwater wetlands, such as lakes, inland deltas, swamps, and marshes. Therefore, as part of LULUCF sectors, streams and rivers provide significant

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services to people and their ecological integrity involves structural and functional quality. The main possible indicators of river functional integrity are organic matter decomposition and ecosystem metabolism, which are seldom taken into account in a stream's CO_2 flux assessment [4]. Their carbon cycle is an important component of the global carbon cycle, and litter decomposition is the main source of wetland carbon. Thus, rivers transfer a large quantity of carbon from terrestrial catchments to the ocean, with organic carbon (OC) accounting for 40%-60% of the total carbon [5,6]. This type of ecosystems is considered important carbon sinks for mitigating climate changes, but the sequestration processes and regulations of climate factors on controlling the variability of carbon fluxes of these ecosystems may differ [7].

The relationship between production and decomposition determines whether a system is a pool or a source of atmospheric CO_2 [8]. Litter decomposition is an important process in wetland ecosystems for converting vegetation carbon to soil surface organic carbon, and litter carbon storage has a considerable impact on soil surface organic carbon [9]. Also, litter from marginal vegetation is an important source of dissolved organic carbon for rivers and lakes, as well as a key source of energy and nutrients for aquatic ecosystems [10]. Plant litter decomposition and its carbon storage and removal varies depending on species and environmental conditions [11]. Through the leaching process, litter decomposition breaks down dead organic material into smaller particles, mineralizing them into H_2O, CO_2, and mineral components, forming recalcitrant compounds and potentially leaching dissolved organic carbon into the soil [12].

In this paper, the litter decomposition rate is determined in the study area of the Dâmbovița river, upstream of the reservoir, in order to compare the loss of vegetation mass between two common species in temperate aquatic ecosystems and the estimation of organic carbon in the litter layer.

2. Materials and Methods

2.1. Site description

This study was conducted in south-eastern Romania, in the Dambovita River, outer district of Bucharest, upstream of an accumulation lake.

Fig. 1. Spatial representation of the measurement plots

Within this location, two types of vegetation, *Phragmites australis* and *Cattails*, were collected in the autumn season, given that these are the most common plant species along the river basin in the selected area. In order to approximate the natural conditions, the vegetation was cut in the drying phase, but while it was still standing, in order to capture the whole process of its degradability. To minimize differences in litter quality, each species was collected from the same area.

2.2. Litter bag method

The litter bag method is the predominant method reported for estimating litter decomposition rates, both in terrestrial and wetland environments. This involved placing an equal amount of 10g of green biomass in fabric litter bags [13] and then examining the temporal pattern of weight loss with a series of collections over a four-week period [14]. Thus, a total number of 40 litter bags were placed in-situ, in the aquatic environment, 10 for each of the two studied vegetation species. The leaves for each bag were chosen to contain both the lower part, which is thicker, and the upper part, which is thinner, so that the content was not homogeneous [15]. Afterwards, the bags were grouped by 5, with leaves from each vegetation species, and submerged to minimize any hydrophobic effect that the mesh they were made from might have caused. After the weekly collection, the leaf litter was transported to the laboratory where it was dried in an oven at a constant temperature of 65 °C [16,17] for about five days until a constant mass was reached, the mass was noted, then the litter was ground until a powder resulted.

The decomposition rate of organic matter during the study period was calculated based on a double exponential decay model [18], especially applied to understand nutrient cycling and carbon release in environments such as wetlands, where litter decomposition occurs in several phases.

$$Wt = Ae^{-k1t} + (1 - A)\, e^{-k2t} \tag{1}$$

Where:

Wt = the percentage of litter weight remaining at time t; A = the portion of labile material relative to the total mass; $1-A$ = the ratio of recalcitrant materials to total mass; $k1$ = the decay rate constant for the labile fraction; $k2$ = the decay rate constant of the recalcitrant fraction; t = time since decomposition started (days).

Thus, the decomposition rates of each litter fraction were determined, this being influenced by different aspects of the functional diversity of the litter. Because litter contains both labile and recalcitrant components, the decomposition of plant biomass was studied in two phases in the present study. The labile fraction was determined in the first stage, which is lost mostly through the passage of water through the litter during the initial stages of decomposition, and the recalcitrant fraction was determined after drying in the second stage.

2.3. Collection of litter samples from the soil surface

The field collection of samples from the litter horizon was carried out according to the methodology from the specialized literature, at 1m between each sample plot. The litter consisted of *Salix Sepulcralis Chrysocoma* leaves and dead wood derived from it in total proportion. It was considered necessary for each plot to collect five samples from the litter horizon, inside a square frame of 20 cm. At the same time, mineral debris and stones were removed, as the organic matter inside the frame was collected.

To convert the green mass into dry mass, the litter samples were dried at a temperature of 65 °C for a period of 72 hours. The quantification of organic carbon was obtained for each component separately (leaves and wood) using the expeditious method proposed by several authors [19], by multiplying the amount of organic matter in a dry state by the conversion factor 0.5. The result obtained was expressed in tons per hectare.

3. Results and discussion

3.1. *Phragmites australis*

Fig. 2 shows the values of the litter mass composed of the *Phragmites australis* species after its collection from the study area and the labile fraction of the material. An initial phase of rapid decomposition occurred during the first 10 days. This was followed by a long phase of relative inhibition of decomposition between days 20-30. Finally, a third stage consisted of the significant loss of mass that occurred because of the massive deposition of organic material and invertebrate microorganisms on the litter bags.

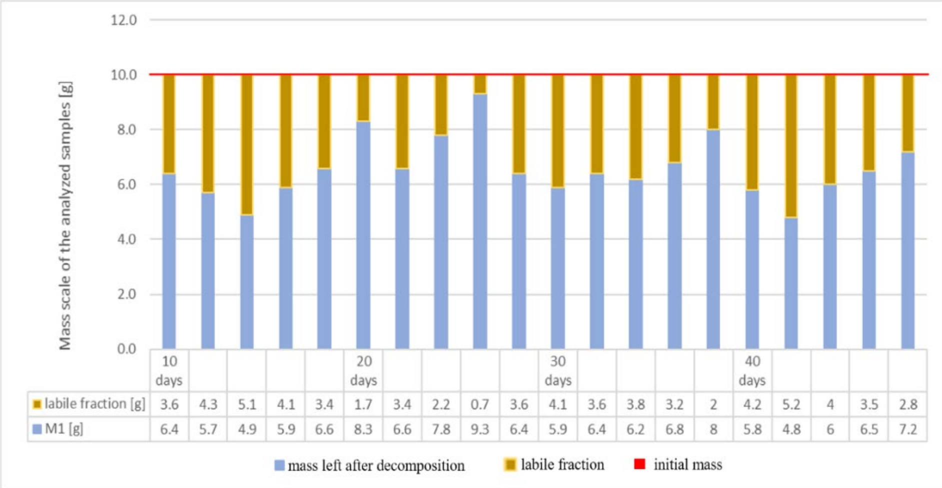

Fig. 2. The values of the labile fraction and of the litter mass collected for the species *Phragmites australis*

The values of the recalcitrant fraction and the final mass of the litter after drying are shown in Fig. 3. Thus, the recalcitrant fraction had values between 1.2g and 0.7g in the first 20 days, and in the last 20 days it stabilized at values between 0.3g and 0.5g. The last stage of stabilization of the recalcitrant fraction indicates that the inactive fraction of carbon in the litter can be affected by the input of deposited organic material and makes it difficult to specify the short- and long-term impact of this input on C stocks.

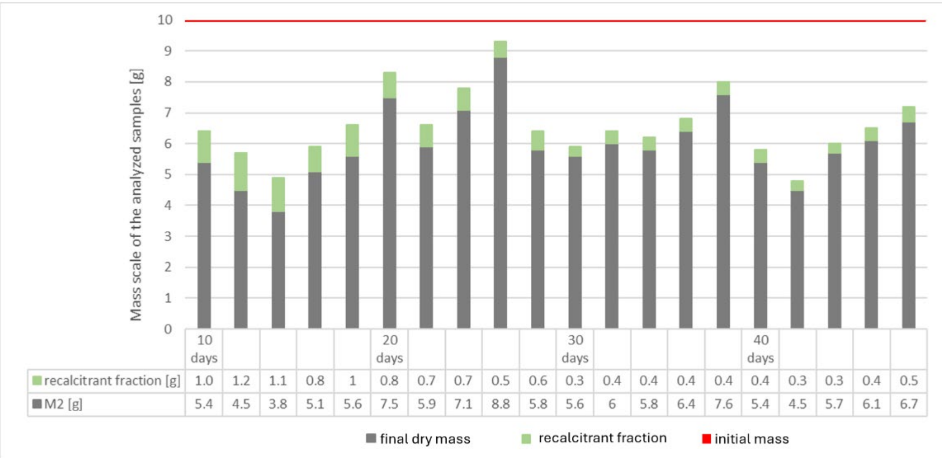

Fig. 3. The values of the recalcitrant fraction and of the final litter mass for *Phragmites australis*

The graph in Fig. 4 shows the values of the active as well as recalcitrant reservoirs of C in the *Phragmites australis* litter. The labile component accounts for most of the litter's total organic carbon (TOC). Although recalcitrant fraction varies during the first phase, having higher values compared to the entirely set of determinations between days 10-20, it later stabilises at constant values and accounts for a small part of the total fraction.

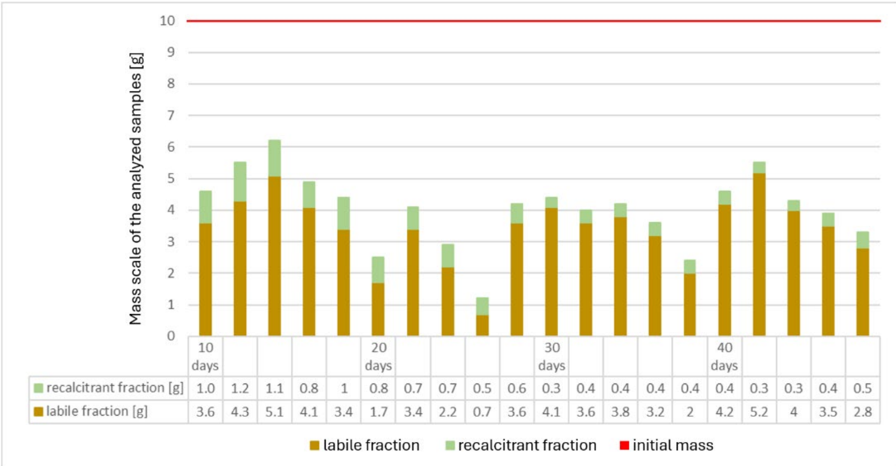

Fig. 4. Total mass loss resulted from the process of decomposition of litter formed by *Phragmites australis*

The quantification of the labile fraction and the recalcitrant fraction estimated the average of total mass loss of the amount of litter studied formed by the species *Phragmites australis*, which is composed of 3.425g of active fraction and 0.61g of recalcitrant fraction.

3.2. *Cattails*

Fig. 5 shows the values of the litter mass composed of the *Cattails* species after its collection from the study area and the labile fraction of the material. The first 10 days have been defined by moderate decline, followed by an extended phase of fast decay between days 20 and 30. Finally, the third phase comprised of inconsistent mass loss within the collected series, with the labile fraction ranging from 4g to 2g over an interval of 40 days.

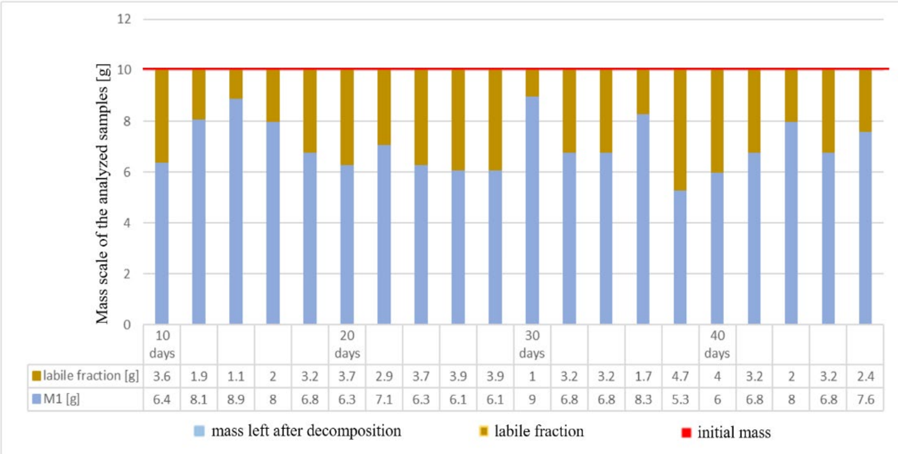

Fig. 5. The values of the labile fraction and of the litter mass collected for the *Cattails* species

The graph in Fig. 6 shows the proportions of the active reservoirs, as well as the recalcitrant ones of C in the *Cattails* litter. The labile fraction constitutes the largest proportions of the total organic carbon (TOC) of the litter. Recalcitrant fraction, although it varies in the first phase, between days 10-20 having increased values compared to the entire series of determinations, then stabilizes at constant values, represents a small percentage of the total fraction.

Fig. 6. The values of the recalcitrant fraction and of the final litter mass for *Cattails*

The graph in Fig. 7 shows the proportions of the active reservoirs, as well as the recalcitrant reservoirs forms by the *Cattails* litter. Recalcitrant fraction varies in the first phase, between days 10-30 having increased values compared to the entire series of determinations, then stabilizes at constant values, represents a small percentage of the total fraction. In the first phase, recalcitrant fraction has values between 1.4g and 0.7g, and in the second phase of collections, it has lower values, but with a linear trend, between 0.3g and 0.5g.

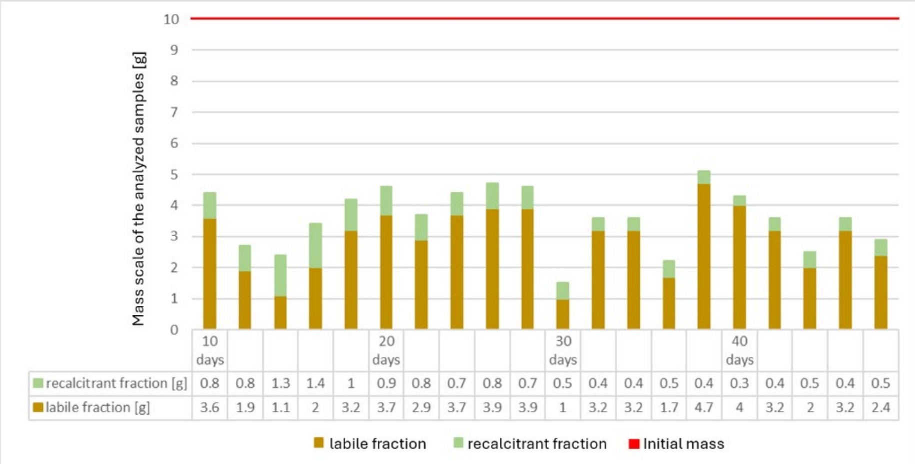

Fig. 7. Total mass loss resulted from the process of decomposition of litter formed by *Cattails*

The quantification of the labile fraction and the recalcitrant fraction estimated the average of total mass loss of the amount of litter studied formed by the species *Cattails*, which is composed of 2.925g active fraction and 0.675g recalcitrant fraction.

3.3. Carbon determination in the litter layer

The litter horizon is, in terms of thickness, quite small compared to the soil profile, but it contains a very high amount of organic matter. The organic carbon in the litter horizon was estimated using a conversion factor of 0.5 of the dry organic mass, according to the methodology for Tier 1 provided by the IPCC guidelines [20].

Table 1.

The carbon content of the litter by components

The litter component	**Carbon content for test surfaces [kg/m^2]**				
	P1*	**P2**	**P3**	**P4**	**P5**
Leaves	13.9 (±1.28)	12.25 (±1.32)	17.65 (±1.040	15.47 (±0.71)	13.51 (±0.86)
Wood	2.31 (±0.13)	4.03 (±1.21)	1.61 (±2.06)	3.30 (±2.30)	2.45 (±1.54)
Total	16.21 (±5.11)	16.28 (±0.60)	19.26 (±0.93)	18.77 (±2.01)	15.96 (±0.69)
**P1÷P5-Plot with 5 samples*					

The litter deposited on the soil of the banks of the Dambovita river, upstream of the accumulation lake, had an average content of 17.3 kg/m^2. The amount of carbon in the leaf litter presented proportions between 75% and 92%

of the total amount of carbon in each sample area, while the wood represented percentages between 8% and 18% of the total amount of carbon (Fig. 8).

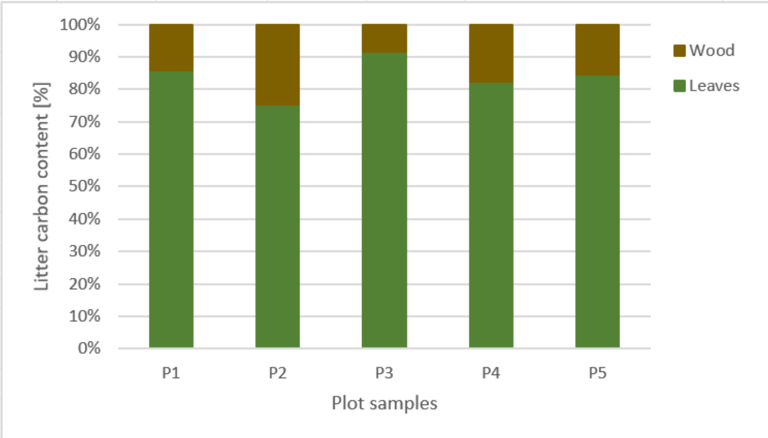

Fig. 8. Proportion of carbon in each litter component for each sample area

The amount of carbon stored in each component of the litter horizon varies quite a bit between the analyzed plots, arguing that these differences are due to the intense biological activities in the soil, but also to the local conditions of vegetation distribution.

4. Future perspectives

This article presents the methodology for estimating the litter decomposition rate and monitoring the degradability of the two main types of vegetation in the study area, namely Phragmites australis and Cattails. The future perspectives are to extend the litter decomposition monitoring period and to correlate the degradation rate of each type of leaf section with CO_2 emissions from this layer through simultaneous measurements using the closed chamber method.

5. Conclusions

The degree of litter decomposition, depending on the type of vegetation specific to the study area, followed, in general, a model of degradation of the quality of the analyzed material, involving a rapid loss of weight, in the initial phase, followed by a slowdown of orders of magnitude of the rate of recalcitrant materials, both for the *Phragmites australis* species and for the *Cattails* species. By analyzing the average labile and recalcitrant fractions, the total mass loss of the litter was determined, being composed of 8.56% active fraction and 1.53%

recalcitrant fraction for the *Phragmites australis* species, and 7.31% labile fraction and 1.69% recalcitrant fraction for the *Cattails* species.

Thus, the results show that, although the decomposition process took place in the same environmental conditions, the species *Phragmites australis* presented a faster decomposition. This could be influenced by the biological communities specialized in decomposition present in the environment that can be associated with a certain species or type of litter, helping to decompose when the litter is in its natural environment.

This degradation of plant biomass controls the amount of litter carbon that is retained in organic matter, and, because labile compounds are released fast in a short period of time, and the recalcitrant fraction typically decomposes over time, also the vegetable mass deposited in the litter layer emits over time.

The litter layer deposited on the soil of the Dambovita river's banks, upstream of the accumulation lake, produced an average value of 17.3 kg/m^2 C. Amount of carbon in the leaf litter represented 75% to 92% of the overall carbon in each sample location, while the amount of carbon in the wood represented 8% to 18% of the total carbon. An intake of plant biomass from the soil surface or from the water, depending on the hydrodynamic regime, of 14.9% from the *Phragmites australis* species and 16% from the *Cattails* species is added to this quantity of carbon from the litter layer of the soil.

It is important to note that the transformation of organic carbon into emissions in the atmosphere depends on the degradation of these plants. From our analysis, the shortest decay time will result depending on the species of the plant material source, thus, the shortest decay time will be for leaves, followed by the species *Phragmites australis* and *Cattails*, and in long-term degradation will be the wood.

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