CARBON AND NUTRIENT INPUTS BY LITTERFALL INTO THREE CHESTNUT HIGH FOREST STANDS IN NORTH PORTUGAL

M.S. Patrício[1], E. Pereira[1], L.F. Nunes[1] and M.L. Monteiro[1,2]

[1]Centro de Investigação de Montanha - CIMO, ESAB - Bragança Polytechnic Institute, [2] Sub-director of General Direction of Forest Resources (DGRF)

INTRODUCTION

Annual return of bioelements to the soil through litterfall is one of the most important renewal factors of forest ecosystem sustainability. Organic residue, accumulated in the soil surface, is responsible for humus formation, which represents a provisional accumulation of nutrients that are gradually released into the soil.

Although sweet chestnut (*Castanea sativa* Mill.) grows on a wide variety of soils, optimal conditions for this species are deep, moderately fertile and acid soils (pH 4.0 – 4.5) (Kerr e Evans, 1993). In Portugal, chestnut stands grow in soil types as regosols, cambisols and leptosols. In poor nutrient soils the ecosystem productivity is highly influenced by the efficiency of nutrient cycling (Duvigneaud, 1984). In this context, litter is an important reservoir of nutrients to the site productivity and sustainability. In accordance with Kavvadias *et al*. (2001), growth and productivity of forest ecosystems depend mainly on the amount, nature and decomposition rate of litter.

OBJECTIVES

In this particular study we quantify litterfall, litter accumulation on soil and also nutrients and carbon sequestration both in two fractions of litter and in the first ten centimetres of soil in three old high forest chestnut stands located in North Portugal. The objective of this study was to quantify and compare the litter biomass produced in the three sites and to evaluate its richness in nutrients and carbon contents that were progressively restored to the soil.

Site condictions

This study is based on litter ground information collected in the three old chestnut high forest stands located in North Portugal: Bornes (41º 29' 42'' N, 6º 55' 12'' W and 800 m above the sea level), Marão (41º 14' 46'' N, 7º 55' 04'' W and 900 m above the sea level) and Padrela (41º 31' 47'' N, 7º 35'' 22'' W and 850 m above the sea level) with 45, 63 and 65 years old, respectively. The total annual rainfall is 1009 mm in Bornes, 2505 mm in Marão and 1132 mm in Padrela. The mean annual temperature is 11.9 ºC, 13.4 ºC and 12.5 ºC, following the same order and maximum and minimum temperatures are 37.2 and -11.4 ºC in Bornes, 39.7 and -6.8ºC in Marão and 37.5 and -7.4 ºC in Padrela. Tree densities are 1227 trees ha^{-1} in Bornes,, 485 trees ha^{-1} in Marão and 259 trees ha^{-1} in Padrela, respectively. Prevailing soil types in the stands are cambisols in Bornes, fluvissols in Marão and regossols in Padrela.

In Portugal, the chestnut area is mainly composed by orchards, coppices and young stands, while the high forest chestnut area of old stands is reduced. In the study area, where the chestnut has got its largest distribution, the stands occupy an area just about 8 hectares.

MATERIALS AND METHODS

Litter was collected in December, after the litterfall, during two successive years, by using the 0.5x0.5 m quadrate method sampling. In each study place 18 randomly sampling points were considered. In each sampling point it was collected four kinds of samples – (1) leaf litter constituted by vegetal materials resulting from the litter fall of the year (L); (2) leaf litter constituted by a mixture of vegetal materials in different decomposition stages (F+H); (3) soil from 0-5 cm depth and (4) soil from 5-10 cm depth.

Litter of the year was separated into the fractions: leaves, branches, fruits and fruit cases. Fractions were oven-dried to a constant weight at 70ºC, weighted and milled. Ground material was analysed for N, P, K, Ca, Mg, S, B and C, by applying specific analytical methodologies. N, P and K were extracted by sulphuric digestion, Ca, Mg and S by nitric-perchloric digestion and B, by means of dry incineration method. The analytical determinations of N, P and B in the extract were obtained by atomic absorption spectrophotometry, the determination of K was performed by flame emission spectrophotometry, Ca and Mg through atomic absorption spectrophotometry and S via turbidimetry. Carbon amounts were obtained by incineration at 1100ºC with subsequent CO_2 determination by NDIR operation principle (Non-Dispersive Infrared).

Soil samples were taken in each sampling point at 0-5 cm and 5-10 cm depth. Samples were dried at 40ºC and sieved. Chemical analysis were performed on the earth fraction (<2mm). Concerning the soil samples, organic carbon content was determined using the Walkey-Black (1934) procedure. Nitrogen was determined after Kjeldahl digestion. The available P was measured colorimetrically after Égneir-Riehm procedure (Balbino, 1968). Concentrations of K and Na were analysed by flame emission spectrophotometry. Ca and Mg contents were determined using atomic absorption spectrophotometry. Soil pH was determined with 1:2,5 soil paste and water (McLean, 1982).

An ANOVA was performed to compare the total litterfall among the three study sites. A Tukey test was done for mean multiple comparisons. The same statistical analysis was used to compare the biomass mineral concentrations.

RESULTS AND DISCUSSION

Total litterfall was 12.44 Mg $ha^{-1}year^{-1}$ in Padrela, 7.73 Mg ha^{-1} $year^{-1}$ in Marão and 8.28 Mg ha^{-1} $year^{-1}$ in Bornes (Fig.1). There were significant differences (p<0.05) among locals. Padrela stand produced significantly more biomass than the other sites and, consequently, nutrients return to the forest floor was higher than in the other sites. The maximum value of carbon sequestration was observed also in Padrela.

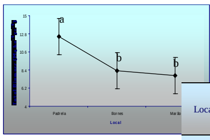


Fig. 1. Total litterfall in the three study sites.

Note: Letters indicate significant differences at p≤0.05 among means (Tukey test) for total litterfal.

Table 1. Biomass and nutrient return to the forest floor from total litterfall (L), biomass components and litter fraction (F+H), in three old chestnut stands.

Local	Litter layer	Biomass Comp($Mg\ ha^{-1}\ yr^{-1}$)		N	P	K	Ca	Mg	S	B*	C
				($kg\ ha^{-1}\ yr^{-1}$)							
Padrela	L	Leaves	6.23	85.79	6.30	22.17	39.59	18.66	6.21	71.28	3164.77
		Fruits	1.24	12.00	1.05	6.47	1.76	1.88	0.49	8.37	611.98
		Branches	2.62	17.80	0.74	5.70	17.52	4.24	0.72	22.12	1354.31
		Fruit cases	2.35	26.00	2.32	11.30	6.10	4.33	0.99	15.24	1176.64
		Total	12.44	141.59	10.41	45.64	64.98	29.11	8.41	117.00	6307.71
	F+H		15.02	217.58	15.70	182.13	66.00	51.85	12.43	122.88	5035.32
Marão	L	Leaves	4.82	63.95	3.85	6.69	18.84	13.02	2.38	62.28	2568.84
		Fruits	0.45	6.13	0.55	2.66	0.38	0.83	0.21	5.06	226.81
		Branches	1.52	9.87	0.48	1.31	7.80	2.23	0.28	12.76	812.29
		Fruit cases	0.94	8.25	0.67	2.37	1.38	1.70	0.19	6.66	477.82
		Total	7.73	88.20	5.54	13.04	28.40	17.78	3.05	86.76	4085.75
	F+H	**									
Bornes	L	Leaves	4.5	37.19	3.75	12.38	34.13	25.63	1.56	57.07	2379.92
		Fruits	0.32	2.47	0.29	1.97	0.61	0.66	0.06	2.19	155.57
		Branches	2.67	12.39	0.55	3.42	23.37	5.63	0.45	23.10	1405.54
		Fruit cases	0.79	5.39	0.38	3.27	2.51	2.12	0.17	5.01	399.54
		Total	8.28	57.44	4.97	21.04	60.62	34.05	2.23	87.36	4340.57
	F+H		8.43	88.52	8.16	123.37	38.90	38.54	4.76	72.84	2661.14

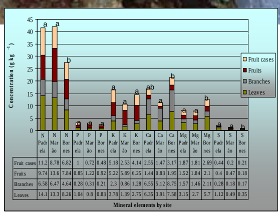
* B, (g ha-1); ** in this site the abundant grass did not allow to collect the fraction F+H.

Leaves are the main component of the litterfall and sequester the largest amount of nutrients and carbon (Table 1).

-In Padrela, litter fraction is constituted by 50.08 % of leaves, 9.94 % of fruits, 21.09 % of branches and 18.89 % of fruit cases.

-In Marão, litter fraction components are: 62.29 % of leaves, 5.85 % of fruits, 19.72 % of branches and 12.15 % of fruit cases.

- In Bornes, litter fraction is composed by 54.36 % of leaves, 3.81 % of fruits, 32.28 % of branches and 9.55 % of fruit cases.



	N Padrela	N Marão	N Bornes	P Padrela	P Marão	P Bornes	K Padrela	K Marão	K Bornes	Ca Padrela	Ca Marão	Ca Bornes	Mg Padrela	Mg Marão	Mg Bornes	S Padrela	S Marão	S Bornes
Fruit cases	11.2	8.78	6.82	1	0.72	0.48	5.18	2.53	4.14	2.55	1.47	3.17	1.87	1.81	2.69	0.44	0.2	0.21
Fruits	9.74	13.6	7.84	0.85	1.22	0.92	5.22	5.89	6.25	1.44	0.83	1.95	1.52	1.84	2.1	0.4	0.47	0.18
Branches	6.58	6.47	4.64	0.28	0.31	0.21	2.3	0.86	1.28	6.55	5.12	8.75	1.57	1.46	2.11	0.28	0.18	0.17
Leaves	14.1	13.3	8.26	1.04	0.8	0.83	3.78	1.39	2.75	6.35	3.91	7.58	3.15	2.7	5.7	1.12	0.49	0.35

Fig. 2. Nutrients concentration in total litterfall and litterfall fractions by site. *Letters indicate significant differences at p≤0.05 among means (Tukey test) for total litterfal.*

Leaves have the highest concentration of N, Mg, S and B. Branches are the richest in Ca and fruits in K (Fig. 2). P is present in high quantities both in leaves and fruits. The nutrients concentration in total litterfall are significantly different (p<0.05) in the three study sites. Padrela differs significantly from Bornes (p<0.05) and Bornes from Marão for the N, Mg and S (Fig. 2). The concentration of P, K and B cannot be considered different between locals (p<0.05). The concentration of Ca differs between Bornes and Marão.

Table 2. pH-value, exchangeable cations and other elements of the soil.

Local	Depth	pH	P	N	k^+	Ca^{++}	Mg^{++}	Na^+	B	C
	(cm)	H_2O	($kg\ ha^{-1}$)							
Padrela	0-5	4.55	5.49	9642.21	63.48	199.17	82.01	24.27	0.97	66587.63
	5-10	4.91	1.64	4212.80	35.46	129.60	49.38	24.88	0.38	53429.87
Marão	0-5	4.02	7.98	5562.70	20.11	98.37	41.92	34.35	0.82	88569.87
	5-10	3.92	4.91	5380.65	9.30	80.46	37.22	14.58	0.54	92106.90
Bornes	0-5	4.55	9.22	2928.25	24.80	174.10	84.97	14.92	0.46	86661.18
	5-10	4.65	1.73	2353.17	13.88	116.08	63.91	18.90	0.21	101601.50

The available amounts of soil nutrients (Table 2) are plenty higher in the layer 0-5 cm than in the layer 5-10 cm. The nutrients show a decreasing pattern as we stood back of the layer F+H. The amounts of carbon accumulated in the soil are very high relatively to the litter.

The higher Ca-concentration in total litterfall in Bornes can be explained by the observed high concentrations of exchangeable Ca in soil. Chatelus (1987) and Leonardi *et al.* (1996) made similar observations in chestnut coppice. The Mg-concentration in chestnut litterfall is generally lower compared to Ca and K and the highest Mg-concentration were found in leaves. According to Marschner (1995), physiologically active parts of plants tend to have higher Mg-concentrations what might explain the highest concentration in leaves.

Padrela canopy

Zimmeremann *et al*. (2002) refer amounts of biomass at Copera (Swiss) similar to those observed at Bornes and Marão (7.59 Mg ha-1yr-1) but Padrela presents higher values despite to the smallest density, due to the deeper and largest dimension of the crowns that produce more leaf litter. The proportions of litter fractions at Copera agree well with our data, excepting for fruits and branches: 56% leaves, 18 % fruits, 3 % branches. In our case we found larger amount of branches and smaller amount of fruits than in Copera. The amounts of fruits are difficult to control with this methodology because they are picked up by people and wildlife. Salazar and Regina (2005) reported 5.14 Mg $ha^{-1}year^{-1}$ as mean annual litterfall for a chestnut coppice stand, located at Sierra de Francia (Spain).

CONCLUSIONS

In the three studied chestnut stands, the amounts of returned organic matter and nutrients in litterfall can be explained by several factors such as site conditions (geology, chemistry, microbiology), biogeochemical cycle and also forest age. In the older chestnut stand (Padrela), the total litter return are plenty higher than values reported in literature, but in the others two sites they are similar to those verified in older chestnut stands. This can be explained with a more deep and largest crown dimensions. This pattern was registered in a period of two years.

Leaves are the main litter component and the largest amount of nutrients released by the trees was in fallen leaves following, in general, the pattern N>Ca>Mg>K>P>S. The ranking order of the element concentration in fruits was N>K>Mg>Ca>P>S. In branches, the amounts of N and Ca dominate clearly and the fruit cases are rich in N>K>Ca>Mg. The observed nutrients concentration in litterfall is strongly dependent on the soil nutrient concentration.

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