

Assessment of Biomass and Carbon Litterfall in Three Chestnut High Forest Stands in Northern Portugal



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Introduction

Sweet chestnut (*Castanea sativa* Mill.) is an important species in the North of Portugal for fruit as well as for timber. Today, the role of the chestnut areas is not only limited to production of fruit and timber but also other aspects such as landscape, environmental and ecological protection are very important. Consequently, its sustainable management is essential to maintain the health and vitality of the chestnut areas, therefore increasing the economical and social benefits of the local population. The site sustainability depends on the knowledge of the inputs and outputs of the system. Litter is an important reservoir of nutrients in maintaining the site's productivity and sustainability. In poor nutrient soils, the ecosystem's productivity is highly influenced by the efficiency of nutrient cycling (Duvigneaud, 1984). However, growth and productivity of forest ecosystems depend mainly on the amount, nature and decomposition rate of litter (Kavvasias *et al.*, 2001). Species/soil interrelationships, climate, and stand age influence net primary production (NPP) of forests (Gower *et al.*, 1997). Water and nutrient availability differ among different soils and influence both NPP and carbon allocation (Gower *et al.*, 1995). Large differences in carbon allocation may affect the soil carbon cycle because the different plant tissues decompose at very different rates (Gower *et al.*, 1997).

Objectives

- The first objective of this study is to assess the biomass and carbon litterfall restored to the soil.
- The second is to evaluate the aboveground net primary production (ANPP) for three chestnut mature high forest stands in Northern Portugal.

Materials and Methods

The study was conducted in the three mature chestnut stands located in Northern Portugal:
 ✓ **Marão** - 41° 14' 46" N, 7° 55' 04" W and 900 m above sea level, of 71 years of age. The mean annual precipitation is 2505 mm and the mean annual temperature is 13.4°C. Tree density is 360 ha⁻¹. Main soil type is Umbric Regosols.
 ✓ **Padrela** - 41° 30' 41" N, 7° 37' 15" W and 850 m above sea level, of 64 years of age. The mean annual precipitation is 1132 mm and the mean annual temperature is 12.5°C. Tree density is 470 ha⁻¹. Main soil type is Dystric Regosols.
 ✓ **Bornes** - 41° 29' 42" N, 6° 55' 12" W and 800 m above sea level, of 53 years of age. The mean annual precipitation is 1009 mm and the mean annual temperature is 11.9°C. Tree density is 1260 ha⁻¹. Main soil type is Dystric Cambisols.

Aboveground foliage litterfall was measured using seven circular 1m² littertraps that were randomly placed inside and outside of the sample tree plots (area 1000 m²) in each stand. Littertraps were deployed in September 2008 and litter was collected in October, November, December and January. The litter was separated into leaves, branches, fruits and burs. All litter fractions were dried to constant weight at 70°C. The litter fractions were analysed for N, P, K, Ca, Mg, S and C, by applying specific analytical methods. N, P and K were extracted by sulphuric digestion, Ca, Mg and S by nitric-perchloric digestion. The analytical determinations of N and P 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 1100°C with subsequent CO₂ determined by NDIR operation principle (Non-Dispersive Infrared).

In each chestnut stand, a permanent plot with 1000 m² had been established to evaluate the growth and yield of trees. The dimension of the plots and the large number of trees are sufficient to adequately characterize the forest. Diameter at breast height (DBH) (1.30 m) and total height were measured for all trees in each plot.

Aboveground NPP was calculated according to Gower *et al.* (1997) methodology. Therefore, aboveground wood (stems plus branches) was calculated for the period 2000-2009 using allometric equations (Patrício *et al.*, 2005). The mean increment of biomass by hectare and year was used in the considered period.

The understorey vegetation was collected using ten 1 x 1 m replicate plots in each stand randomly placed next to the littertraps. All aboveground understorey vegetation that had been growing in 1x1 m replication plots during a year was collected. Vegetation was separated into annual herbs, bracken, blackberry shrubs, seedlings and sprouts of chestnut. Samples were dried at 70°C and weighed to the nearest 0.01 g. Total biomass was calculated as the sum of the dry biomass of all species in each plot. The ANPP was calculated as the sum of the dry biomass increment of stems and branches plus litterfall collected in the traps and understorey vegetation components. The biomass of the tree components, stem and branches, were multiplied by 0.48 and litterfall by 0.52 (Patrício, 2006) and the understorey vegetation by 0.50 to estimate carbon content.

An ANOVA was performed to compare the total amounts of litterfall among the three study sites. A Tukey test ($\alpha = 0.05$) was done for mean multiple comparisons. The same statistical analysis was used to compare the biomass mineral concentrations.



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Results and Discussion

✓ Table 1 summarizes the stand characteristics for the three stands.

Table 1 – General characteristics of the studied chestnut stands.

Chestnut stands	Marão	Padrela	Bornes
Age in 2009	71	64	53
Altitude (m)	900	850	800
Slope (°)	5-10	25-30	15-20
Density (trees ha ⁻¹)	360	470	1260
Mean DBH (cm)	40.5	34.0	26.8
Mean height (m)	29.9	21.3	23.8
Mean annual temperature (°C)	13.4	12.5	11.9
Mean annual precipitation (mm)	2505	1132	1009

✓ Annual litterfall production and potential nutrient return to the soil are indicated in Table 2. As can be seen, total litterfall was similar in the three old chestnut stands ($p > 0.05$). Comparing these results with Patrício *et al.* (2009) relatively small quantities of litterfall were now observed. This discrepancy is due to the different methodologies used to collect the litterfall (quadrat method and littertraps). Posterior research will be necessary to compare and verify both methodologies in the same period of litterfall collecting.

✓ As in the case of most forest ecosystems, the leaves comprised the most important fraction of litter biomass ranging from 3.1 to 3.3 Mg ha⁻¹ year⁻¹ representing 69.8–79.4 % of the total litterfall. They also sequester the largest amount of carbon.

✓ Branches fall contribution was smaller than leaves and only represented 4.6 % of the total litterfall.

✓ Fruits and burs represented 6.4-12.4 % and 7.8-13.9 %, respectively of the annual total litterfall.

✓ These results are consistent with Regina (2000) for the leaves component but not for the others because, in our case, the contribution of burs and fruits is greater than branches. However, the densities and ages of the stands are very different. The values of total litterfall are approximate to the values of 3.9 Mg ha⁻¹ year⁻¹ reported by Pires *et al.* (1994) for chestnut groves and 4.9 Mg ha⁻¹ year⁻¹ referred to by Regina (2000).

✓ N and Ca are the major nutrient contributions to the ecosystem. However, the leaf litter fraction was the main vector of the potential return of all bio-elements to the soil.

✓ Bornes presents the lowest input amount of N litterfall in relations to the other sites due to the scarcity of this element in its soil.

Table 2 - Average annual litter production and bio-element amounts of litterfall components in three high forest mature chestnut stands. Letters indicate significant differences at $p \leq 0.05$ among means (Tukey test) for total litter.

Stands	Litter fraction	Litter production		N	P	K	Ca	Mg	S	C
		Mg ha ⁻¹ yr ⁻¹	%							
Marão	Leaves	3.33	79.43	49.72	3.42	5.81	14.61	8.38	1.50	1819.31
	Branches	0.27	6.38	1.63	0.13	0.30	3.08	0.71	0.07	142.65
	Burs	0.33	7.79	2.93	0.26	0.64	0.64	0.63	0.05	171.97
	Fruits	0.27	6.41	3.06	0.29	1.14	1.25	0.99	0.11	143.36
	Total	4.19a	100.0	57.34a	4.10b	7.89b	19.57b	10.70c	1.72b	2277.29a
Padrela	Leaves	3.21	69.78	46.37	3.73	14.87	22.41	10.61	2.77	1575.70
	Branches	0.18	3.99	1.54	0.09	0.48	1.43	0.31	0.06	92.78
	Burs	0.64	13.85	8.46	0.76	3.60	3.69	1.30	0.36	311.85
	Fruits	0.57	12.38	7.43	0.58	2.90	1.95	1.23	0.29	281.90
	Total	4.60a	100.0	63.79a	5.16a	21.86a	29.48a	13.44b	3.48a	2262.21a
Bornes	Leaves	3.09	78.04	31.6	3.41	14.79	28.01	16.03	1.22	1653.86
	Branches	0.19	4.74	1.03	0.07	0.20	1.47	0.34	0.02	95.72
	Burs	0.33	8.28	2.31	0.22	1.03	1.62	1.24	0.07	167.31
	Fruits	0.35	8.94	3.79	0.38	2.15	0.49	0.70	0.11	176.07
	Total	3.96a	10.0	38.73b	4.09b	18.16a	31.60a	18.31a	1.43b	2092.97a

✓ The NPP of the three stands is presented in Table 3. The first results obtained showed that ANPP for the three chestnut stands ranges from 3.7 to 5.2 Mg C ha⁻¹ year⁻¹ in 2009.

Table 3 - Aboveground Net Primary Production (ANPP) (Mg ha⁻¹ year⁻¹) by component for chestnut high forest stands.

Stands	Density (tree ha ⁻¹)	Age (yr)	Biomass (Mg ha ⁻¹ yr ⁻¹)		Carbon (Mg ha ⁻¹ yr ⁻¹)	
Marão	360	71	Stem	1.573	Stem	0.755
			Branches	0.679	Branches	0.326
			Understorey	0.864	Understorey	0.432
			Litterfall	4.193	Litterfall	2.180
			ANPP	7.309	ANPP	3.693
Padrela	470	64	Stem	4.382	Stem	2.103
			Branches	1.119	Branches	0.537
			Understorey	0.335	Understorey	0.167
			Litterfall	4.598	Litterfall	2.391
			ANPP	10.434	ANPP	5.198
Bornes	1260	53	Stem	4.246	Stem	2.038
			Branches	1.050	Branches	0.504
			Understorey	0.509	Understorey	0.254
			Litterfall	3.958	Litterfall	2.058
			ANPP	9.763	ANPP	4.855

✓ As can be observed, the NPP is lower in Marão, the oldest stand. This situation is due to the lower density of trees and probably to the carbon allocation. Carbon allocation patterns change as a stand ages, and these changes may directly or indirectly cause forest productivity to decline in older stands (Gower *et al.*, 1996; Ryan *et al.*, 1996).

✓ Litterfall production is a major component of ANPP for the oldest chestnut stand (Marão) followed by tree (stem and branches) contribution. In Bornes, the youngest stand, the contribution of the stem is greater than the litterfall.

✓ The litter component is practically the major pathway for carbon input into the soil.

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