Above and belowground biomass and nutrient contents of four even-aged *Quercus robur* L. stands in NW Spain

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OBJECTIVES

- To estimate the **above and belowground biomass** of even-aged *Quercus robur* stands in Northwestern Spain by fitting regression equations for different tree components
- To assess the **nutritional status** of these pedunculate oak stands, by determining the **nutrients amounts** in tree biomass, litter layer and soil
- To characterize the carbon amounts accumulated in the system, especially the **carbon sequestration** of tree biomass

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- To assess the role of these natural stands as **canbon sinks**
- To begin the knowledge
  - -**Nutrient balance** of these systems
  - -**Nutrients fluxes** due to both silvicultural management practices and harvesting operations, as well as to calculate the nutrient budgets corresponding to the logging residues left on the site

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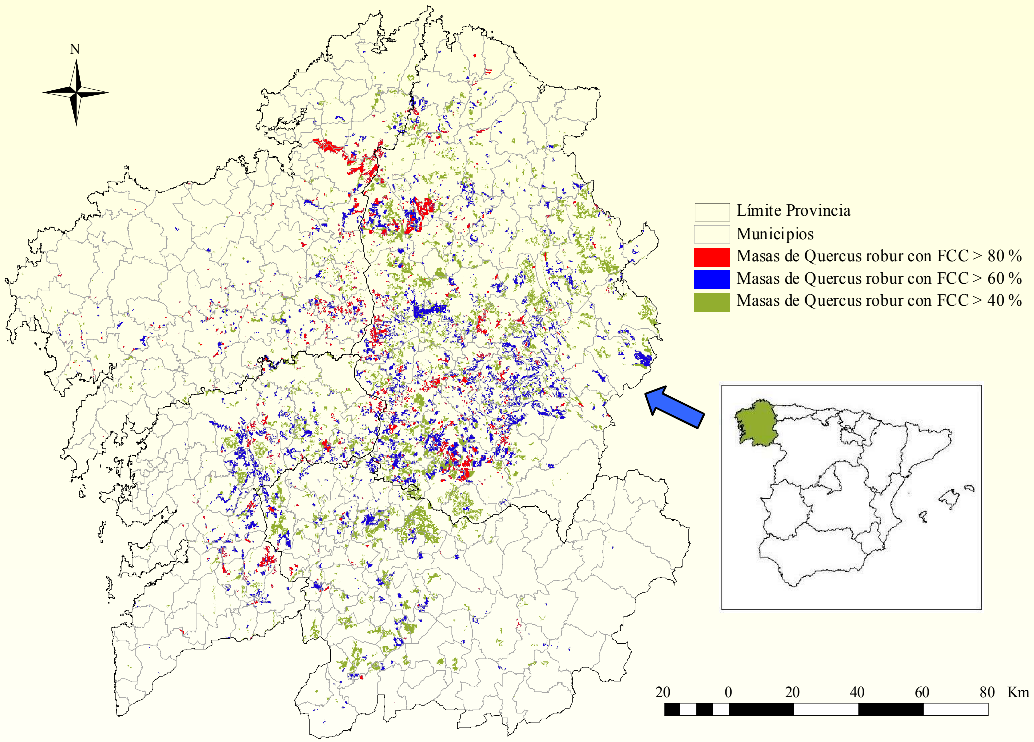
We could make management decisions that will favour **productivity and nutrient conservation** over the long term

SITE CHARACTERISTICS

• Four stands of *Quercus robur* located in Northwest Spain

•Oak stands are the climax formations in a large part of this region, occupying areas from sea level to an altitude over 1000 m



•The second most important tree species in terms of surface area occupied; there exist 190,000 ha of monospecific stands: 10 % of the forest surface area and 7 % of the total surface area

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BIOMASS EQUATIONS

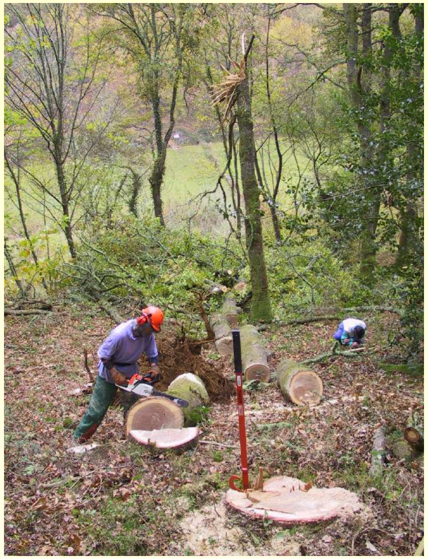
• **Destructive biomass harvesting** was carried out in 31 oaks in 4 stands

• A complete inventory (area = 900-1400 m^2) was also carried out in each stand for characterize the **stem diameter distribution**

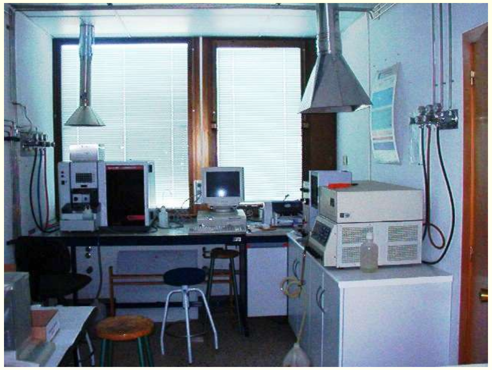
• 6-9 trees per sampled stand were felled.

• **Tree dimension variables** as diameter at breast height, total height and live crown length were measured.

• Tree **components** biomass was **separated and weighted** in the field and in the laboratory into fractions:



Stem wood
Stem bark
Branches >7 cm
Thick branches (diameter 2-7 cm)
Thin branches (diameter 2-0.5 cm)
Twigs (diameter < 0.5 cm)
Leaves
Roots



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BIOMASS EQUATIONS

BELOW-GROUND BIOMASS

- **Destructive harvesting was carried out in 11 of the 31 felled oaks**

- **A tractor with a hydraulic-ram was used to pull the root system from the soil, assisted with digging up to a 2 m depth**

- **5 m diameter circumference around the sampled tree was considered to analyse the root system → problems with fine roots**

- **Total fresh weight of roots biomass was measured in the field or in industrial scales**

- **Finally, stem disks and representative composite samples of all above and belowground components were used to determine the moisture content (65ºC)**

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BIOMASS EQUATIONS

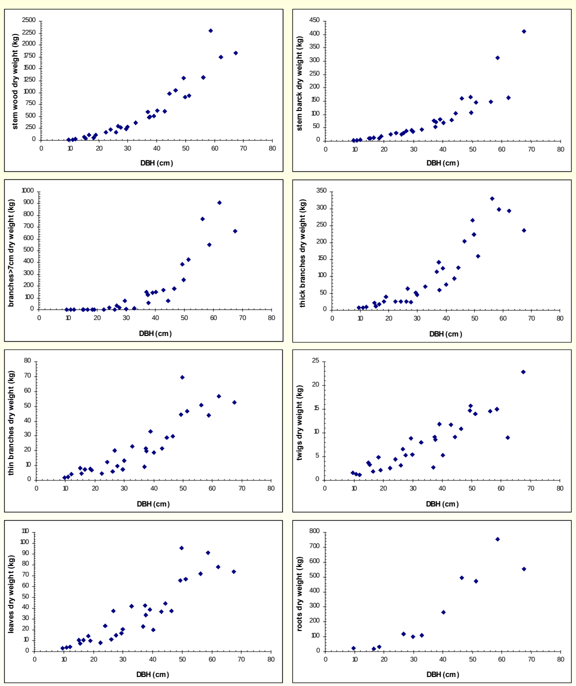
FITTING REGRESSION EQUATIONS

Stand variables

Tree variables

Dry weight of tree components

→ **To estimate above and below-ground biomass per stand (ha), by using multilinear regressions**



1.- Regression equations for each fraction separately

- **Nonlinear regression equations transformed into linear by taking logarithms**
- **Weighted linear models, using weighted regression**

2.- Selected equations from each biomass component were fitted simultaneously by using regression SUR

Statistic	dbh (cm)	h (m)	Stem wood (kg)	Stem bark (kg)	Branches >7cm (kg)	Thick branches (kg)	Thin branches (kg)	Twigs (kg)	Leaves (kg)	Aerial biomass (kg)	Roots (kg)
Average	34.07	18.83	586.86	80.17	167.07	104.14	22.10	7.74	34.24	1002.31	267.30
Maximum	67.48	27.55	2297.55	412.56	909.41	330.97	69.42	22.91	95.44	3611.27	752.52
Minimum	9.60	11.34	13.16	2.57	0.00	7.56	1.99	1.19	3.42	31.07	19.54
S.D.*	16.09	3.93	596.73	91.99	249.05	99.22	18.76	5.38	27.28	1049.11	257.38
VC**	47.21	20.89	101.68	114.74	149.07	95.27	84.85	69.52	79.68	104.67	96.29

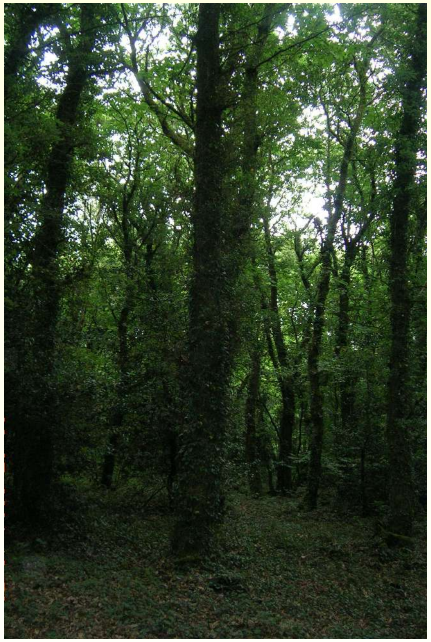
NUTRIENTS CONTENT IN BIOMASS AND SOIL

Beginning from soil pits and plant and litter layer biomass samples we determined nutrient contents

1.- Tree components biomass

2.- Soil horizons

3.- Litter layer



C, N, S in milled plant and soil samples were analyzed by combustion, using a Leco analyzer

Macro and microelements were determined by ICP-EOS

SOIL PROPRETIES AND NUTRIENT CONTENT

Horizon [1]	Soil depth (cm)	Sieved soil < 2 mm (%)	pH_{KCl}	Bulk density (g cm^{-3})	C*	S*	N*	P**	Ca**	Mg**	K**
					------------ % -----------			---------------- mg kg^{-1} --------------			
Hor. 1	10.8	68.1	3.91	0.66	6.4	0.09	0.49	6.5	92.9	40.2	122.9
	(1.5)	(8.2)	(0.20)	(0.09)	(2.8)	(0.03)	(0.20)	(2.8)	(26.5)	(22.0)	(63.6)
Hor. 2	26.3	72.4	4.27	0.95	3.0	0.05	0.27	3.4	15.7	7.2	68.8
	(2.5)	(9.1)	(0.13)	(0.10)	(0.8)	(0.02)	(0.07)	(2.9)	(11.6)	(4.2)	(52.7)
Hor. 3	41.3	69.3	4.45	0.94	2.0	0.04	0.19	2.0	12.1	3.1	34.2
	(19.7)	(10.8)	(0.05)	(0.13)	(0.7)	(0.01)	(0.06)	(0.7)	(6.1)	(1.1)	(23.9)

- Characteristics of soils were similar to those of most **natural forest** soils in the region

- **Cambisols** showing different degrees of development and are **quite acidic** with pH_{KCl} values around 4.0

- All of the soils contained particularly **low concentrations** of nutrients
  - **P** 6.5 mg kg^{-1}
  - **Ca** 93 mg kg^{-1}
  - **Mg** 40 mg kg^{-1}
  - **K** 123 mg kg^{-1}

- These soils have low or moderate fertility, due mainly to the low amounts of cations in the parent material

- Sampled soils were rich in organic matter and had high concentrations of total N. The C:N ratios in the surface horizon were < 15 ➡ an adequate rate of decomposition and mineralization of the organic matter

LITTER LAYER BIOMASS AND NUTRIENT AMOUNTS

Plot location	Litter layer (Mg ha^{-1})	C	S	N	P	K	Ca	Mg
		------------------------------			mg g^{-1}	------------------------------		
Lanzós	54.2	311.0	3.7	16.1	0.75	2.20	3.60	3.74
Santaballa I	124.8	115.0	0.7	5.2	0.32	0.75	2.44	1.61
Santaballa II	64.6	432.0	4.8	19.3	0.84	1.57	3.38	1.64
Ramil	72.4	395.0	4.3	19.1	0.67	0.95	5.24	0.88
Average	79.0	313.3	3.4	14.9	0.64	1.37	3.67	1.97
S.D.*	31.4	141.5	1.8	6.6	0.23	0.66	1.17	1.23

- **The average mass of the litter layer in the sampled stands was 79 Mg ha^{-1}**
- **It appears that K is the element that is most rapidly lost due to decomposition**
- **Concentrations of Mg were quite similar in leaves and litter layer**
- **The organic horizon accumulated on average**
  - **Ca 290 kg ha^{-1}**
  - **Mg 156 kg ha^{-1}**
  - **P 51 kg ha^{-1}**

TREE BIOMASS DISTRIBUTION

- The average proportions of components expressed as a percentage of the <u>aboveground tree biomass</u> were:

	Stem wood	Stem bark	Branches>7cm	Thick branches	Thin branches	Twigs	Leaves	Roots
Average	60.1 %	9.9 %	9.6 %	12.6 %	3.4 %	1.6 %	2.8 %	20.0 %
S.D.*	4.9 %	0.6 %	5.1 %	3.1 %	0.9 %	0.8 %	1.0 %	7.1 %

<u>Aboveground tree biomass</u>

<u>Whole tree biomass</u>

- Belowground biomass represented 20 % of the <u>whole tree biomass</u>

- Oak stands had a relatively high proportion of non-wood components, which made up 40 % of the aboveground tree biomass

STAND TREE BIOMASS AMOUNTS

- The values of the aerial biomass accumulated in the stands ranged between 141 and 402 Mg ha^{-1}, which correspond to the stands with lower and higher basal area respectively (28 and 56 m^2 ha^{-1})

Plot location	Stem wood (t ha^{-1})	Stem bark (t ha^{-1})	Branches>7cm (t ha^{-1})	Thick branches (t ha^{-1})	Thin branches (t ha^{-1})	Twigs (t ha^{-1})	Leaves (t ha^{-1})	Roots (t ha^{-1})
Lanzós	239.8 (65.9 %)	34.0 (9.8 %)	51.6 (6.7 %)	45.3 (10.4 %)	10.4 (3.3 %)	4.9 (1.2 %)	16.4 (2.7 %)	102.8
Santaballa I	129.7 (62.5 %)	17.5 (10.0 %)	18.7 (10.7 %)	25.6 (10.6 %)	6.1 (2.6 %)	2.2 (1.3 %)	9.6 (2.2 %)	57.2
Santaballa II	143.5 (56.0 %)	19.7 (10.6 %)	32.4 (4.6 %)	28.3 (17.1 %)	6.8 (4.7 %)	2.8 (2.8 %)	10.7 (4.2 %)	63.4
Ramil	85.5 (56.0 %)	14.2 (9.2 %)	5.1 (16.2 %)	19.6 (12.4 %)	5.2 (2.9 %)	3.2 (1.0 %)	8.3 (2.2 %)	41.9
Average	149.6 (60.1 %)	21.4 (9.9 %)	26.9 (9.6 %)	29.7 (12.6 %)	7.1 (3.4 %)	3.3 (1.6 %)	11.2 (2.8 %)	66.3
S.D.*	50.2 (4.9 %)	7.4 (0.6 %)	13.9 (5.1 %)	8.9 (3.1 %)	1.9 (0.9 %)	1.1 (0.8 %)	3.0 (1.0 %)	25.9

- The crown fractions (branches and leaves) consisted of on average 30 % of the aerial tree biomass, corresponding to amounts ranging between 41 and 128 Mg ha^{-1}

- The importance of the roots in nutrient accumulation is clear, as an average of 66 Mg ha^{-1} was accumulated in this fraction

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NUTRIENT CONCENTRATIONS IN BIOMASS COMPONENTS

Tree fraction	C	S	N	P	K	Ca	Mg
				mg g^{-1}			
Stem wood	484.4	0.17	2.57	0.21	1.57	3.21	0.28
	(37.0)	(0.09)	(1.78)	(0.14)	(0.86)	(5.39)	(0.24)
Stem bark	512.0	3.26	13.28	0.83	3.45	9.75	1.48
	(12.8)	(4.26)	(5.65)	(0.36)	(0.72)	(3.90)	(0.32)
Branches d>7 cm	490.9	0.17	2.23	0.21	1.37	1.52	0.30
	(8.2)	(0.05)	(0.57)	(0.03)	(0.25)	(0.48)	(0.14)
Thick branches	484.0	0.56	3.85	0.39	2.37	4.27	0.53
	(20.7)	(0.38)	(0.37)	(0.08)	(0.92)	(0.76)	(0.06)
Thin branches	502.7	0.46	7.51	0.68	2.55	5.59	0.88
	(1.1)	(0.04)	(0.73)	(0.02)	(0.32)	(2.13)	(0.02)
Twigs	506.8	0.80	12.39	0.79	2.75	6.78	0.85
	(5.0)	(0.19)	(3.15)	(0.03)	(0.24)	(4.09)	(0.18)
Leaves	503.8	1.48	23.41	1.23	5.54	4.39	1.25
	(25.3)	(0.81)	(12.94)	(0.82)	(2.61)	(0.89)	(0.59)

- **Mean concentrations of P and K decreased in the following order: leaves > stem bark > twigs > fine branches > coarse branches = stem wood = roots**

- **The pattern decreased in the following order for concentrations of Ca and Mg: stem bark >> twigs > leaves = fine branches > stem wood = roots > coarse branches**

- **Leaves, stem bark and twigs showed the highest concentrations of nutrients, although these components only represented 15 % of the aboveground biomass**

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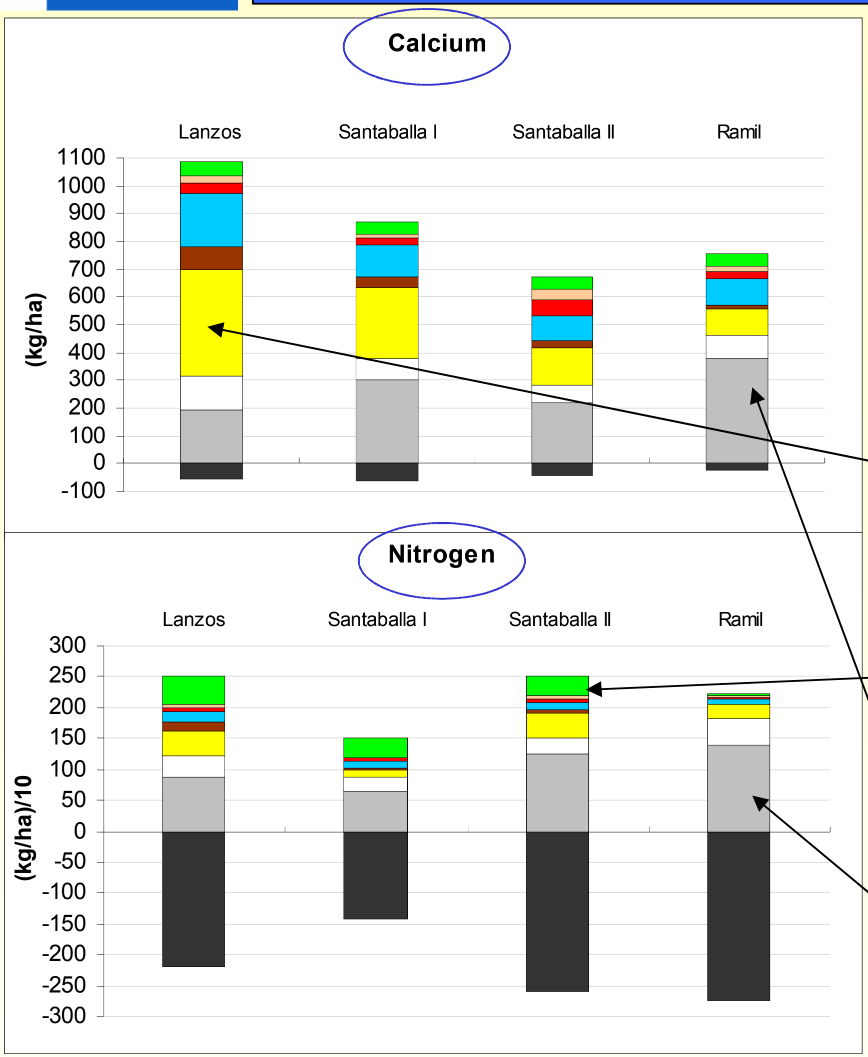
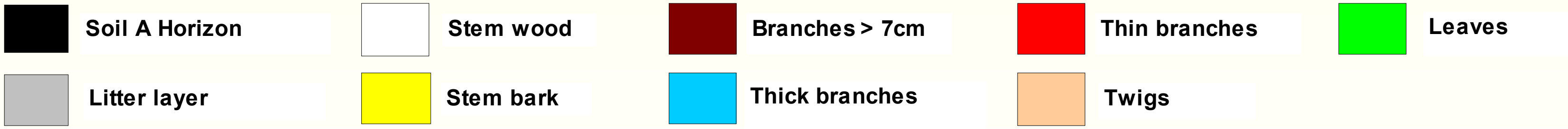
NUTRIENT AMOUNTS



•**<u>Stem wood</u> is the fraction in which the greatest amounts of most macronutrients were accumulated**

•**The largest amounts of <u>Ca</u> were accumulated in the <u>bark</u>, and largest amounts of <u>N</u> in the <u>leaves</u> and <u>bark</u>, even though these fractions accounted for <u>13 % of the aerial tree biomass</u>**

•**<u>Litter layer</u> also accumulates large amounts of <u>N, Ca</u>**



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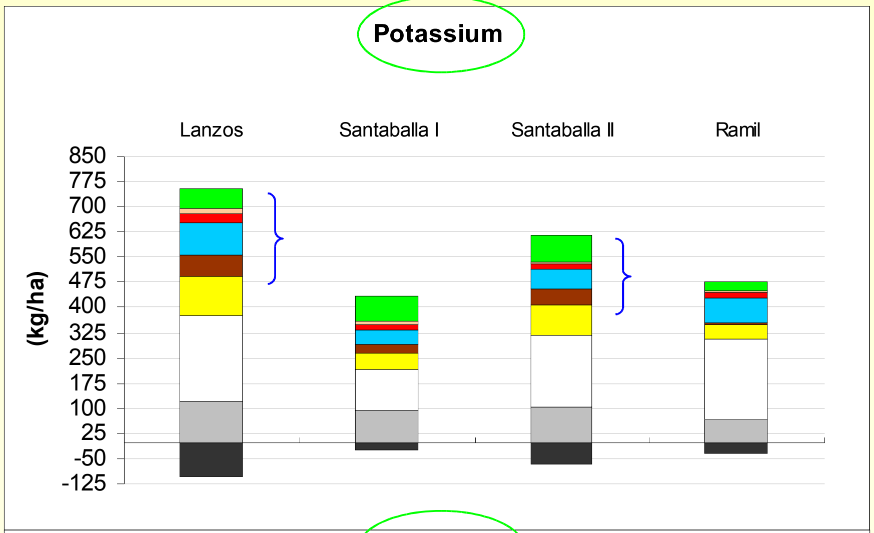
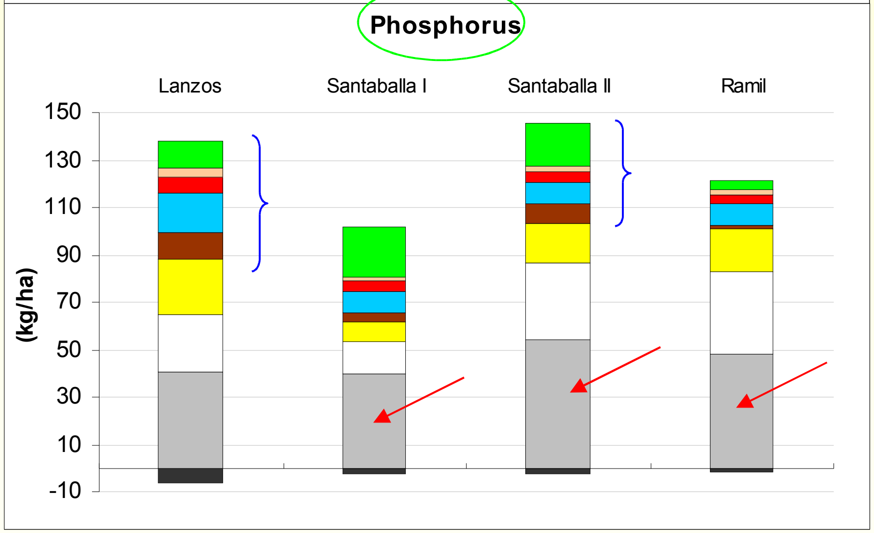
NUTRIENT AMOUNTS

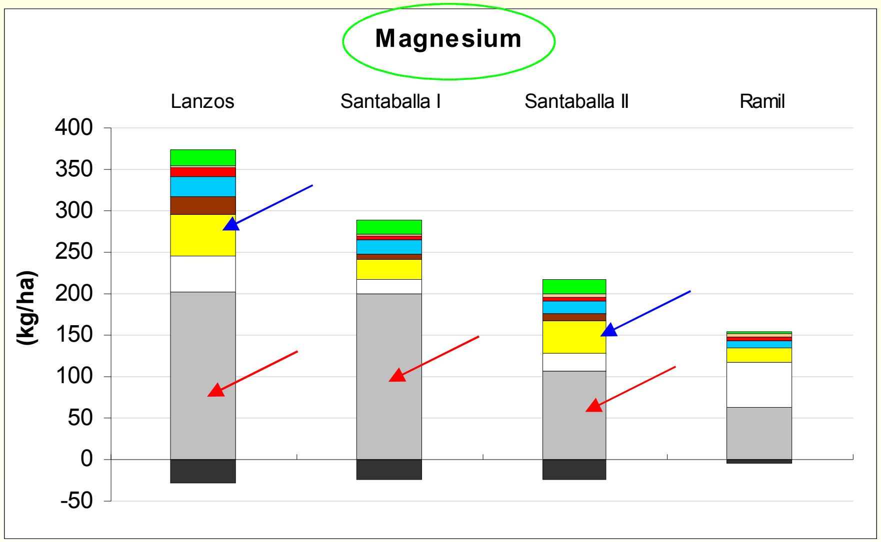




•The crown biomass accounted for only 30 % of the aerial biomass and accumulate 50 % of the N and Ca, and 40 % of the K, Mg and P stored in the aerial tree biomass

•Accumulation of Mg was higher in bark - a mean concentration of 32 kg ha^{-1}, which accounted for 18 % of the total accumulated in the tree biomass

•Litter layer accumulates greatest amounts of P and Mg in the system



Soil A Horizon
Stem wood
Branches > 7cm
Thin branches
Leaves
Litter layer
Stem bark
Thick branches
Twigs

CARBON POOLS IN TREE BIOMASS

- **Carbon <u>concentration</u> was very similar for the six tree fractions, and represented approximately the <u>50 % of the dry weight</u>**

- **Carbon sequestration of total tree biomass at stand level in final cut ranged from <u>90 t ha^{-1}</u> (lowest stand basal area) to <u>248 Mg ha^{-1}</u> (highest stand basal area)**

- **In the event of considering <u>even-aged stands with a rotation age of 130 years</u>, an average value of <u>NPP of 1.2 t ha^{-1} $year^{-1}$</u> would be reached**

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CONCLUDING REMARKS…

- Importance of considering the role of nutrient amounts of tree biomass in the nutritional dynamics of these forest systems.
- Importance of crown biomass, stem bark, and litter layer as nutrient budgets
- Importance of these natural stands as carbon sinks


"That's all Folks!"

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