ASSESSING FORESTRY BIOMASS BY MEANS OF FIELD WORK A GEOSTATISTICS PROCESSES. A CASE STUDY IN NORTH PORTUGAL

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ABSTRACT
To assess Forest Biomass availability requires a hard field work survey and elaborate calculation techniques for vegetation classification and quantification. In March, April and May 2006, 900 sampling plots were surveyed with a help of a portable GIS (Geographical Information System) with GPS (Global Positioning System) capabilities. Within each sampling plot, an extensive field work was made in order to completely classify and quantify available forestry biomass. Data collection was regarding total number of trees within sampling plot, individual trees diameter at breast height, mean tree's height, mean tree's volume, mean tree's canopy height and mean tree's age. The results showed a range of values from 6.00 up to 21.00 dry ton./ha for adult *Pinus pinaster* (maritime pine) stands and from 1.00 up to 6.00 dry ton./ha for adult *Eucalyptus globulus* (eucalyptus) stands, both for thinning stands or for clear cut stands. In a second stage, they were applied geostatistic techniques (e.g. Weighted Inverse Distance, Kriging) in order to extend sampling plot results to fully study area and to create continuous biomass maps.

Keywords: Biomass, Shrubs, *Pinus pinaster*, Geostatistic, GPS, Remote Sensing, GIS

INTRODUCTION
Biomass consists of organic residues from plant and animal primarily obtained from harvesting and processing of agriculture and forestry crops. Pruning, forest slash, wood residues generated by timber processing operations are some of the materials undergo this definition. All of these organic products result from agro-forestry activities, and their energy value is nearly one third of the oil energy value, but biomass availability is larger in nature than fossil fuels [1, 2, 3, 4, 5, 6, 12].
Portugal has an appreciable potential in renewable energetic resources. With a forested area of 3 million hectares, *Pinus pinaster* and *Eucalyptus globulus* are the mainly used species in timber and pulp production. These forested areas generate a large quantity of biomass, deriving from forestry management operations, harvesting and clear cut, which as a enormous potentially for energy production. The rise in value of the forest biomass has been assumed as an important task, with the goal to transform a residue, with a great influence in the wildfire occurrence in summer time, in a raw material capable of originating profitability. His utilization will be efficaciously important in energetic terms, namely under the caloric form of burners, under the electric form, starting from the production of thermoelectric power stations or even, under the biocombustible form in the transportation sector. Nevertheless, the main difficulty in the creation of a forest residue market is originated by the fact of the non existence of a management plan of this exploitation, through which the landowners, associations or municipalities can be interested in knowing the potential that they have at their disposal [8, 9, 10, 11, 12].
The creation of a GIS (Geographical Information System) for the management of the forest residue is the leading bases for a tool capable to integrate several information levels of spatial nature in one single model that will be able to provide the knowledge about how much possess, where and when the residues should be explored. The GIS will be able to combining the station conditions and the forest peopling making possible to create a sustainable scheme of organized management techniques based on: 1) production distribution; 2) production evolution; 3) exploitable conditions.

MATERIALS AND METHODS

Site description

This research was derived in two study areas in North Portugal, as presented in Fig. 1, one locate in Vale do Alto Tâmega (forward designated by TAMEGA), and one locate in Vale do Lima (forward designated by LIMA).

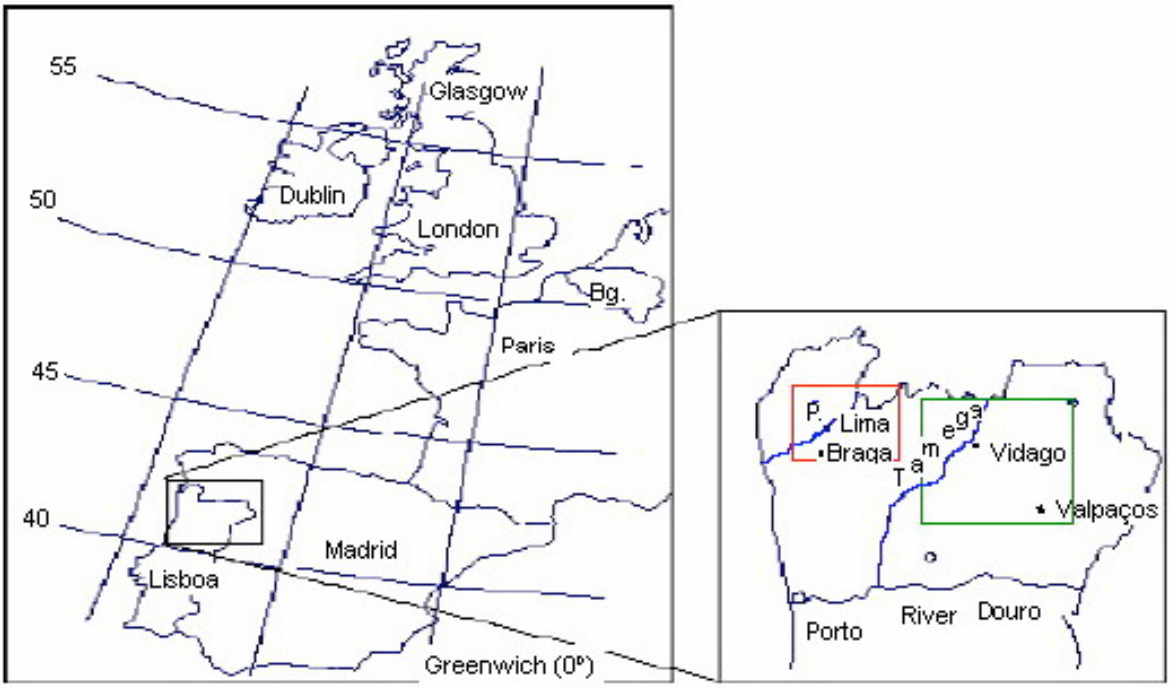

Fig. 1 - Study area location.

Altitude ranges from 150m near River Tâmega (Southeast) to 1250m in mountainous areas (Northeast). Is an area under Atlantic influence with an average temperature of 10 degrees Celsius and a total rainfall of 800 mm/year, in average.

Material

This research was carried out using IDRISI32, a raster based Geographical Information System, ArcGis 9.1, a vector based Geographical Information System, ArcPad 6.03 a vector based Geographical Information System for PDA - DGPS (Personal Digital Assistant - Differential Global Positioning System and Pathfinder, a GPS data processing software.

Methodology

Data collection

A total of 500 systematic sampling plots were established throughout TAMEGA area and 400 throughout LIMA area, previous updated with a classified satellite image. Then, all sampling plots located within forested areas were selected to be surveyed. Using a portable GIS (Geographical Information System) with DGPS (Differential Global Positioning System) facilities all sampling plots were surveyed. Within each 200m^2 circular plot, they were measured the following biophysical parameters: total number of trees; diameter at breast height; total height; canopy height and diameter and age.

Data analyses

Data collected during field work was used to create a georreferenced tabular database. This database was further updated with biomass production models [8, 9, 10, 11, 12] in order to estimate vegetal biomass resulting from forestry management operations, harvesting or clear cut.

This biomass results from branches and coppices which usually remains in filed after timber harvesting or trees thinning.
After biomass calculation, for all sampling plots, they were used geostatistical methods (e.g. Inverse Distance Weighting, Kriging, etc.) in order to extent the results to all study area and to create continuous biomass maps.

RESULTS AND DISCUSSIONS

Results from data processing are presented in Table 1.

Table 1 - Sampling plots statistical characteristics

	TAMEGA		LIMA	
Parameter [dry ton/ha)]	Pp biomass		Pp biomass	Eg biomass
Minimum	6.00		6.00	1.00
Average	14.13		10.17	6.51
Standard deviation	4.09		3.19	2.80
Maximum	21.00		19.35	16.00
Number	102		129	122

Legend: Pp - *Pinus pinaster*; Eg – *Eucaliptus globulus*; biomass – branches and coppices

As previous table shows, the biomass resulting from forestry activity is valuable, being the trees from TAMEGA area more productive than trees from LIMA area.
The preliminary results from geostatistical methods application, presented in Tables 2 and 3, show that these procedure is suitable to estimate biomass for forestry areas.

Table 2 - Geostatistical results for TAMEGA area

	Application			Validation		Model	Estimated	
Parameter [dry ton/ha)]	RSME	n		RSME	n		Minimum	Maximum
Pp biomass	4.30	80		4.13	22	IDW	6.00	21.00
Pp biomass	4.30	80		4.12	22	Kriging	8.02	18.90

Legend: IDW – Inverse Distance Weighting (Quadratic)

Table 3 - Geostatistical results for LIMA area

	Application			Validation		Model	Estimated	
Parameter [dry ton/ha)]	RSME	n		RSME	n		Minimum	Maximum
Pp biomass	3.54	99		2.97	30	IDW	6.00	19.35
Pp biomass	3.05	99		3.02	30	Kriging	7.65	13.19
Eg biomass	2.89	93		2.58	29	IDW	2.57	10.30
Eg biomass	3.05	93		3.10	29	Kriging	4.10	8.23

Legend: IDW – Inverse Distance Weighting (Quadratic)

Analysing Table 2 and Table 3, its possible to see that Kriging model it’s more accurate both in the application and in the validation phases, but it overestimate the minimum and underestimate the maximum values. Thus, it was selected the Inverse Distance Weighting (Quadratic), in all the estimations, in order to use a model that enable to calculate estimation within all range of variation (minimum and maximum, see Table 1).

Branches and coppices, resulting from timber harvesting or trees thinning, can generate a large amount of biomass, as presented in Tables 4, 5 and 6.

Table 4 - Branches and coppices for *Pinus pinaster* trees growing in TAMEGA area

Class [dry ton/ha)]	area [ha]	[dry ton]
6	467.55	2805.30
8	1814.58	14516.64
10	6399.54	63995.40
12	15280.47	183365.64
14	22485.24	314793.36
16	9126.09	146017.44
18	1466.82	26402.76
20	110.79	2215.80
Total	57151.08	754112.34

Table 5 - Branches and coppices for *Pinus pinaster* trees growing in LIMA area

Class [dry ton/ha)]	area [ha]	[dry ton]
8	5038.92	40311.36
10	27905.58	279055.80
12	25230.24	302762.88
14	11874.06	166236.84
16	2021.49	32343.84
18	210.87	3795.66
20	50.13	1002.60
Total	72331.29	825508.98

Table 6 - Branches and coppices for *Eucaliptus globulus* trees growing in LIMA area

Class [dry ton/ha)]	area [ha]	[dry ton]
2	13.14	26.28
3	189.27	567.81
4	564.48	2257.92
5	2079.27	10396.35
6	2241.99	13451.94
7	3021.30	21149.10
8	427.23	3417.84
9	79.56	716.04
10	0.99	9.90
Total	8617.23	51993.18

CONCLUSIONS

The presented work demonstrate that geographical information system and geostatistical methods allow to create biomass availability maps, expected from forestry operations, as well as the easiness that this exploitation can be done. The gathering of this information levels in a single map allows the standardization of the biomass exploitation viability for a certain area.

The created GIS is a first tool to forest management, however it must be present that intensity of cultural interventions in stands, will limits the quantities of biomass, available to be annual exploited. Hence it’s necessary to know some parameters, as the number of trees cut by unit of area. With this tool its possible predicts the potential areas suitable for future exploitation of forest biomass, and so be a helpful tool in new stand installation.

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