Creation of geodatabase using Geographical Information Systems (GIS): its integration in forest road network and application in calculating biomass supply chain costs - case study from northern Spain.

Sánchez-García S., Prendes, C., Canga, E., Majada, J.
CETEMAS, Forest and Wood Technology Research Centre.Sustainable Forest Management Area. Finca Experimental “La Mata” s/n 33820 Grado, Asturias, Spain.
* Corresponding author. Tel.: +34 985754725. E-mail addresses: ssanchez@cetemas.es (S. Sánchez-García).

Summary

The overall objective of this study was to evaluate, through a theoretical model, the potential availability of biomass in a public forest and the viability of the forest as a supplier for a boiler located in a public building. For this, the stock of biomass was estimated using biomass equations. Then, the amount of biomass for each stand, in terms of scheduled treatment for different years of implementation, was calculated. In order to know how much influence transport conditions would have on harvesting operations, and to evaluate their costs, the most important variables related to the characteristics of forest roads were defined and included in a geodatabase. The forest road network was digitized using GPS and ArcPad software and then analysed by the extension Network Analyst from ArcGIs.10 software. Finally, an annual average yield of biomass of 160 GT ha^{-1} (Green Tonnes) per hectare was estimated, with an average harvesting cost of 23.89 (€ GT^{-1}). This amount proved to be sufficient to feed the hypothetical biomass boiler, whose woodfuel demand is estimated at 48 GT $year^{-1}$.

Keywords: biomass, GIS, forest road, supply costs.

Introduction

For the profitable and sustainable exploitation of biomass in Asturias it is essential to develop planning tools which enable estimation of the availability and economic viability of harvesting. Forest road are essential to forestry management and studies have shown the cost of transporting forest biomass from the production area to the site of consumption to be between 8 and 40% of the total cost of production of biofuel (Anttila *et al*, 2001; Moller *et al*., 2007; Panichelli and Gnansounou, 2008).

To be able to take into consideration the relevant aspects of transport costs in logistics analysis, it is a fundamental requirement to have a digitized map of the existing network of forest roads in order to create a GIS database of the principal characteristics of each forest road. Based on the creation of a transport network, there are tools such as Network Analysis, developed by the ESRI group (Redlands, California), which allow optimal routes to be identified according to various criteria and under specific restrictions or limitation scenarios. The objective of this study was to evaluate, through a theoretical model, the available biomass in a public forest and the economic feasibility of its use for a theoretical demand point.

Material and Methods

The study area is located in Asturias, in the northwest of Spain. It is a public forest which is subject to a Forest Management Plan (2008-2018), and includes *Pinus pinaster* Ait., *Castanea sativa* Mill., *Pinus radiata* D. Don and *Quercus robur* L., together with a number of other broadleaf species.

From dasometric information and through biomass equations, total biomass in (Green Tonnes) per hectare (GT ha^{-1}) with reference moisture content of 50% and biomass per stand were calculated for the period of the Forest Management Plan. In relation to the thinning of stands, it was considered that the whole tree would be used for biomass. In contrast, for final fellings, only the biomass residues were included in the calculations.

The network of existing forest roads was digitized using ArcPad® (ESRI, 2011) and the principal characteristics of each forest road defined and registered (distance, width, time, vehicle speed, traffic conditions, type of road surface, and the type and number of vehicles used) in order to create a GIS database for network analysis.

To calculate forwarding and trucking distances, optimal routes were calculated from the centre of the stand to the nearest of the three existing landings (stage 1) and from the landing to the hypothetical biomass consumption point (stage 2) in such a way as to minimise travelling time. To create and analyse these routes, the methodology of Aruga *et al*., (2011) was followed for stage 1, and for stage 2 the Network Analyst tool of ArcGis 10.0 (ESRI, 2014) was used.

Standard logistics systems were established depending on type of harvesting (thinnings or final fellings) taking into account forest conditions and the machines operating in this region. For the calculation of supply costs of these systems in euros per Green Tonne (GT), costs of different operations (harvesting, forwarding, chipping at landing and transporting) were calculated based on the results of other authors (Ilavsky *et al.*, 2007; Canga *et al*., 2009; Eliasson *et al*. 2011).

A theoretical biomass consumption point was established at the town hall of the municipality where the study was conducted with the aim of analysing the viability of supplying a hypothetical woodfuel boiler with biomass from the study area. The fuel demand of the public building (D) was calculated considering its energy needs (kW h $year^{-1}$), the calorific value of the woodchips (kWh kg^{-1}) and the performance of the boiler. Subsequently, a comparison was made with a diesel boiler, estimating its requirements in the same way.

Results

Table 1 shows total biomass data by fraction for each stand available for woodfuel harvesting at the outset of the Management Plan (year 0) and in the harvesting year (year n). Average biomass per stand was calculated as 452.46 GT ha^{-1} in year *n*.

Table1. Biomass values for the stands available for harvesting.

Initial biomass by fraction (year 0)			Biomass by fraction (year n)		
W_{stem}	W_{crown}	W_{total}	W_{nstem}	W_{ncrown}	W_{ntotal}
17,316.4	7,155.8	24,472.2	31,953.6	9,791.6	41,745.2

Note: calculated by biomass equations in terms of 50% moisture content

Average forwarding distance was found to be 14 km, a low value in respect to the usual distances covered in Asturias. With regards to the truck, it is worth noting that trucking distance is short given that the theoretical consumption point is located very close to the forest, an average of 8.1 km. This fact of course has implications for the very advantageous global costs of the harvesting.

Average supply cost was calculated as 23.89 € GT^{-1}, a relatively low value compared to those obtained in other studies (Canga *et al*., 2009), mainly due to the very low average transport costs 5.23 € GT^{-1}. Figure 1 shows a map of the estimated costs for each stand (€ GT^{-1}).

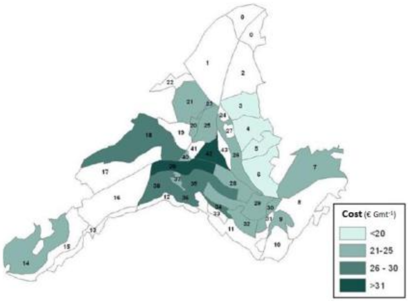

Fig. 1. Supply cost per each stand (€ GT^{-1})

Table 2 describes the itemised costs (€ GT^{-1}) in relation to the distinct activities involved in the harvesting and total costs.

Table 2 . Descriptive statistics of the different forest operations (€ GT^{-1})

	Harvesting	Forwarding	Chipping	Trucking	Total
Average	2.84	9.33	6.49	5.23	23.89
Minimum	0.00	7.32	6.49	4.01	18.67
Maximum	3.68	12.18	6.49	13.09	35.44
Standard deviation	1.58	1.23	0.00	1.95	3.49

In order to supply a biomass boiler installed in the theoretical consumption point, 48 $GT.yea^{-1}$ of biomass per year would be required. The forest system under study was found capable of supplying an average of 1,476 GT $year^{-1}$ (160 GT ha^{-1}), meaning that from a technical point of view, supplying the boiler from local woodchip supply is viable. Furthermore, it was calculated that a saving of 5,875.50 € $year^{-1}$ would be made by the boiler using a woodfuel rather than a diesel boiler.

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