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Assessment of biomass potential for Power Production

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Abstract.

The aim of this research Project is to develop a methodology to evaluate forest biomass for calculating energy production and resources cartography by means of the use of GIS (Geographic Information System) in the Urdaibai (Biscay). The project tries to determine the potential, available, and usable as energy resource, residual forest biomass, after the treatments of forest species in the area. The first part of the project aims at validating the ground map of the Urdaibai (Spain) obtained in the last Inventario Forestal Nacional (IFN3). In order to complete this part of the project, it is necessary to carry out a study on the ground composition in the area by sampling and subsequent laboratory analysis. In this inventory phase, the use of U.S.L.E/R.U.S.LE (Universal Soil Loss Equation) for calculating soil loss is suggested, since this equation is one of the main tools able to estimate the mean erosive rate of a territory. By means of this empiric model, it will be possible to determine the current soil erosion rate and its potential evolution due to different forest treatments that are characteristic of the most representative forest species in the area.

Key words

Bioenergy potential, Forest residues, GIS, erosion

1. Introduction

The following is a widely accepted definition for biomass: "biodegradable fraction of waste products and residues from agriculture, forestry and related industry, as well as the biodegradable fraction of industrial and municipal residues" (Directive 2003/30/EU). Residual Forest Biomass (RFB) is the name given to any organic matter coming from forest treatments necessary for preserving and improving forest masses. The overall energy potential of biomass the biosphere would be able to generate annually is estimated at 68,080 Gtoe. This represents an enormous biomass production potential worldwide [1]. In Spain, the energy potential of residual biomass is about 26 M toe y^{-1}. In the Autonomous Community of the Basque Country, biomass is currently the most widely used source of renewable energy [2]. As an example, the contribution of renewable energies to the final consumption of energy in the Basque Country was 6.8%. From this amount, 85% was biomass [3].

The use of forest biomass as energy resource, instead of fossil fuels, means some first order environmental advantages: minimum emissions of pollutants and particles, reduction of forest fire risk as well as plagues of insects. Moreover, the energy exploitation of forest residues does not contribute to the increase of greenhouse effect, since the balance of CO_2 emissions to the atmosphere is neutral. This fact helps to reach the international agreements on the topics of polluting emissions, fight against climate change and promotion of sustainable development [4]. However, the energy valuation of forest biomass presents some problems due to its low energy density and the scattered production of the resource. Generating energy from biomass is currently rather expensive due to technological limitations in terms of lower conversion efficiencies, and to logistical constraints.

One of the main hindrances to biomass energy management is the difficulty of ensuring a steady supply for heat or electricity generating plants. Nonetheless, identifying and assessing the potential of different forest species for energy purposes is a priority task that is being undertaken in most of developed regions worldwide in order to replace fossil fuels and hence contribute to biosphere sustainability. As a result of this, the quantity of biomass becomes essential since its supply to the energy plant must be guaranteed [5- 7].

There are models that simulate the tactic of growing biomass energy crops to secure a regular production in line with feedstock needs, and logistics-based tactics, e.g. for the optimal collection of forestry biomass [8].

A GIS (Geographic Information System) model can save between 5 and 18% of the cost of logistics, according to Yu et al. [9].

In this work, the biomass resources considered has been those produced in the forestry sector as consequence of field operations. Forest field byproducts (residues) are considered to be those vegetal materials produced in forests which have experienced, up to the present date, little or null commercial demand. Forest by-products usually consist of branches, tops, bushes, understory vegetation, and, in general, wood not exploited for conventional uses such as timber sawing, pulp, or board production. Table 1 shows the types of forest residues [10].

Table I. Origin of forest residues

Resource	Residue generating process	Residue
Forest residues	Forest treatments	Branches, scrubs and feet not for timber industry
	Feet cuts for timber industry	Tops, branches

2. Assessment of residual forest biomass for bioenergy

This article describes the methodology applied and the results obtained in a research project developed in the Urdaibai Biosphere Reserve (Basque Country). Its mouth is located in the estuary of Urdaibai and the area takes up a surface of 220 km2. Its high environmental value was labeled by UNESCO in 1984 as Biosphere reservoir [11-13]. Urdaibai is a region located in the North of Spain at a latitude of 43º12'N, and a length of 2º 33'W (figure 1).

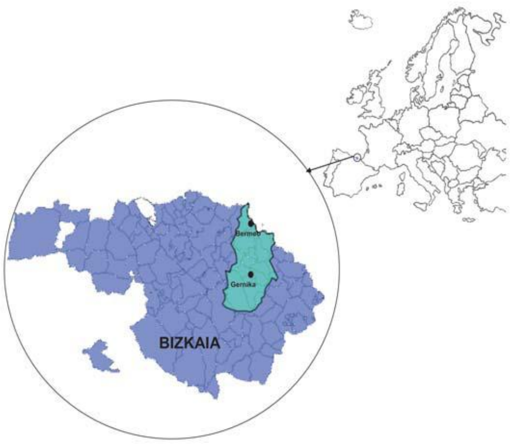

Fig. 1. Urdaibai’s landscape

The first approach has consisted of estimating the potential “residual” resources produced in the forest activities. In a second step, different constraints have been taken into account and hence, a reduction of the potential resources have been produced.

The study of forest biomass is based on the application of updated national data bases such as the Third National Forest Inventory (3NFI) [Tercer Inventario Forestal Nacional (IFN3)] and the Spanish Forest Map (SFM) [Mapa Forestal Español (MFE) [14], since these bases provide us with quantitative data about wooded surfaces and these are described by strata.
Once the forest masses have been classified per strata, the most adequate forest treatments that can be carried out in each stratum are identified.

The forest biomass residue quantities that could be obtained in each stratum are estimated in accordance with those treatments. In this way, in order to determine the residue estimator generated in each sampling plot, it is only necessary to know which stratum contain the forest species for which the treatment has been defined in accordance with its mass state.

The methodology followed is based on the biomass fractions introduced by Montero *et al.* [15]. Such a method develops a logarithmic model which relates the normal diameter of the tree to the net dry biomass. The evaluation method ought to consider the different phases across the complete rotation of a forest stand and the silvicultural tasks performed in each phase.

For estimating the amount of annual biomass (metric tons/year) that might be generated by current forest masses in Urdaibai, the methodology applied uses a Geographic Information System (GIS) with the help of Arcview GIS 10, a program used as a tool for managing analysis and data representation. The annual available quantities of dry biomass (expressed in t) will be obtained as:

$$W = \sum_i A_i * E_{ri} \qquad (1)$$

Where Ai represents the suitable area (ha) and E_{ri} the annual residue estimator, which indicates the available annual residual biomass for energy production expressed in t ha-1 In a second step different constraints have been taken into account and hence, a reduction of the potential resources have been produced. The environmental restrictions that have been adopted for all forest including protected areas have been the following:

1) The organic carbon content in top soil
2) The slope
3) The erosion risk

For the organic matter content and erosion maps, the classification used differentiates between good, normal and poor soils (table II) for the optimum development of the forest masses as shown in the results obtained by other researchers [16,17]. In this way, limit values for each parameter are established in order to define the real availability of the forest biomass.

Table II. Soil classification for the development of forest biomass

	OM* (% kg dry mass)	K** $tha^{-1}.MJha.mm^{-1}h^{-1}$
Good	>2	0-0.15
Poor	1-2	0.15-0.30
Bad	0-1	0.30-0.45

*Organic matter, ** Soil erodibility

Steep slopes play a drastic role in the biomass extraction/collection activities, reducing the effective area down to almost one half in certain zones of the north of Urdaibai. Such factor should be rigorously taken into account when performing any estimation relating biomass quantification.

The quantities reduced after the application of the constraints are the so-called Available Resources. Slope was derived from the digital elevations model. The digital elevation model was made using a pixel size of 2 metres. Three ranges of slopes have been delimited: under 35%; 35-60% and slopes of over 60%. The first range (≤35%) corresponds to the most appropriate topographical area for the supply of biomass with the least risk of erosion. The second range of slopes (35-60%) presents a moderate suitability with moderate risk of erosion and the third range (≥60%) would correspond to the less appropriate areas for the extraction of biomass due to its high risk of erosion. The quantities that can be collected after the application of the restrictions are summarized in table III. As can be observed, biomass in slopes over 60% has been considered unavailable due to the problems of accessibility to the proposed machinery.

Table III. Biomass available (%) in different conditions of slope, erosion risk andborganic carbon in top soil

Slope (%)		*≤35*	*35-60*	*≥60*
K ($tha^{-1}.MJha.mm^{-1}h^{-1}$)	*0-0.15*	*100*	*80*	*60*
	0.15-0.30	*90*	*70*	*50*
	0.30-0.45	*0*	*0*	*0*
Organic Carbon (% in 30 cm top soil)	*>2*	*100*	*80*	*60*
	1-2	*80*	*50*	*0*
	0-1	*0*	*0*	*0*

The digital elevation model was made using a pixel size of 2 metres. Organic carbon content in soils was obtained by analysing the soil sample. Erosion risk was obtained from the soil erodibility (Factor K) of the USLE/RUSLE model. Factor K evaluates the susceptibility of the soil to erosion. According to a number of different researchers, this model is particularly appropriate for calculating the average soil removed by laminar erosion or in the irrigation channels of a river basin [18,19].

3. Implementation of the method in a geographic information system

Geographic Information Systems (GIS) are useful tools for understanding the geographic context of a wide range of issues pertinent to bioenergy, especially energy demand and biomass supplies. The program package ArcInfo v.10 was used in the present study. The tools of ArcInfo are structured as three applications whose combined use allows access to all of the package's functionality: ArcMap, ArcCatalog and ArcToolbox.

We used the 500 m resolution geographical maps of merchantable forest biomass to estimate the amounts of forest residuals.

4. Available energy potential

In order to calculate the energy potential, the forestry species that would be suitable for exploitation were selected on the basis of two aspects: the quantities of usable residue for energy production and the technological feasibility of such use. With these premises, the selected species were: P. radiate and *E. globulus*. The potential energy of the residues (P) is a function of the Lower Heating Value (LHV), times the total residue for each species considered:

$$P = \sum_i A_i * E_{ri} * LHV \qquad (2)$$

Where, P represents potential energy (GJ y^{-1}), and LHV the lower heating value in humid base (GJ t^{-1} y^{-1}) of the forest residue obtained at the same humidity level at which productivity is considered (30%).

The energy potential is defined as the energy contained in the biomass which can be technically and economically used for energy production purposes.

The different operations such as cleaning, thinning and felling have taken into account in the cost and the terrain slope have been used as influencing factor for the operations cost. The estimates of residue extraction costs also included representation of basic ecological sustainability and technical accessibility constraints.

As preliminary approach, costs have been estimated for the operations of harvesting and short distance transportation. The basic method evaluated for forest residues handling consisted in three operations:

a) Piling up residues
b) Forwarding bulk residues to roadside (max. 500 m)
c) Baling

The basic costs have been estimated for different specie categories (*P. radiata* and *E. globulus* and for the different operations (thinnings, fellings). Furthermore, due to the influence of the topography on forest machinery operational costs, three different situations have been considered: slopes lower than 35%, between

35 and 60% or higher than 60%. The slope of the land is the physical variable that most influences the costs.

5. Results and Conclusions

The results obtained from statistical analyses of the data showed that the amount of mean forest biomass achieved with an interval of 95% is 7,775.32 t odt y^{-1}, from which 6,334 t y^{-1} correspond to *P. radiata* residue and 1,441 t odt y^{-1} to *E. globulus* (table IV)

Table IV. Heating values (GJ t^{-1}), biomass production (t y^{-1}) and Energy (GJ) of the types of residue under study

Biomass residues	LHV[a] (GJ t^{-1})	Biomass Production (t y^{-1})	Energy potential (GJ y^{-1})
P. radiate	12,67	6334,12	80,253.30
E. globulus	12.85	1441,20	18,519.42
Total		7775,32	98,772.72

[a] Lower heating value

Estimators for the P. radiata forest ranged from 286 to 885 kg ha^{-1} $y^{-1,}$ and 346 to 2156 kg $ha^{-1}y^{-1}$ of Eucalyptus (dry mass, which corresponds to 408.6-1264.3 and 494-3080 kg ha^{-1} y^{-1} wet mass). The residue mean estimator in this stratum takes values of 0.843 - 0.914 t ha^{-1} y^{-1} (dry mass) or 1.204 - 1.305 (wet mass) (figure 2). As it has been mentioned in previous sections, a humidity of 30% is considered when the residual biomass for energy valuation is collected.

Average costs of forest residues are estimated at 50 €/odt 46,99 €/odt Conifers and 52,43 €/odt E. Globulus..

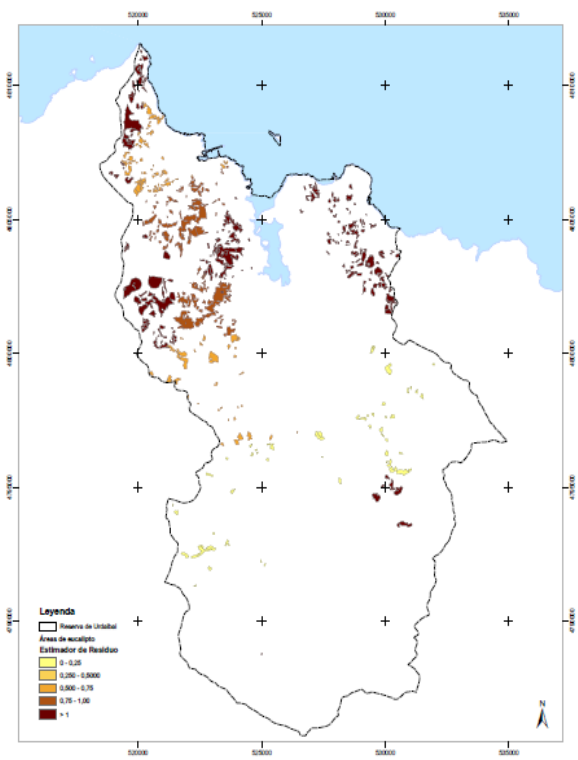

Fig. 2. Annual residue estimator E_r of forest biomass (t ha^{-1} $y^{-1)}$.

The concentration of residual forest biomass in specific zones is important because such zones will serve as a basis for the possible location of industries that could use the biomass as fuel, or those which could produce electricity using biomass as an energy source. We believe that in the Basque Country, the most promising applications are cogeneration in medium-sized power stations and combustion in small and medium-sized plants for heat and steam generation. The specific features of the economy of scale restrict the design of energy plants to those with a minimum production capacity of at least 1.5 MW, this corresponds to a need for 7,000 t^{-1} of raw material. The major challenges faced by these energy conversion technologies include how to collect, prepare (chipping, briquetting, etc.) and transport biomass to electric power plants with the lowest possible financial and environmental costs, and how to assure supplies over time

An increase in the use of residual forest biomass as a source of energy instead of conventional fossil fuels will represent important environmental advantages and will help to follow the aims of the EU policies in terms of energy rationalization and fight against global heating, and thus, 20% of the energy consumed in 2020 would come from renewable sources. The use of forest biomass as energy resource converts biomass in one of the prospective sources of employment, thus increasing economical activity within the area of study, and also being an important element for territory equilibrium, mainly in rural areas.

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References

[1] IDAE, “Manuales de energías renovables, Manual de energía de la biomasa”, Madrid, (1996) p. 155.
[2] J. Fernandez, Biomasa. Energias renovables, Cuaderno Energías renovables para todos: Biomasa. In: http://www.energiasrenovables (2007)
[3] J.I. Hormaeche, La energía de la biomasa convertida en calefacción, Jornadas sobre la energía renovable de la biomasa, EVE, Gobierno Vasco (2011)
[4] A.J. Finkral, A.M. Evans, “The effects of a thinning treatment on carbon stocks in a northern Arizona ponderosa pine forest”, For. Ecol. Manage, 255, (2008), pp. 2743-2750.
[5] E. Tolosana, “Manual técnico para el aprovechamiento y elaboración de biomasa forestal”, Fucovasa y Mundi-Prensa, Madrid, (2009).
[6] Basoa Fundazioa, Guía de buenas prácticas en el sector forestal y de transformación de la madera, Gobierno Vasco, (2007).

[7] IDAE, “Manuales de energías renovables, Manual de energía de la biomasa”, Madrid, (1996) p. 155.
[8] Frombo, R. Minciardi, M. Robba, F. Rosso, R. Sacile Planning woody biomass logistics for energy production: a strategic decision model Biomass Bioenergy, 33 (3) (2009), pp. 372–383.

[9] X. Zhu, X. Li, Q. Yao, Y. Chen Challenges and models in supporting logistics system design for dedicated-biomass-based bioenergy industry Bioresour Technol, 102 (1) (2011), pp. 1344–1351.
[10] Esteban L., García, R., Ciria P. and Juan Carrasco J. Biomass Resources and Costs in Spain and Southern EU Countries, Clean Hydrogen-rich Synthesis Gas, Nº 36, Ciemat, (2009).
[11] G. Rodríguez-Loinaz, I. Amezaga, M. San Sebastián, L. Peña, M. Onaindia,. Análisis del paisaje de la reserva de biosfera de Urdaibai. Forum de Sostenibilidad 1, (2007) pp. 59-69.
[12] IKT S.A., and Patronato de la Reserva de Urdaibai. 2006. Ficha Informativa de los Humedales Ramsar (FIR). Ría de Mundaka-Gernika (http://www.mma.es/
[13] M. Ibarrondo and , M. J. González. Forest management in urdaibai biosphere reserve: a lost opportunity Boletín de la A.G.E. 46, (2008), pp. 417-418
[14] Tercer Inventario Forestal Nacional en versión digital para la provincia de Vizcaya (IFN3) Ministerio de Medio Ambiente, (2006)
[15] G. Montero, R. Ruiz-Peinado, M. Muñoz, “Producción de biomasa y fijación de CO2 por los bosques españoles”, Instituto Nacional de Investigaciones y Tecnología Agraria y Alimentaria (INIA); 2005.
[16] Edeso, J. M., Merino, A., González, M. J., Marauri, P.: Manejo de explotaciones forestales y pérdida de suelo en zonas de elevada pendiente del País Vasco. Cuaternario y Geomorfología. 12, (1998), pp. 105–116.
[17] A. Merino, A. Fernández-López, F. Solla-Gullón, J.M. Edeso, “Soil changes and tree growth in intensively managed Pinus radiata in northern Spain” For. Ecol. Manage. 196, (2004) pp. 393–404.
[18] B. Egoh, B. Reyers, M. Rouget, D.M. Richardson, D.C. Le Maitre and A.S. Van Jaarsveld, 2008. “Mapping ecosystem services for planning and management” in Agriculture, Ecosystems and Environment, 127, (2008) pp. 135-140.
[19] L.S. Esteban, M. Ciria, and J.E. Carrasco, “An assessment of relevant methodological elements and criteria for surveying sustainable agricultural and forestry biomass by-products for energy purposes” Bioresources, 3, (2008) pp. 910-928.