Multidimensional sustainability assessment of forest resource supply chain

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Summary

Valorisation of biomass resources is recognized as a new frontier of economically sustainable and environmentally friendly activities. Nevertheless, it is not possible to assume a positive comprehensive balance in term of sustainability of products based only on the fact that they are bio-based, but it is necessary to perform exhaustive studies in a life cycle perspective. A multidimensional approach to sustainability assessment is therefore needed in order to support decision making at various level, trough comprehensive composite indicators. The present study develops a methodology for assessing the sustainability level of a technological/ operational options applied in a specific context, taking into account sustainability criteria. A comparison may be done among a number of different technologies to choose the best option in term of environmental, economic and social performance. A set of specific indicators is developed to assess the performance of a number of potential options for the implementation of forest biomass system exploitation.

Keywords: sustainability assessment, carrying capacity, decision support system, forest biomass, spatial analysis.

1. INTRODUCTION

The multyfunctionality of forest has been remarked constantly in European policies. Forests can ensure several ecosystem services: providing raw material for goods, regulating local and global climate, buffering weather events, regulating the hydrological cycles, protecting watersheds and their vegetation (Nasi et al., 2002). The valorisation of biomass resources is recognized as a new frontier of economically sustainable and environmentally friendly processes; nevertheless, it is not possible to assume a positive comprehensive balance in term of sustainability of products based only on the fact that they are bio-based, but it is necessary to perform exhaustive studies in a life cycle perspective, considering also site-specific characteristics (e.g. the local availability of raw material and the distance from the processing plant to the delivery point) and the sustainability of the system in term of energy efficiency, total material requirement, CO_2 emissions, etc (Sala & Castellani, 2009). Though composite indicators can be misleading if poorly constructed and can involve subjective evaluations (e.g. about weights), the decision to aggregate the data together to produce a performance index comes from the consciousness that composite indicators can help to measure multi-dimensional concepts (as sustainability) that cannot be capture by single indicators (Castellani & Sala, 2009).

Evaluation of the trade-off between the benefits coming from forest resources' use and the conservation of forest ecosystems is needed. Considering the use of biomass for energy purpose, on one hand the use of wood resources should be based on an evaluation of the "carrying capacity" of the forest ecosystem and site-specific characteristics (e.g. the local accessibility of raw material and the distance from the processing plant to the delivery point); on the other hand, the role of biomass valorisation has to be assessed considering the socio economic benefit or drawbacks due to the further development of the supply chain. E.g, positive effect related to an increase employment in less developed mountain areas and to a direct relation beetwen population and territory needs to be quantified.

Our main interest was to identify the major components at several levels of supply chain organization and to assess the sustainable use and conservation of biodiversity through indicators based on Life Cycle Assessment methodology, otherwise, in the context of a site–specific sustainability assessment of a wood energy supply chain, the research focuses on development of an expeditious methodology to obtain geo-referred quantity of biomass at local scale for mountain forest areas, in order to facilitate energy planning that considers the local system carrying capacity and the potential of substitution of fossil fuels. Finally, a tailor-made sustainability approach is proposed, considering the actual sustainability of technologies in relation to the scale and context specific.

2. METHODOLOGY

The increasing disruption of natural ecosystems from anthropogenic sources highlights the need to develop methodologies for assessing changes in biodiversity. The evaluation and monitoring of ecosystems requires the development and application of appropriate indicators. Indicators should be:

- reliable and able to synthesize the complex relationships;
- measurable and transparent in order to make communication easy;
- suitable for providing information to support decisions.

LCA is interesting for comparative purposes but when working at the local scale, is still weak on the aspects of ecosystems "really" impacted. The LCIA method (impact assessment) generally disregards ecosystem services and do not consider:

- soil compaction (harvester and forwarder);
- damage to roots and plants not involved in cutting (harvester, forwarder and cable crane);
- removal of undergrowth;
- absorption capacity of the system.

An assessment of the specific site could be a useful tool to refine the procedure of "risk assessment" or LCA methodologies in order to create a list of indicators "site-specific". It requires a combined effort to process and methodology in a comprehensive tool, especially if taken as a decision support system, especially for local policies.

The present methodology allows assessing the sustainability level of a technological/ operational options applied in a specific context, taking into account sustainability criteria. A comparison may be done among a number of different technologies to choose the best option in term of environmental, economic and social performance. A set of specific indicators is developed to assess the performance of a number of potential options for the implementation of forest biomass system exploitation. This may help decision makers in choosing not only the technology and the operational options that seems more efficient, in theoretical condition, but the best solution in the specific local context. The steps of the methodology are:

1. setting sustainability criteria. Considering forest management and harvesting, sustainability criteria for a technological/operational options in forest management are: use of local resource considering carrying capacity of the system; short supply chain development, greenhouse gases compensation ability, limited environmental impact, financial profitability, capability of positive economic and social effect in the local context;

2. defining system boundaries and collecting information about available technological and operational options for forest management in the specific context to populate technological/operational efficiency indicators (for example quantity of wood that could be harvested per day);
3. defining and populate indicators. The indicators for each specific technological/ operational option are related to: resource availability, environmental impact, economic efficiency, social impact;
4. implementing LCA of the technological/ operational options. In this step, a consequential LCA methodology seems the best choice, as it allows to increase the understanding of product chain and to identify the processes and relation most important to improve (Finnveden et al., 2009). Within the context of environmental assessment, some aspects are considered particularly critical, such as the impact on biodiversity and the evaluation of vulnerability of exposed ecosystem (De Lange et al., 2010);
5. definition of an "optimum of application" trough the application of law limits, policy objectives, benchmark of excellence, expert judgement. This step could be enriched by the result of a stakeholders consultation, especially regarding expected economic and social benefits;
6. score attribution to each indicators, related to level of achievement of the optimum;
7. comparison among sustainability level achieved by each technological/operational option using a dashboard of indicators. An aggregated index is less meaningful: the visualisation of single performance values allows to identify priority area of intervention to increase sustainability of the analysed option.

3. Results and Discussion

The methodology developed for the site-specific assessment of the biomass availability, with respect to carrying capacity, consists of quantification and mapping (using Geographic Information System) of forest biomass that considers local features (e.g. abundance, spatial distribution and type of species) as reported in local territorial plans and it applies Life Cycle Assessment for supporting the overall environmental assessment. The calculation of carrying capacity is showed in the remainder of this section.

Biomass value calculated has been converted from volume to mass, considering species features and water content. The result is compared with current utilization of wood, and waste products from forestry processing are estimated, in order to quantify the mass available for energy valorisation. Then, the Energy potential is estimated, from biomass quantity and from wood features, principally the lower calorific value and water content for each species. Finally, the potential of substitution of fossil fuels is calculated, knowing energy potential from available biomass for energy use.

The methodology is applied to two mountain areas, Comunità Montana Lario Intelvese (CMLI) and Comunità Montana Triangolo Lariano (CMTL), in Northern Italy (Como Province). Results are summarised in Table 1, and Figure 1. Humidity content considered was 20% and 40% (threshold values of the fuel in the case of forest chips boilers). Current utilization is estimated through the elaboration of Forest Activity Statements: 62% for CMLI and 66% for CMTL. Considering data from (ITABIA, 2008) and (ISTAT, 2008), combustible fraction adopted to estimate potential available biomass for energy use is 80%.

Policy of the Province of Como identifies small biomass plants (power below 1 MW thermal) as optimal solution in order to use the resource in energetic valorisation. CMLI area has already a thermal power plant forest chips for district heating. Considering the consumption of such facilities and the biomass availability calculated, it is estimated that for each study area can be provided for 20-30 similar plants. The location of these facilities should be based not only on the demand for energy, but also on the spatial distribution of biomass and accessibility of forests, considering the different types of roads and paths for transport and storage of firewood. LCA was used to assess the overall environmental impact.

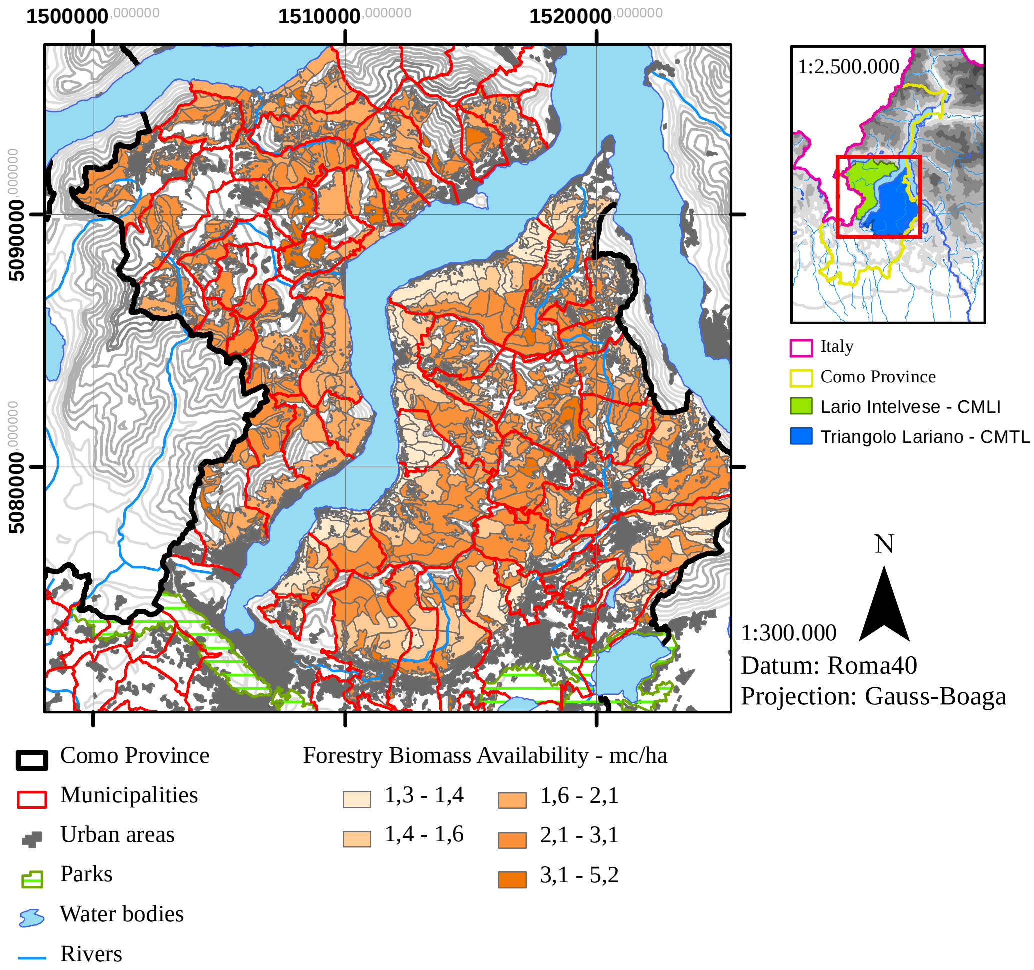
Table 1. Results.

Local authority area	Potential available biomass (t/y)		Current Utilization of wood* (t/y)	Potential available biomass for energy use* (t/y)	Energy potential* (GJ)	Replacement of fossil fuels* (tep)
CMLI	25,277	± 3,636	15,672	7,684	89,486	2,138
CMTL	31,110	± 4,475	20,533	8,462	98,395	2,351

* Medium values

The present work highlights the importance of the implementation of sustainability LCA as a basis of technological/operational assessment, also in supporting policy making at local scale. A promising sector of application of the model is the assessment of the sustainability of whole short supply chain, where environmental benefit has to be assessed and important economic and social beneficial to local community are expected. Further development of the research could include widen sustainability Life Cycle Analysis of the wood supply chain and the comparison between the environmental, social and economical benefits in developing a short supply chain (wood-energy) or (wood-furniture) one.

Figure 1: forestry biomass availability of the mountain areas (CMLI and CMTL).



4. CONCLUSIONS

The proposed methodology evaluates the possibility for forests to provide the supply of raw material for energy production among ecosystem services. In addition, this assessment aims to integrate considerations to protect the other ecosystem services. Moreover, the proposed methodology is useful for a preliminary assessment of the possibility to considering forestry biomass in energy planning at local level. Finally, spatial distribution, quantity and accessibility of wood resources should be compared with the energy demand in order to identify land optimize location and characteristi cs of the plant for energy production and minimize the logistic within the supply chain.

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