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Review

Environmental factors in woodfuel production: Opportunities, risks, and criteria and indicators for sustainable practices

B. Lattimore[a,*], C.T. Smith[a], B.D. Titus[b], I. Stupak[c], G. Egnell[d]

[a]Faculty of Forestry, University of Toronto, Toronto, Ontario M5S 3B3, Canada
[b]Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC V8Z 1M5, Canada
[c]Danish Forest & Landscape Research Institute, Faculty of Life Sciences, University of Copenhagen, Hoersholm Kongevej 11, 2970 Hoersholm, Denmark
[d]Faculty of Forest Sciences, Swedish University of Agricultural Sciences, SE-901 83 Umeå, Sweden

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ABSTRACT

Bioenergy from sustainably managed forest ecosystems could provide a renewable, carbon-neutral source of energy in many nations and communities throughout the world. In order for forest bioenergy to be an ecologically sustainable fuel source, woodfuel procurement systems must not adversely impact forest ecosystems or the environment. Sustainable forest management (SFM) certification schemes are one mechanism for applying standards and monitoring regimes to forest management systems to ensure ecological sustainability. This paper provides a global review of the main environmental risks to forest ecosystems that can arise from household- to industrial-scale woodfuel production systems, including forest soil quality and site productivity, water resources, biodiversity and carbon budgets. A set of regionally adaptable principles, criteria, indicators and verifiers of sustainable forest management were developed, based on criteria and indicators from existing internationally recognized certification frameworks and scientific literature and tailored to address issues relevant to producing and harvesting forest bioenergy feedstocks. A *variable monitoring approach* and a *three-tiered certification approach* are proposed as two methods for enabling the adoption of certification and associated monitoring requirements across a wide range of forest operations in regions with widely differing levels of development. The importance of the Adaptive Forest Management framework inherent in certification systems to ensuring the efficacy and continual improvement in woodfuel sustainability is stressed. The proposed principles, criteria, indicators and verifiers can be adapted to local conditions and incorporated into existing sustainable forest management and green energy certification schemes, as well as other criteria and indicator frameworks, to ensure the environmental sustainability of woodfuel production systems.

1. Introduction and approach

Wood and wood-derived fuels (woodfuels) are a primary energy source for many domestic households in developing countries. They are also used as an energy source in industrial facilities, particularly in Europe and North America. Utilization of forest biomass to produce solid and liquid fuels and to supply a developing bio-based economy has the potential to intensify

* *Corresponding author*. Tel.: +1 416 9785273.
E-mail address: brenna.lattimore@utoronto.ca (B. Lattimore).
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globally as governments strive to increase renewable energy production, reduce carbon emissions (especially from fossil fuels), and expand the use of domestic fuel sources. Forest bioenergy is considered a renewable, low-carbon or carbon-neutral energy source because it is derived from harvested vegetation that sequesters atmospheric carbon during growth, releases carbon back to the atmosphere when vegetation is converted to energy, and sequesters it once again as the next crop develops. The carbon balance of any bioenergy production system must be assessed over the life cycle of the product; carbon accounting protocols for bioenergy production systems must quantify the net carbon emitted to the atmosphere and reductions in fossil fuel-derived carbon emissions achieved. They therefore must include the carbon required to grow, harvest, process, transport and convert the biomass into energy, and the carbon emitted through the disposal of wastes produced at any stage in the value chain, from the forest to consumers to materials recycled back to the forest. Forest bioenergy must be economically, socially and environmentally sustainable along the entire supply chain if it is to reach its full potential as an energy source. In this paper, however, we focus primarily on the environmental sustainability of the first link in the bioenergy supply chain, which is forest biomass production.

Forest bioenergy feedstocks can be derived from a variety of sources, including silvicultural thinning operations, residues from merchantable trees, mill wastes, dedicated energy plantations, agro-forestry operations and fuelwood gathering from forest stands in and around populated areas. These feedstocks are produced and harvested at a range of scales, from small-scale domestic firewood gathering to large-scale industrial energy plantations and mechanical extraction of virtually all above- and below-ground biomass from intensively managed forests. Most bioenergy in developed countries is currently derived from primary and secondary wood product manufacturing operations. Environmental risks are thought to increase if forest bioenergy production systems entail more intensive forest management and utilization of biomass than conventional forest management involving removal of only merchantable, traditional products such as saw logs and pulpwood over relatively long rotations. Regardless of scale and intensity, sustainable production systems must be designed so that they: maintain or improve the quality of forest ecosystems (including soil and water resources, site productivity and biodiversity); maintain or improve the ecological integrity of landscapes; and reduce excessive pollution.

Criteria and Indicators (C&I) can be used to measure sustainable forest management, and hence to assure society that long-term utilization of forest resources is environmentally sound. Such C&I have been developed through international protocols such as the Montreal Process [1], and by non-governmental certification organizations such as the Forest Stewardship Council (FSC) [2] and schemes under the Programme for the Endorsement of Forest Certification (PEFC) [3]. While current protocols and certification systems cover some aspects of forest bioenergy feedstock production and are broadly applicable (in that this production is a sub-set of sustainable forest management), comprehensive sets of C&I for forest biomass production that integrate with current systems are lacking. Furthermore, recent efforts to develop criteria and indicators for sustainable biomass production, such as those developed by the Cramer Commission [4] and a preliminary version released in August of 2008 by the Roundtable on Sustainable Biofuels (RSB) [5], set good basic guidelines but do not address sustainable forest management specifically, nor do they provide specific indicators to measure success. Sustainable forest management certification systems that do contain this level of detail, and that address all of the known risks of forest biomass production and harvesting, can help to ensure that the broader criteria put for by such national and international efforts are met.

This paper therefore has two main objectives: (i) to identify and summarize the environmental risks associated with managing forests for bioenergy feedstock production, with examples of mitigation techniques that can be used at the operational level, and (ii) to address the identified environmental risks with a set of sustainable forest management principles, criteria, indicators and verifiers (PCI&V) for use in forest bioenergy certification systems that could, with some modification, help to ensure the sustainability of forest biomass production systems. The first section of this paper therefore presents an overview of the breadth of environmental issues that should be considered in sustainable forest management for bioenergy; in the second section, we propose PCI&V to address these environmental issues. The proposed PCI&V can be applied at a variety of spatial scales in management systems around the world, and can be used in the planning phases of forest management (e.g., site planning, operator training and technology selection) and for assessment of the sustainability of production systems.

2. Environmental risks of woodfuel production systems

Woodfuel production systems exist in various forms and at a range of scales around the globe, from the domestic collection of firewood to large-scale cultivation and harvesting of forest biomass for industrial energy production. Woodfuel production can be integrated into conventional forest management activities (e.g., residue removal from existing operations, pre-commercial thinnings), or can be the primary focus of forest management (e.g., dedicated energy plantations). As with any type of forest management, these practices will impact local ecosystems in some way, and impacts will vary in nature and extent according to the scale, intensity and type of production system used.

To address our first objective of reviewing the breadth of environmental issues that may be encountered in forest biomass harvesting and production systems, the existing literature (notably key review articles) was examined and potential environmental issues were identified and tabulated under six headings:

1. Soils (Table 1)
2. Hydrology and water quality (Table 2)
3. Site productivity (Table 3)
4. Forest biodiversity (Table 4)
5. Greenhouse gas balances (Table 5)