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Sustainable forest management for land rehabilitation and provision of biomass-energy

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Key messages

- There is potential for certain types of degraded land to be restored into sustainable forest and to produce biomass for renewable energy, if implemented under careful management.
- Improved strategies are needed to increase the efficiency and sustainability of bioenergy production from forests and restored degraded land.
- The first requisite step towards the development and implementation of forest-based energy systems are feasibility studies in order to avoid harmful environmental impacts, and to improve socioeconomic well-being.
- Efficient energy production from forest biomass requires the development of interdisciplinary strategies to sustain continuous biomass supply from available land and maintain ecosystem services and community needs; as well as the employment of suitable energy technologies.

Introduction

The International Energy Agency observed that global energy supply has to increase by 37% to meet the projected energy demand by 2040 (IEA 2014). With the clear imperatives of keeping global warming below 2°C and reducing dependence on dwindling fossil fuel resources, investment in renewable energy sources is essential. There are several technologies that produce renewable energy from abiotic natural resources (e.g. sunlight, wind, water, tides, waves and geothermal heat) and various technologies that produce energy from biomass of varying properties and from multiple sources (e.g. food industry, agriculture, forestry). However, bioenergy production poses many challenges and is controversial in many parts of the world because it competes for land with food production and could potentially degrade the natural environment. Thus, sustainable forest management strategies are needed to provide renewable bioenergy, while preserving or even improving valuable ecosystem services. One way to achieve this is the rehabilitation of degraded and otherwise unproductive land with forests for renewable energy production.

Globally, many human activities, such as agricultural mismanagement and deforestation, have seriously degraded land and hence impaired the efficiency and effectiveness of forest ecosystem services and functions (Nkonya et al. 2012; ELD Initiative 2015). Processes such as soil erosion and physico-chemical deterioration (Jie et al. 2002; Barman et al. 2013), often reduce land productivity and ecosystem services provided by vegetation and soil (Barman et al. 2013; ELD Initiative 2015).

Clearly, the loss of productive land conflicts with the need to provide food security for a growing world population (Godfray et al. 2010; Barman et al. 2013; ELD Initiative 2015) and to maintain net-carbon accumulation by plants to mitigate climate change. Thus, preventing further land degradation and enabling land rehabilitation are both crucial to establishing resilient ecosystems. These joint aims are potentially attainable by adopting systems that have been carefully designed and managed to produce biofuels (Bouma 2014; McCormick et al. 2014; ELD Initiative 2015). Forests are important components of the terrestrial carbon cycle through their accumulation and storage of large amounts of carbon in biomass and soil (Dixon et al. 1994; Hollyet al. 2007). Thus, the capacity of forests to capture atmospheric CO_2 has always mitigated climate change, and improving forest health and productivity can help to offset further CO_2 emissions caused by fossil fuel combustion (Pregitzer and Euskirchen 2004; IEA 2010). However, achieving a conversion of non-managed, degraded land into managed plantations that provides these competing services is challenging, to say the least (Brown and Lugo 1994; Lamb and Gilmor 2003; Meuser2013; Baral et al. 2016). The design and management of forests that provide environmental services approaching the quality and quantity of those supplied by a natural, non-degraded forest will require specialist skills, technologies and resources (see Baral et al. 2016).

One response to the challenge is to design forestry systems that combine land restoration with sustainable bioenergy production. To gain scientific experience on this issue, the Center for International Forestry Research (CIFOR) and the Korean National Institute of Forest Science (NIFoS) hosted a session on "Forest-based sustainable bioenergy in Asia and the Pacific" at the 2016 IUFRO Regional Congress for Asia and Oceania, 24–27 October, Beijing, China. The session brought together experts from developed and developing countries to discuss and share experiences and research in forest-based bioenergy production from their countries. This paper summarizes this shared learning, providing a summary of the session and expanding on general directions of relevance for the policy and practice of sustainable bioenergy production using forests.

Processes and technologies used in the forestry related bioenergy sector

Numerous technologies have been developed to convert woody biomass into bioenergy, but their wide and efficient use has been limited in many countries. Thus, in order to achieve sustainable biomass and bioenergy production, research, outreach and up-scaling of new knowledge and technologies are required, as explained by Jeong et al.(2016), Hu et al.(2016) and Stinner et al. (2016). Their presentations illustrated the results of recent research on technologies that converted various types of biomass into bioenergy:

- Traditional uses of biomass are very common in many regions (e.g. firewood, charcoal), but their efficiency could be greatly improved (e.g. by employing closed charcoal production units and the capture of solid, liquid and gaseous fuel fractions). Transition from traditional to technically more advanced biomass-energy applications (combined heat and power systems, biofuels, etc.) is challenging because large investments are required to establish and maintain these bioenergy technologies. This indicates an urgent need to develop and implement simple, efficient and environmentally friendly bioenergy technologies that can be easily integrated with existing biomass supplies and technologies (i.e. wood chips or pellets from wastes, to replace coal).
- More complex systems intended to replace fossil fuels also need to be assessed, to determine: (i) amount and type of energy demand (e.g. electricity, liquid fuel, etc.) and (ii) potential biomass supply to feed bioenergy units. Although biomass can be transformed into energy by various biological and/or chemical processes, the economic viability of these processes remains uncertain in non-developed countries. New bioenergy approaches should be carefully assessed locally for their socio-economic benefits and dis-benefits to ensure the development of improved energy systems.

Combining bioenergy strategies and sustainable forestry

Combining bioenergy production and reduced-impact forestry to support the development of sustainable energy systems was an essential outcome of this session, as explained by Aziz et al.(2016), Borchard et al.(2016), Poudyal et al.(2016) and Stinner et al.(2016). Increasing energy production, while keeping the Earth green, is a challenge and strategies to produce energy without harming nature can be categorized as follows:

- Implementing methods to produce woody bioenergy crops on degraded or abandoned lands. This may result in initially low yields, but the approach depends on careful selection of species for all sites and establishment of mixed stands and careful utilization, as well as studies of yields over time.
- Using bioenergy residues (ash, char and slurries) directly for soil amelioration can recycle nutrients into soils to prevent their degradation. However, nitrogen and other essential macro nutrients for plants are usually lost during biofuel and bioenergy production through gaseous emissions or carbonization. Thus, designing slow-release fertilizers from bioenergy residues (or modified biochar) to facilitate controlled uptake long-term ammonium nutrition (CULTAN) offers a promising way to manage nitrogen fertilization by preventing environmental pollution.
- In countries with forests managed by communities, the implementation of bioenergy strategies is intended (e.g. in Indonesia and Nepal) to increase socio-economic welfare, but the impact of the bioenergy sector on those communities has hardly been addressed.

Reliable selection of woody species

Borchard et al.(2016) and Leksono et al.(2016) introduced advanced technologies and bioenergy strategies to integrate solid, liquid and gaseous biofuels into existing energy production systems. Two types of biofuels were discussed:

- Typically, fast-growing species are selected for biomass production. In the tropics, *Calliandra calothyrsus* and *Gliricidia sepium* are widely used, but these are not well-adapted to water logged soil conditions. South-east Asia has large areas of peatland, which requires (for its protection) high water tables, at least during the wet season. Thus, there is an urgent need to identify woody crops that are adapted to semi-terrestrial soils, which can produce valuable biomass outputs.
- Another important source of energy are species that produce oil that can be converted to biodiesel and/or bioethanol. Several species (e.g. *Calophyllum inophyllum*, *Pongamia pinnata* and *Reutealis trisperma*) have been identified and assessed for their oil production and its conversion into valuable liquid fuels.

Conclusion and implications for future activities

Research activities to develop and assess the efficiency of renewable energy strategies are expanding globally. However, while developed countries remain the major driver of modern renewable energy technologies, emerging and non-developed countries are increasingly investing in establishing renewable energy strategies with the aim of ensuring energy security. Biofuels and bioenergy are an essential part of reliable future energy production, although modern wood-based bioenergy technologies are not widely implemented in forestry sectors, due to limited biorefinery capacity and lack of integration into existing energy production systems. Even in industrial countries, most bioenergy from forest industries is produced from waste products. Thus, various categories of research and development for the bioenergy sector are required to ensure the development of efficient forest-based bioenergy systems in Asia and the Pacific:

- Developing forest-based bioenergy strategies that are adapted to: (i) local energy demands; (ii) socio-economic and environmental conditions to ensure successful implementation; (iii) providing beneficial combinations of renewable energy types (e.g. bioenergy, water energy, etc.).
- Developing simple assessment tools to enable the development of sustainable and economically feasible forest-based bioenergy production strategies (covering biomass production, bioenergy technologies, efficient reuse of residues and effective policies).
- Assessing forest community-based bioenergy approaches for their environmental and socio-economic impact, as options to promote energy security and poverty reduction in developing countries.
- Encouraging governments to develop policies and regulations that support forestry-based bioenergy development in terms of training, economical incentives and the promotion of bioenergy activities.

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