CHAPTER 1

An introduction to bioenergy and landscape restoration

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Abstract: Land degradation is becoming a global challenge, with Indonesia being no exception. Rising populations and their associated food and biomaterial demands have accelerated the conversion of forests for other land uses; a trend that persists in many parts of the world. Forest landscape restoration (FLR) is being promoted as a means for reversing land degradation while providing multiple products and services, including bioenergy. FLR using biofuel-friendly trees under climate smart agroforestry practices and utilizing fruits, nuts and biomass for energy could solve multiple issues by turning unproductive degraded lands into productive landscapes; preventing further conversion of natural vegetation for other uses; compensating for the high initial investments required for FLR; and providing multiple ecosystem services, including climate regulation. The chapters in this book investigate multiple issues associated with FLR and bioenergy, such as policy analysis, geospatial assessment for identifying land suitability, farmers' perceptions and species-specific details useful for land managers, planners and policymakers.

Keywords: Bioenergy, sustainability, landscape restoration, carbon

1.1 Introduction

Healthy forests and landscapes are essential for people and the planet, not only because of their contributions to the myriad ecosystem goods and products essential to local well-being, but also their multiple ecosystem services. These services include their natural capacity to store carbon, support biodiversity, regulate water and maintain soil health. According to Indonesia's Ministry of Environment and Forestry (MoEF), the country has more than 14 million hectares of degraded land, which includes two million hectares of degraded peatlands that play a vital role in climate mitigation through their vast stores of carbon. With such a large area of degraded land, Indonesia's need for forest landscape restoration (FLR) is inevitable.

Meanwhile, Indonesia's energy demand is growing rapidly in line with its population and economic growth. This trend is likely to continue into the foreseeable future due to the government's ambitious plans to provide energy to the entire population through its National Energy Policy (*Kebijakan Energi Nasional*) as stipulated under Government Regulation No. 79/2014. Following the Paris Agreement in 2015, through its Nationally Determined Contribution (NDC), Indonesia has committed to reducing its greenhouse gas (GHG) emissions by 29 percent compared to a business-as usual scenario by 2030. The country has also committed to new and renewable energy making up 23 percent of its national energy mix by 2025. Bioenergy production is one of the strategic measures aimed at achieving these targets.

The existence of vast areas of degraded land and ever-increasing demand for energy can pose both challenges and opportunities. FLR is a costly undertaking and a key obstacle to achieving its targets is the lack of financial resources to support FLR activities. Meanwhile, increasing energy demand and the promotion of biomass energy could exert further pressures on the country's remaining natural forests and food production; something known as the food-energy-environment trilemma. However, if designed and implemented appropriately, FLR can produce multiple goods and services including wood, biomass for energy, biomaterials, agri-food products and essential oils, as well as economic and social benefits while supporting nature conservation. For example, restoration of degraded and underutilized land using biofuel-producing species in climate-smart agroforestry systems can create vast bioenergy potential without causing competition for land required for other purposes, such as food production or nature conservation. Due to high net primary productivity, this presents an important opportunity for Indonesia to develop modern sustainable bioenergy while pursuing ambitious landscape restoration initiatives, such as its NDC target of restoring 14 million hectares of degraded land by 2030.

This book offers scholars, practitioners, small and medium enterprises and private sector actors interested in biomass energy and landscape restoration with insights from an interdisciplinary group of scientists who combined forces to integrate bioenergy and landscape restoration in Indonesia. The book covers a wide range of topics relating to bioenergy production and landscape restoration, including Indonesian government policies and initiatives in recent decades, geo-spatial assessments of degraded land available for bioenergy production, landowners' perceptions of bioenergy crops and landscape restoration, and specific information on promising bioenergy species such as *nyamplung*, bamboo and pongamia.

Table 1. Summary of the book's chapters and content

Chapter	Main topic	Research area	Methodology	Contributing manuscripts
2	Indonesian bioenergy policies, initiatives and research	Indonesia	Policy analysis	Widayati et al.
3	Potential degraded land for bioenergy production	Indonesia	Spatial analysis	Jaung et al.
4	Landowner perceptions and preferences for bioenergy production	Buntoi Village, Central Kalimantan	Survey questionnaire, interviews, focus group discussions	Artati et al.
5	Suitable tree species for bioenergy production under diverse conditions	The tropics	Narrative review	Shin et al.
6	Socioeconomic and environmental outcomes of agroforestry systems with bioenergy tree species	Wonogiri District, Central Java	Field research, focus group discussions	Rahman et al.
7	Suitability of bioenergy tree species on burned and degraded peatlands	Buntoi Village, Central Kalimantan	Field research	Maimunah et al.
8	Changes in soil biodiversity after peatland fires	Buntoi Village, Central Kalimantan	Field research	Shin et al.
9	Growth Performance of *Calophyllum inophyllum* on previously burned land	Bukit Soeharto Forest, East Kalimantan	Field research	Leksono et al.
10	Characteristics and benefits of bamboo as a potential bioenergy species	Indonesia	Literature review	Sharma et al.
11	Oil content of *Pongamia pinatta* seeds extracted using improved extraction methods	Ujung Kulon National Park, Banten	Field research	Hasnah et al.
12	Potential of *Calophyllum inophyllum* for green energy production and restoration of degraded lands	Gunung Kidul and Wonogiri Districts, Central Java	Field research	Leksono et al.
13	*Pongamia pinatta* as a possible option for degraded land restoration and bioenergy production	Indonesia	Review and synthesis	Leksono et al.
14	Lessons from the Mentawai biomass gasification power plant project	Mentawai Islands District, West Sumatra	Case study	Wahono et al.

1.2 Key contributions and findings

The book's chapters cover a broad range of topics: bioenergy policies, geospatial mapping and analysis of degraded lands and their suitability for bioenergy production, landowners' perceptions and preferences, the socioeconomic and environmental benefits of bioenergy plantations, and suitable bioenergy species for producing biomass and biodiesel (Table 1). Under the right conditions, and if managed appropriately, bioenergy species can be intercropped with food crops to create systems that simultaneously support energy security, food security and landscape restoration. Well-designed agroecosystems could produce bioenergy crops that contribute substantially to Indonesia's bioenergy targets, while minimizing unintended social and environmental effects and enhancing local livelihoods. The potential of bioenergy crops at the agroecosystem level is high, but questions remain over economies of scale for bioenergy production at the macro level, the availability of suitable lands, and operational and transaction costs. System designs need to ensure bioenergy production is sustainable and does not lead to further land and forest degradation. The chapters in this book answer these questions and build a comprehensive picture of using bioenergy crops for landscape restoration in Indonesia.

In Chapter 2, Widayati et al. investigate bioenergy initiatives and their applications for industries in Indonesia. Results indicate bioenergy studies progressing in the country, but knowledge being hard to access, and broader deployment remaining hard to achieve. Their research emphasizes the need for enabling conditions, including policies, financing and incentives, and for bioenergy provisioning in multifunctional land use or waste recycling systems.

In Chapter 3, Jaung et al. estimate the extent of degraded lands suitable for growing biodiesel and biomass species. Their research involved a spatial analysis to identity potentially suitable land, and two possible production, growth model and carbon stock scenarios: one involving five biomass and biodiesel producing species; and the other only biodiesel species. Study results reveal approximately 3.5 million ha of suitable degraded land with the potential to produce 1,105 PJ yr^{-1} of biomass and 3 PJ yr^{-1} of biodiesel under the first scenario and 10 PJ yr^{-1} of biodiesel under the second scenario.

In Chapter 4, Artati et al. apply Firth's logistic regression model to study landowners' perceptions of bioenergy tree species and their preferences for restoring degraded lands. Results show most landowners preferring familiar species with available markets, and few choosing the bioenergy species *Calophyllum inophyllum* L. due to the uncertainty of the bioenergy market. Their research recommends applying familiar bioenergy species, ensuring bioenergy markets for landowners, and providing extension support and capacity building.

In Chapter 5, Shin et al. identify bioenergy species suitable for different conditions. Results provide comprehensive information on bioenergy tree species, their ideal growing conditions (temperature, precipitation, pH etc.) and energy outputs, and provide insights for improved strategies for bioenergy production.

In Chapter 6, an article by Rahman et al. examines the social, economic and environmental benefits of *nyamplung* or *Calophyllum inophyllum*-based bioenergy production in different agroforestry systems combined with rice, maize, peanuts and honey. Through its calculations of crops' and different combinations of crops' net present values (NPV), the study's results show *nyamplung*-based agroforestry systems providing socioeconomic and environmental benefits on different scales.

In Chapter 7, Maimunah et al. explore, assess and compare the survival and growth performance of potential bioenergy crops in extreme environments (burned and degraded peatlands). Results demonstrate *nyamplung* and *kemiri sunan* species both performing better under agroforestry systems than as monocultures. Their research recommends growing these two species in agroforestry systems to maximize productivity in supporting livelihoods and sustainable development.

In Chapter 8, Shin et al. investigate and assess the soil macrofauna biodiversity and properties, and changes in soil fauna patterns in a burnt peatland area undergoing restoration with the establishment of a bioenergy plantation. Results show peatland fires causing hugely reduced numbers of soil mesofauna and microfauna individuals, and bioenergy tree survival rates and biodiversity being higher on unburnt than burnt peatland.

In Chapter 9, Leksono et al. report on the growth performance of *nyamplung* on previously burned land. Their findings indicate *nyamplung* trees showing robust adaptivity with a 90% survival rate on low fertility and acidic soils, and the trees enhancing soil properties and biodiversity by attracting birds and insects while providing a source of renewable energy. Surprisingly, they also show fertilizer applications and slope gradients having no significant effects on growth performance.

In Chapter 10, Sharma et al. discuss the benefits and characteristics of bamboo as a potential bioenergy species in Indonesia. The chapter describes bamboo in terms of availability, familiarity, livelihood potential and climate change, as well as the food-energy-environment trilemma. They show potential challenges in bamboo cultivation and management being displacement of native species, simplification of forest structure, and pollution from fertilizer use.

In Chapter 11, Hasnah et al. use a solvent extraction method to demonstrate the oil content of *Pongamia pinatta* seeds. Their results show pongamia producing more oil (27% to 45%) than bulk seed (15 to 19%). Findings also reveal that extraction methods, extraction machines and genetic factors can all influence pongamia oil production.

In Chapter 12, Leksono et al. explore the potential of *Calophyllum inophyllum* for green energy production and restoration of degraded lands in Indonesia. Their research shows the species being tolerant to and growing well in various environmental conditions, and concludes that with its high volume of non-edible oil, *Calophyllum inophyllum* is ideal for producing biodiesel, medicines, cosmetics and animal feed, and providing compost for soil enrichment. They show agroforestry systems growing the species on degraded land being socially, economically and environmentally favourable for local communities.

In Chapter 13, Leksono et al. provide a concise synthesis about how the nitrogen-fixing tree *Pongamia pinatta* is an ideal candidate for restoring degraded land while providing multiple economic benefits, including bioenergy. The study, which highlights the key benefits of pongamia in providing wood, fodder, medicine, fertilizer and biogas, suggests this multipurpose species holds great potential for helping Indonesia meet its energy demand while restoring much of its degraded land.

Finally, in Chapter 14, Wahono et al. investigate a biomass gasification power plant project in the Mentawai Archipelago to look at a potential development solution for the renewable energy industry. The chapter argues that local biomass production could provide the answer to the challenge of providing energy in rural areas. They propose a community- and biomass-based power generation system for rural electrification, which could result in affordable electricity, local economic growth and land restoration from biomass production.

1.3 Concluding comments and a way forward

For an energy-secure and low-carbon future, bioenergy is being promoted globally and in Indonesia as a feasible alternative to unsustainable fossil fuels for producing energy. Properly designed and well-managed systems for producing bioenergy on degraded lands can help Indonesia meet its energy targets, whilst facilitating a sustainable environment and improving local livelihoods. Research in various conditions and consideration of local communities are critical for sustainable bioenergy production and restoration of degraded lands and forests. Interdisciplinary strategies could make sustainable bioenergy production and ecosystem services possible. Careful planning is needed to ensure bioenergy crop development is environmentally friendly and does not compete for land with agricultural production, which could increase food insecurity and food commodity prices. In addition, system designs need to ensure bioenergy production is sustainable and does not lead to further land and forest degradation.

Over the past six years, CIFOR and partners have been conducting research to examine the potential benefits and challenges – from social, economic and environmental standpoints – of developing bioenergy crops on degraded lands in Indonesia. Hopefully, the studies included in this book can provide valuable contributions for consideration in decision making by investors, managers and policymakers.

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