sustainability

MDPI

Opinion

Bamboo as an Alternative Bioenergy Crop and Powerful Ally for Land Restoration in Indonesia

Roshan Sharma [1,2,*], Jaya Wahono [3] and Himlal Baral [2]

1 School of Global, Urban and Social Studies, RMIT University, 124 La Trobe St, Melbourne VIC 3004, Australia
2 Center for International Forestry Research (CIFOR), Jalan CIFOR, Situ Gede, Sindang Barang, Bogor (Barat) 16115, Indonesia; H.Baral@cgiar.org
3 Clean Power Indonesia, Graha Mitra 8th Floor #804 Jl. Gatot Subroto 24, Jakarta 12930, Indonesia; jaywahono@gmail.com
* Correspondence: roshan.sharma@rmit.edu.au

Received: 16 October 2018; Accepted: 20 November 2018; Published: 23 November 2018

Abstract: The energy demand in Indonesia has increased significantly with its population growth, urbanization, and economic development. The growing concern of meeting energy demand while reducing dependency on fossil fuels has resulted in an increasing demand for renewable energy. As a country with a rich biomass base, bioenergy is now an important component of Indonesia's energy agenda. However, a crucial problem in bioenergy production is the selection of species that can provide a sustainable supply of feedstock without having an impact on food security and the environment. In this context, we discuss the characteristics and benefits of using bamboo, a perennial grass, as a potential species for bioenergy feedstock in Indonesia. We describe the fuel characteristics of bamboo along with the possibility to align its cultivation, production, and usage with environmental and developmental agendas which makes it a suitable bioenergy crop in the country. In addition, its ability to grow on degraded lands, fast growth, long root system, and easy maintenance prove it as a powerful ally for the restoration of degraded land. We recommend in-depth research on the social, ecological, and economic feasibility of using this species for bioenergy production.

Keywords: bamboo; bioenergy; land restoration; environmental benefits; Indonesia

1. Introduction

Indonesia has the largest population in South East Asia and is one of the fastest growing economies among the G20 countries. Energy demand has significantly increased in parallel with its population growth, urbanization, and economic development [1]. The primary energy source in Indonesia is based on fossil fuels, such as oil, gas, and coal, and it continues to account for the most significant share of the energy mix in the country [2]. In a path to de-carbonization of its economy, the Government of Indonesia has pledged to reduce greenhouse gas (GHG) emissions. In the Nationally Determined Contribution (NDC) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2016, Indonesia has committed to reducing GHG emissions by up to 29% of the business-as-usual scenario by 2030 [3]. At the same time, Indonesia continues to face challenges in the energy sector. Although the national energy security is increasing, it is below average and less satisfactory than in many other developed and developing countries [4]. Many rural areas are still deprived of modern sources of energy and largely depend upon the direct burning of traditional bioenergy sources, such as fuelwood, that cause health problems [5] and has environmental impacts [6].

Ensuring universal access to affordable, reliable, and clean energy services is the cornerstone of sustainable development as it is intrinsically linked to many other goals, such as no hunger, good health and well-being, poverty reduction, and climate action [7]. The Government of Indonesia is also committed to providing energy to its growing population for the country's economic development and to supporting in lifting 11% of the population living below the poverty line through the National Energy Policy. The policy emphasizes achieving energy diversification, environmental sustainability, and utilization of domestic energy resources. As the international community is seeking affordable and clean renewable energy as a response to the current UN-driven sustainable development goals (SDGs), Indonesia is also looking into expanding its renewable energy share in its energy mix. Currently, renewable stands at 13% of the national energy mix, and the country aims to increase it to 23% by 2025 [8]. In this planned renewable energy mix, bioenergy is expected to contribute to the highest share of 10%. Bioenergy is an important renewable energy produced from plant biomass and plant-derived residues and wastes to generate heat or electricity or to produce liquid fuels for transport [9]. It includes solid biomass (e.g., charcoal), liquids (e.g., bioethanol, biodiesel), and gases (e.g., biogas) produced from plants, woods, and agricultural waste, among many other feedstocks.

Indonesia has vast land resources with large variations in elevation, climate, soil, and physiographic conditions that allow farming of various types of plants for bioenergy production. However, the expansion of plantations for bioenergy could cause competition for land and water resulting in impacts on food production and biodiversity conservation [10]. Currently, bioenergy in Indonesia is produced primarily from oil palm, which is highly contested as it is found to cause widespread deforestation, peatland drainage, and other environmental and social issues [11,12]. Thus, to avoid negative impacts on food security and biodiversity and to diversify bioenergy production, it is important to identify suitable crops to be used as bioenergy feedstock. In this context, this opinion paper discusses bamboo, a perennial grass, as an alternative raw material for the sustainable production of bioenergy in the country. We reviewed scientific publications, reports, and other grey literature to synthesize the literature on the benefits of using bamboo for bioenergy.

Bamboo is distributed in the tropics and subtropics and is the most widely utilized flowering perennials of the Poaceae family, with nearly 1500 species under 87 genera [13]. The human use of bamboo dates back to thousands of years. Traditionally, bamboo is used as a source of food, fiber, and firewood in Indonesia. The strong and flexible woody stem of bamboo is also used as a construction material and is frequently called "timber of the poor". In recent years, modern technology and demand for sustainable goods and services have expanded the use of bamboo beyond the traditional uses. For example, it is processed to design and develop durable tools, furniture, and building materials. Currently, it can be utilized in many ways; in fact, it has more than 1500 applications [14]. Due to its fuel characteristics, high productivity, and short rotation, bamboo is now being explored as a potential feedstock to generate electricity through power plants and biofuels to substitute fossil fuels [15]. Although bamboo has been traditionally used in Indonesian culture for centuries (e.g., direct combustion for cooking), its use as a feedstock for bioenergy production is relatively new and is still in its infancy.

2. Suitability of Bamboo for Energy Production

2.1. Energy Generation and Fuel Characteristics

As with other bioenergy crops, energy can be recovered from bamboo biomass in three main ways: thermal, thermochemical, and biochemical conversion [16]. Thermal conversion through direct combustion in the presence of oxygen is the most common way of converting solid biomass to energy [17]. The traditional method in Indonesia is using bamboo as firewood to generate heat for household purposes, such as cooking and boiling water. However, these conventional applications are relatively inefficient, often result in high indoor air pollution, and are a major health concern in the developing world [18]. At the industrial scale, biomass like bamboo can be used in power plants to produce heat and power for electricity and district heating plants [19]. The heat produced by direct biomass combustion in a boiler under controlled conditions can be used to generate electricity by running a steam turbine or engine. Direct combustion in power plants is the cheapest and most reliable route to producing power from biomass in standalone applications [20].

Another thermal conversion method, which is more efficient, is pyrolysis. Pyrolysis is the thermal degradation of biomass at a moderate-to-high temperature in the absence of oxygen. It can be used to convert bamboo biomass to solid fuels (charcoals), liquid fuels, and gas (syngas) [21]. Bamboo charcoal can be used as a fuel the same way as coal and it is a byproduct of the biomass gasification process. The liquid fuels or pyrolysis fuels can be processed in a biorefinery to produce biofuels. Syngas can be used to produce power or electricity. In biochemical conversion, different strains of microorganisms are used to transform biomass to biogas or biofuels. The basic principle of biochemical conversion is the fermentation of sugar or other substances in the bamboo biomass into (bio)ethanol, methane, and other fuels. Thus, bamboo biomass can be utilized in a variety of forms.

Moreover, bamboo has good fuel characteristics, such as high heat values and volatile contents and lower ash and moisture content, that makes it a suitable crop for bioenergy production [22–24]. In addition, in comparison to other biomass, bamboo has high cellulose and lignin content [25]. These properties may differ according to species, location, maturity stage, and management practices, among others [24]. However, in general, its overall heating value and composition lie between herbaceous biomass and hardwoods. The fuel characteristics (e.g., heating value and chemical composition) of bamboo are similar to those of other dedicated biomass feedstocks. Table 1 shows the fuel characteristics of Giant asper *(Dendrocalamus asper)*, a common bamboo species found in Indonesia, and other biomass sources.

Table 1. Fuel characteristics of bamboo compared to other biomass sources.

Biomass Type	Ash (%)	Moisture (%)	Volatile Matter (%)	Heating Value (kJ/kg)
Rice husk	12.73	12.05	56.98	14.63
Palm shell	3.66	12.12	68.31	18.44
Corn stalk	3.80	41.69	46.98	11.63
Bamboo	2.70	5.80	71.70	17.58
Acacia *	0.36	11.2	65.7	17.40

Source: [23] and [26]*.

2.2. *Local Availability and Familiarity*

Bamboo is found in the 30 provinces of Indonesia and covers about 2.1 million hectares [27]. There are around 135 species of bamboo in Indonesia [27]. They are either found naturally or cultivated deliberately. In the wild, bamboo is found in protected forests, national parks, and nature reserves. As a planted crop, it is found in community forests, village gardens, and in company plantations. In Indonesia, households can grow bamboo on APL (non-forest lands), HPK (Convertible Production Forest), HP (Permanent Production Forest), and HL (Protection Forest) through a License for Non-Timber Forest Product Utilization and in certain areas of KSA (Nature Reserve Area) and KPA (Nature Conservation Area) through the Environment Cooperation Agreement. Bamboo is a familiar local species and is rooted in the Indonesian culture and traditions, as it has been used for centuries. Most farmers have some bamboo plants in their gardens. Indonesians commonly utilize bamboo as an essential material in their daily lives. They use it for food, firewood for heating and cooking, and as material for furniture and building. The strong and flexible woody stem of bamboo is also used as a construction material. The local familiarity with the species could mean that there will be high community acceptability and participation in the bamboo-based bioenergy production.

2.3. *Avoiding the Food-Energy-Environment Trilemma*

The production of feedstocks for bioenergy requires land and water. Thus, bioenergy is often debated because of its potential to cause negative impacts on food production and biodiversity due to the direct and in-direct land-use change and competition for resources [28]. Using bamboo as a feedstock for bioenergy can avoid these conflicts, especially when bamboo is grown on degraded and underutilized land. Bamboo is abundantly available, fast-growing, and can grow on degraded and marginal lands or in combination with other crops in forestry or agroforestry systems; thus, there will be no competition for land [29]. As a fast-growing species that can develop in degraded lands, it can also establish a habitat for biodiversity. Also, the increased availability of bamboo for bioenergy will help to replace the use of firewood from forests, thereby lowering the pressure on the forests. Bamboo crops are usually ready in 5–12 years and can be systematically harvested without removing the clump every year for the next life cycle of 30–50 year [30–32], while other bioenergy crops require replanting after harvest. In fact, managing the stand's age and density by annual thinning—using the derived material as feedstock—can increase bamboo productivity [33]. Thus, bamboo can provide a sustained source of feedstock for bioenergy production.

2.4. Livelihood Improvements

The agriculture and forestry sectors contributed significantly to the economy of Indonesia and supplied nearly 12% of the GDP in 2017 [34]. Thus, these sectors serve as a key driver for economic growth. Around 67% of the total land is constituted by forests, and about 30% of the land is used for agricultural purposes [35]. In total, 49 million Indonesians (about 41 percent of the total workforce of the country) are employed in these sectors. Moreover, about 25,000 villages in Indonesia are located inside or near forest areas, and 70% of the population in those villages rely on forest resources for their income. These farmers and communities can earn additional income by engaging in bamboo cultivation, management, and processing for biomass feedstock and other bioenergy enterprises. Bamboo plantations are easy to establish and can be harvested for bioenergy production after 3–5 years, opening new avenues of income generation and boosting the local economies in a short period. Bamboo also requires less agricultural input compared to other bioenergy crops [29,36], so its production will be a cost-saving resource for the people. Further, in contrast to the estate plantations that offer casual jobs [37], bamboo plantations under active management may also offer a high number of long-term jobs for the local people [38]. Indeed, the diversification of the income streams will broaden the livelihood options and reduce the vulnerability of the farmers to crop failure, helping them adapt to the changing climate [39]. In addition, the electricity generated through bamboo power plants, mainly in regions that lack modern energy sources, could support the local communities to increase their household income by engaging in economic activities, such as running small industries. The bioenergy from the bamboo power plants could thus catalyze rural economic activities and could provide a basis for the alleviation of poverty in the country.

2.5. Climate Action

Indonesia is among the world's top five largest emitters of GHGs. As per the World Resources Institute, CAIT Climate Data Explorer, the total GHG emissions (including the Land-Use Change and Forestry) of the country in 2014 was 2471.64 $MtCO_2e$ [40]. The land-use sector is a major contributor to the country's GHG emissions. The main emissions come through the land-use change and forestry (68%) and agriculture (7%) [40]. In the Nationally Determined Contribution (NDCs), Indonesia committed to reducing its GHG emissions by 29% by 2030 compared to the business-as-usual scenario, and this requires major interventions in the land-use sector. Bamboo bioenergy offers a number of opportunities for emission reduction in the land-use sector. First, bamboo contributes to reducing emissions by replacing the use of fossil fuels for energy generation. Second, as a fast-growing species, it can rapidly sequester and store carbon in its biomass [41].

The availability of carbon storage and sequestration data for bamboo in different cultivation systems is limited, but several studies around the world have made estimations based on the type of species composition, geographic location, environmental conditions, and management practices. In China, the managed bamboo ecosystems have a high carbon storage (102 t ha^{-1}–288 t ha^{-1}) which is comparable to other forest types (122 t ha^{-1} to 337 t ha^{-1}) [41]. A managed Moso bamboo

(Phyllostachys edulis) ecosystem can store up to 106.36 t ha^{-1} (34.3 t ha^{-1} in the aboveground green vegetation and 72.2 t ha^{-1} on the forest floor and soil up to 60 cm in depth) [41,42]. On the other hand, the carbon sequestration potential of many bamboo species is comparable to and often higher than that of many fast-growing tree species. For instance, a study in Bangladesh show that the total carbon sequestration of five-year-old Common Bamboo *(Bambusa vulgaris)* is higher (15.53 t ha^{-1} year^{-1}) than that of other fast-growing hardwood species like Acacia *(Acacia auriculiformis)* (10.21 t ha^{-1} year^{-1} for an eleven-year-old crop) [43]. In India, the rate of aboveground carbon sequestration in a mixed patch of bambusa species (*B. vulgaris*, *B. balcooa*, and *B. cacharensis*) range between 18.93 and 23.55 t ha^{-1} year $^{-1}$ [44]. These findings suggest that bamboo can be valuable in sequestering carbon and can be leveraged in bioenergy production to help mitigate climate change.

2.6. Land Restoration

Land degradation is the temporary or permanent decline in the productive capacity of the land that will result in negative consequences for the agriculture, biodiversity, and environment [45]. Further, as it affects people who depend on land-based economic activities, land degradation could lead to increasing poverty in developing countries [46]. Thus, land restoration has received increased attention as a measure to tackle the land degradation crisis, as reflected in the UN Sustainable Development Goals (SDGs) and in conventions such as the United National Framework of the Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification (UNCCD), and the Convention on Biological Diversity (CBD). Decades of exploitative land-use practices, such as mining and drainage, and conversion of peatlands and forests for agriculture, have resulted in large areas of degraded lands in Indonesia [47–50]. According to the "Indonesia Land Degradation Neutrality National Report 2015" by the Ministry of Forests, there are an estimated 24 million hectares of degraded land in Indonesia [51]. In an attempt to address this problem, Indonesia has taken several measures to restore the degraded lands [51].

However, the biophysical and legal constraints of the land and the high costs of reclamation often challenge the restoration efforts [52–54]. The restoration of the large areas of degraded lands in Indonesia using biophysical measures will require significant investments in time and money. The restoration costs are difficult to estimate, as they depend upon the location, methods, and level of degradation, among other factors, but the literature suggests that the restoration costs using forest species can generally exceed USD2300 per hectare [55]. This implies that there will be long timeframes for productivity and financial returns, which will make the farmers and investors hesitant to engage in restoration. In such cases, one common approach to minimizing costs is to plant fast-growing species that can grow in low fertility soils with minimum management intervention [56]. Thus, the ecological properties and economic savings and benefits of bamboo make it a unique plant for land restoration.

Bamboo can grow well in degraded and marginal soils with low fertility and requires little fertilizer or water in comparison to other traditional sources of biomass [29,36]. This implies that, even with less resource input, bamboo can thrive in severely degraded areas where other native species cannot grow. Further, the extensive fibrous root and rhizome systems, dense foliage, and leafy mulch of bamboo stabilize soil, control soil erosion, and retain water [36]. The leaf litter from bamboo adds organic matter to the soil and contributes to the fertility of the degraded soil. Further, bamboo does not require high investments and, once the plantation is established, it could be managed without high maintenance. As bamboo grows fasts and could be harvested continuously without replanting in for about 3 to 4 years, it will yield faster returns on investments, thereby attracting investors and farmers. Smallholder farmers play a cost-effective role in land restoration, and, since they are already used to bamboo cultivation, bamboo in restoration could be easily applied in Indonesia. As the availability of managed bamboo increases, households will also switch to bamboo slats that are a renewable alternative to firewood, thus bamboo will also help to reduce deforestation. Furthermore, bamboo diversifies the landscapes, providing food and habitat for numerous species of insects, birds, and animals [57]. Some bamboo species contain high levels of starch and nutrients that are preferred by some wildlife [58–60].

Although the use of bamboo for land restoration remains relatively small-scale, several initiatives have shown successful results and high potential for implementation at larger scales [61]. For example, in India, a bamboo-based landscape project which started in 1997 has been successful in rehabilitating over 85,000 hectares of degraded lands while supporting thousands of livelihoods [62]. Several member countries of the International Network for Bamboo and Rattan (INBAR) are promoting the use of bamboo for land restoration as part of the Bonn Challenge [61]. Some of the recent bamboo-based restoration programs include the plan of the Chinese State Forest Administration to restore three million hectares, the Philippines aim to restore at least 500,000 hectares, and India program to restore around 100,000 hectares [63]. Indonesia could draw lessons from other tropical countries on using bamboo as a restoration species. The abilities to grow fast with less production input in degraded lands, stabilize and add organic matter to soil, and yield biomass continuously without replanting makes bamboo a unique plant for land restoration in Indonesia.

With proper harvesting and management plans, bamboo plantations established for bioenergy can also help Indonesia to achieve the Forest Landscape Restoration (FLR) goals signed under initiatives such as the 2011 Bonn Challenge and the 2014 New York Declaration on Forests, as well as other UN conventions such as the Convention on Biological Diversity (CBD). The restoration of degraded lands by using bamboo species could create ecological and economic benefits for local communities and support the government's climate and development goals.

3. Potential Challenges

Although bamboo provides many ecological and socioeconomic benefits, there can be several challenges in its cultivation and management for bioenergy production. First, if bamboo plantations are not managed properly, the plant can pose a threat as an invasive species, as it can displace the surrounding native vegetation [64,65]. In addition, bamboo monocultures can increase the forest cover but may also simplify the structure of the forests and modify or decrease its biological diversity [66,67]. Furthermore, there is a potential risk to biodiversity and food security of bamboo plantations if farmers clear-cut native vegetation or convert the farmlands to bamboo plantations in the pursuit of higher profits [59]. Even if bamboo requires less pesticides and fertilizers compared to other crops, in a pursuit of higher production, intensive management that involves harmful chemicals could cause land and water pollution [68]. Like other dedicated bioenergy crops, bamboo may also compete for land and water with food crops, if it is grown on agricultural lands. Careful planning is crucial when considering bamboo species for bioenergy production.

4. Conclusion

This paper discusses the potential of bamboo as a feedstock for bioenergy production along with the delivery of other socio-economic and environmental benefits in Indonesia. We believe that, with proper planning, management, and harvesting, bamboo has a great potential to be used as a feedstock for bioenergy production in Indonesia. Bamboo is abundantly available, familiar to local people, fast-growing, has multiple uses, can rapidly store and sequester carbon, grows in degraded lands, and has good fuel characteristics for modern bioenergy production. The integration of multi-purpose perennial bamboo crops in the energy systems can contribute substantially to achieving renewable energy targets while supporting land restoration goals by offsetting the high costs involved in meeting the restoration goals of the Bonn Challenge in Indonesia. Yet, there is a dearth of literature on bamboo in the Indonesian context, and, to our knowledge, no studies have been conducted on the social, economic, and ecological feasibility of using bamboo for bioenergy. We recommend further studies on the production and management of bamboo for bioenergy in the country, such as how much bamboo is locally available for bioenergy production, what species are best suited for bioenergy production, energy content of bamboo based bioenergy fuels, to what extent GHG emissions would be reduced by using bamboo, andthe potential areas for future plantations. In addition studies on the economics of restoration using bamboo, and benefits such as profit margins and return of investment to farmers are needed.

Author Contributions: R.S. conceptualized the idea, developed, and reviewed the manuscript; J.B. and H.B. developed and reviewed the manuscript.

Funding: This research did not receive any funding.

Acknowledgments: The Center for International Forestry Research (CIFOR) provided an internship for Roshan Sharma during the literature search, review and writing. We acknowledge the National Institute of Forest Science, the republic of Korea for making this article available to all by sponsoring CIFOR's payment of the journals Article Processing Fee. The authors are grateful to the editor and anonymous reviewers for their comments and suggestions. We thank the two anonymous reviewers whose critical comments helped to significantly improve the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. National Energy Council. *Indonesia Energy Outlook 2016*; National Energy Council, Secretariat General: Jakarta, Indonesia, 2016.
2. Ministry of Energy and Mineral Resources. *Handbook of Energy & Economic Statistics of Indonesia*; Ministry of Energy and Mineral Resources: Jakarta, Indonesia, 2017.
3. Government of Indonesia. *First Nationally Determined Contribution (Republic of Indonesia)*; UNFCCC: Bonn, Germany, 2016.
4. Erahman, Q.F.; Purwanto, W.W.; Sudibandriyo, M.; Hidayatno, A. An assessment of Indonesia's energy security index and comparison with seventy countries. *Energy* **2016**, *111*, 364–376. [CrossRef]
5. Huboyo, H.S.; Tohno, S.; Lestari, P.; Mizohata, A.; Okumura, M. Characteristics of indoor air pollution in rural mountainous and rural coastal communities in Indonesia. *Atmos Environ.* **2014**, *82*, 343–350. [CrossRef]
6. Masera, O.R.; Bailis, R.; Drigo, R.; Ghilardi, A.; Ruiz-Mercado, I. Environmental burden of traditional bioenergy use. *Annu. Rev. Environ. Resour.* **2015**, *40*, 121–150. [CrossRef]
7. Griggs, D.; Nilsson, M.; Stevance, A.; McCollum, D. *A Guide to SDG Interactions: From Science to Implementation*; International Council for Science: Paris, France, 2017.
8. Government of Indonesia. *Government Regulation of the Republic of Indonesia Number 79 of 2014 on National Energy Policy*; Government of Indonesia: Jakarta, Indonesia, 2014.
9. Souza, G.M.; Victoria, R.L.; Joly, C.A.; Verdade, L.M. *Bioenergy & Sustainability: Bridging the Gaps*; SCOPE: Paris, France, 2015; pp. 978–982.
10. Popp, J.; Lakner, Z.; Harangi-Rakos, M.; Fari, M. The effect of bioenergy expansion: Food, energy, and environment. *Renew. Sustain. Energy Rev.* **2014**, *32*, 559–578. [CrossRef]
11. Sharma, R.; Nehren, U.; Rahman, S.A.; Meyer, M.; Rimal, B.; Seta, G.A.; Baral, H. Modeling Land Use and Land Cover Changes and Their Effects on Biodiversity in Central Kalimantan, Indonesia. *Land* **2018**, *7*, 57. [CrossRef]
12. Obidzinski, K.; Andriani, R.; Komarudin, H.; Andrianto, A. Environmental and social impacts of oil palm plantations and their implications for biofuel production in Indonesia. *Ecol. Society* **2012**, *17*. [CrossRef]
13. Ohrnberger, D. *The Bamboos of the World: Annotated Nomenclature and Literature of the Species and the Higher and Lower Taxa*; Elsevier: Amsterdam, The Netherlands, 1999.
14. Lobovikov, M.; Ball, L.; Guardia, M.; Russo, L. *World Bamboo Resources: A Thematic Study Prepared in the Framework of the Global Forest Resources Assessment 2005*; Food & Agriculture Organization: Rome, Italy, 2007.
15. Singh, S.; Adak, A.; Saritha, M.; Sharma, S.; Tiwari, R.; Rana, S.; Arora, A.; Nain, L. Bioethanol Production Scenario in India: Potential and Policy Perspective. In *Sustainable Biofuels Development in India*; Chandel, A.K., Sukumaran, R.K., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 21–37.
16. Boyle, G. *Renewable Energy: Power for a Sustainable Future*; Oxford University Press: Oxford, UK, 2004; p. 464.
17. Demirbaş, A. Biomass resource facilities and biomass conversion processing for fuels and chemicals. *Energy Convers. Manag.* **2001**, *42*, 1357–1378. [CrossRef]
18. Fullerton, D.G.; Bruce, N.; Gordon, S.B. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Trans R. Soc. Trop. Med. Hyg.* **2008**, *102*, 843–851. [CrossRef] [PubMed]

19. Eisentraut, A.; Brown, A. Technology Roadmap: Bioenergy for Heat and Power. *Technol. Roadmaps* **2012**, *2*, 1–41.
20. IEA. *Bioenergy—A Sustainable and Reliable Energy Source*; IEA: Paris, France, 2009.
21. Kerlero, D.R.; de Bussy, J. *Electrical Valorization of Bamboo in Africa*; ENEA Consulting: Paris, France, 2012.
22. Scurlock, J.; Dayton, D.; Hames, B. Bamboo: An overlooked biomass resource? *Biomass Bioenergy* **2000**, *19*, 229–244. [CrossRef]
23. Sritong, C.; Kunavongkrit, A.; Piumsombun, C. Bamboo: An innovative alternative raw material for biomass power plants. *Int. J. Innov. Manag. Technol.* **2012**, *3*, 759.
24. Kumar, R.; Chandrashekar, N. Fuel properties and combustion characteristics of some promising bamboo species in India. *J. For. Res.* **2014**, *25*, 471–476. [CrossRef]
25. Kuttiraja, M.; Sindhu, R.; Varghese, P.E.; Sandhya, S.V.; Binod, P.; Vani, S.; Pandey, A.; Sukumaran, R.K. Bioethanol production from bamboo (*Dendrocalamus* sp.) process waste. *Biomass Bioenergy* **2013**, *59*, 142–150. [CrossRef]
26. Marsoem, S.N.; Irawati, D. *Basic properties of Acacia Mangium and Acacia Auriculiformis as a Heating Fuel*; AIP Publishing: Melville, NY, USA, 2016.
27. FAO. *Global Forest Resources Assessment 2005: Indonesia Country Report*; Food and Agricultural Organization of the United Nations (FAO)/International Network for Bamboo and Rattan (INBAR): Rome, Italy, 2005.
28. Immerzeel, D.J.; Verweij, P.; Hilst, F.; Faaij, A.P. Biodiversity impacts of bioenergy crop production: A state-of-the-art review. *GCB Bioenergy* **2014**, *6*, 183–209. [CrossRef]
29. Mishra, G.; Giri, K.; Panday, S.; Kumar, R.; Bisht, N. Bamboo: Potential resource for eco-restoration of degraded lands. *J. Biol. and Earth Sci.* **2014**, *4*, 130–136.
30. De Carvalho, A.L.; Nelson, B.W.; Bianchini, M.C.; Plagnol, D.; Kuplich, T.M.; Daly, D.C. Bamboo-dominated forests of the southwest Amazon: Detection, spatial extent, life cycle length and flowering waves. *PloS ONE* **2013**, *8*, e54852. [CrossRef] [PubMed]
31. Benton, A. Priority Species of Bamboo. In *Bamboo: The Plant and its Uses*; Liese, W., Köhl, M., Eds.; Springer International Publishing: Basel, Switzerland, 2015; pp. 31–41.
32. Banik, R.L. Bamboo silviculture. In *Bamboo, The Plant and its Uses*; Liese, W., Köhl, M., Eds.; Springer International Publishing: Basel, Switzerland, 2015; pp. 113–174.
33. Xiao, J.H. Improving Benefits of Bamboo Stands by Classified Management and Oriental Cultivation. *J. Bamboo Res.* **2001**, *20*, 3.
34. Bank Indonesia. *Economic Report on Indonesia (2017)*; Bank Indonesia: Central Jakarta, Indonesia, 2018.
35. Asian Development Bank. *Summary of Indonesia's Agriculture, Natural Resources, and Environment Sector Assessment*; Asian Development Bank: Manila, Philippines, 2015.
36. Ben-zhi, Z.; Mao-yi, F.; Jin-zhong, X.; Xiao-sheng, Y.; Zheng-cai, L. Ecological functions of bamboo forest: Research and Application. *J. of Fores Res* **2005**, *16*, 143–147. [CrossRef]
37. Sinaga, H. Employment and income of workers on Indonesian oil palm plantations: Food crisis at the micro level. *Future Food J. Food Agric. Soc.* **2013**, *1*, 64–78.
38. Xuhe, C. Promotion of bamboo for poverty alleviation and economic development. *J. Bamboo Rattan* **2003**, *2*, 345–350. [CrossRef]
39. Bradshaw, B.; Dolan, H.; Smit, B. Farm-level adaptation to climatic variability and change: Crop diversification in the Canadian prairies. *Clim. Chang.* **2004**, *67*, 119–141. [CrossRef]
40. World Resources Institute. *CAIT Climate Data Explorer*; World Resources Institute: Washington, DC, USA, 2018.
41. Lou, Y.; Li, Y.; Buckingham, K.; Henley, G.; Zhou, G. *Bamboo and Climate Change Mitigation*; Technical Report; International Network for Bamboo and Rattan (INBAR): Beijing, China, 2010.
42. Zhou, G.; Jiang, P. Density, storage and spatial distribution of carbon in Phyllostachy pubescens forest. *Sci. Silvae Sin.* **2004**, *40*, 20–24.
43. Sohel, M.S.I.; Alamgir, M.; Akhter, S.; Rahman, M. Carbon storage in a bamboo (Bambusa vulgaris) plantation in the degraded tropical forests: Implications for policy development. *Land Use Policy* **2015**, *49*, 142–151. [CrossRef]
44. Nath, A.J.; Das, A.K. Carbon pool and sequestration potential of village bamboos in the agroforestry system of northeast India. *Trop. Ecol.* **2012**, *53*, 287–293.

45. IUCN. *Land Degradation Neutrality: Implications and Opportunities for Conservation*; IUCN: Nairobi, Kenya, 2015.
46. Barbier, E.B.; Hochard, J.P. Does Land Degradation Increase Poverty in Developing Countries? *PLoS ONE* **2016**, *11*, e0152973. [CrossRef] [PubMed]
47. Anshari, G.Z.; Afifudin, M.; Nuriman, M.; Gusmayanti, E.; Arianie, L.; Susana, R.; Nusantara, R.; Sugardjito, J.; Rafiastanto, A. Drainage and land use impacts on changes in selected peat properties and peat degradation in West Kalimantan Province, Indonesia. *Biogeosciences* **2010**, *7*, 3403–3419. [CrossRef]
48. Margono, B.A.; Potapov, P.V.; Turubanova, S.; Stolle, F.; Hansen, M.C. Primary forest cover loss in Indonesia over 2000–2012. *Nat. Clim. Chang.* **2014**, *4*, 730. [CrossRef]
49. Wijaya, A.; Budiharto, R.S.; Tosiani, A.; Murdiyarso, D.; Verchot, L. Assessment of large scale land cover change classifications and drivers of deforestation in Indonesia. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2015**, *40*, 557. [CrossRef]
50. Gaveau, D.L.; Sheil, D.; Salim, M.A.; Arjasakusuma, S.; Ancrenaz, M.; Pacheco, P.; Meijaard, E. Rapid conversions and avoided deforestation: Examining four decades of industrial plantation expansion in Borneo. *Sci. Rep.* **2016**, *6*, 32017. [CrossRef] [PubMed]
51. United Nations Convention to Combat Desertification (UNCCD). *Indonesia—Land Degradation Neutrality National Report*; United Nations Convention to Combat Desertification: Jakarta, Indonesia, 2015.
52. Sayer, J.; Chokkalingam, U.; Poulsen, J. The restoration of forest biodiversity and ecological values. *For Ecol. Manag.* **2004**, *201*, 3–11. [CrossRef]
53. Stavi, I.; Lal, R. Achieving zero net land degradation: Challenges and Opportunities. *J. Arid. Environ.* **2015**, *112*, 44–51. [CrossRef]
54. Sabogal, C.; Besacier, C.; McGuire, D. Forest and landscape restoration: Concepts, approaches and challenges for implementation. *Unasylva* **2015**, *66*, 3.
55. Sukhdev, P.; Wittmer, H.; Schröter-Schlaack, C.; Nesshöver, C.; Bishop, J.; Brink, P.; Gundimala, H.; Kumar, P.; Simmons, B. *The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB*; UNEP: Ginebra, Suiza, 2010.
56. Yu, Z.; Peng, S. *Ecological Studies on Vegetation Rehabilitation of Tropical and Subtropical Degraded Ecosystems*; Guangdong Science & Technology Press: Guangzhou, China, 1996. (In Chinese)
57. Lou, Y.; Henley, G. *Biodiversity in Bamboo Forests: A Policy Perspective for Long Term Sustainability*; International Network for Bamboo and Rattan (INBAR): Beijing, China, 2010.
58. Li, R.; Zhang, J.; Zhang, Z. Values of bamboo biodiversity and its protection in China. *J. Bamboo Res* **2003**, *22*, 7–13.
59. Song, X.; Zhou, G.; Jiang, H.; Yu, S.; Fu, J.; Li, W.; Wang, W.; Ma, Z.; Peng, C. Carbon sequestration by Chinese bamboo forests and their ecological benefits: Assessment of potential, problems, and future challenges. *Environ. Rev.* **2011**, *19*, 418–428. [CrossRef]
60. Reid, S.; Díaz, I.A.; Armesto, J.J.; Willson, M.F. Importance of native bamboo for understory birds in Chilean temperate forests. *The Auk* **2004**, *121*, 515–525. [CrossRef]
61. FAO; INBAR. *Bamboo for Land Restoration*; INBAR: Beijing, China, 2018.
62. Benton, A. *Greening Red Earth: Restoring Landscapes, Rebuilding Lives*; The International Development Research Center (IDRC)/Utthan Centre for Sustainable Development and Poverty Alleviation/International Network for Bamboo and Rattan (INBAR): Beijing, China, 2014.
63. Buckingham, K. Rebranding Bamboo for Bonn: The 5 Million Hectare Restoration Pledge. Available online: http://www.wri.org/blog/2014/12/rebranding-bamboo-bonn-5-million-hectare-restoration-pledge (accessed on 9 October 2018).
64. Richardson, D.; Canavan, S. Understanding the Risks of an Emerging Global Market for Cultivating Bamboo: Considerations for a More Responsible Dissemination of Alien Bamboos. In Proceedings of the 10th World Bamboo Congress, Damyang, Korea, 17–22 September 2015.
65. O'connor, P.J.; Covich, A.P.; Scatena, F.; Loope, L.L. Non-indigenous bamboo along headwater streams of the Luquillo Mountains, Puerto Rico: Leaf fall, aquatic leaf decay and patterns of invasion. *J. Trop. Ecol.* **2000**, *16*, 499–516. [CrossRef]
66. Xu, Q.; Jiang, P.; Xu, Z. Soil microbial functional diversity under intensively managed bamboo plantations in southern China. *J. Soils Sediments* **2008**, *8*, 177. [CrossRef]

67. Xu, Q.-F.; Jiang, P.-K.; Wu, J.-S.; Zhou, G.-M.; Shen, R.-F.; Fuhrmann, J.J. Bamboo invasion of native broadleaf forest modified soil microbial communities and diversity. *Biol. Invasions* **2015**, *17*, 433–444. [CrossRef]
68. Mariyono, J.; Kuntariningsih, A.; Suswati, E.; Kompas, T. Quantity and monetary value of agrochemical pollution from intensive farming in Indonesia. *Manag. Environ. Qual. Int. J.* **2018**, *29*, 759–779. [CrossRef]