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Bioenergy Production on Degraded Land: Landowner Perceptions in Central Kalimantan, Indonesia

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Abstract: Bioenergy production from degraded land provides an opportunity to secure a new renewable energy source to meet the rapid growth of energy demand in Indonesia while turning degraded land into productive landscape. However, bioenergy production would not be feasible without landowner participation. This study investigates factors affecting landowners' preferences for bioenergy production by analyzing 150 landowners with fire experience in Buntoi village in Central Kalimantan using Firth's logistic regression model. Results indicated that 76% of landowners preferred well-known species that have a readily available market such as sengon (*Albizia chinensis* (Osb.) Merr.) and rubber tree (*Hevea brasiliensis* Müll.Arg.) for restoration on degraded land. Only 8% of preferred nyamplung (*Calophyllum inophyllum* L.) for bioenergy production; these particular landowners revealed a capacity to handle the uncertainty of the bioenergy market because they had additional jobs and income, had migrated from Java where nyamplung is prevalent, and preferred agricultural extension to improve their technical capacity. These results contribute to identifying key conditions for a bottom-up approach to bioenergy production from degraded land in Indonesia: a stable bioenergy market for landowners, application of familiar bioenergy species, and agricultural extension support for capacity building.

Keywords: bioenergy; renewable energy; degraded land; farmer's perceptions; Firth's logistic regression model; restoration

1. Introduction

Bioenergy is promising and most versatile form of renewable energy [1,2] and its production from degraded lands has the potential to support meeting the global energy demand [3,4]. It might increase the supply of renewable energy [4] and improve land use efficiency [5,6]. These benefits have encouraged many countries to promote bioenergy consumption and support development of technologies and policies related to bioenergy production [1,2]. The government of Indonesia, for example, set a target to increase biodiesel and bioethanol consumption up to 30% and 20%, respectively, of the total energy consumption by 2025 (Presidential Regulation No. 12/2015) [7] in order to manage the rapid growth of energy demand. In Indonesia, the energy demand in 2025 is expected to be 1.8 times higher than the energy demand in 2015 [8] due to population growth, urbanization, and economic development [9–11].

Lately, there has been increased interest in bioenergy production by growing non-food seed oil, such as nyamplung (*Calophyllum inophyllum* L.), in degraded lands since its multiple benefits [12] It could minimize a trade-off between food and fuel production as some of these non-food crops could grow in degraded lands that cannot support food production [13–16]. It could reduce environmental impacts if these crops are harvested from degraded and underutilized lands that have limited value to store carbon and preserve native vegetation and biodiversity (e.g., [9,15,17]). In addition, it could support restoration of degraded lands with these bioenergy species and provide a variety of ecosystem services, such as carbon storage, reduction of soil erosion, and improvement of biodiversity [18,19]. It also creates employment opportunities in rural areas, particularly in developing countries where large populations live and rely on marginal lands for farming [16,20–22].

Capturing these benefits from bioenergy production on degraded land, however, would not be feasible without landowner participation. In other words, bioenergy production should meet landowner preferences. Otherwise, owners of degraded lands would use these lands for alternative activities that meet their preferences and expectations. Since 2007, for instance, the Government of Indonesia has implemented and tested an "Energy Sufficient Village" program (or *Desa Mandiri Energi*) in Java, Indonesia [23–28]. The program aimed not only to encourage bioenergy production by local communities for energy security in rural areas, but also to create more jobs and reduce poverty in these communities. Most pilot projects of this program, however, discontinued recently due to its top-down approach, which failed to engage landowner and meet their preferences. This failure indicates that a bottom-up approach would be necessary—one that would motivate landowner participation in bioenergy production, stably supply bioenergy feedstocks to the market, and reflect local needs. A preliminary step to test the feasibility of such a bottom-up approach is to investigate what would encourage—or discourage—landowner participation in bioenergy production from degraded and underutilized land.

This study examines landowner perceptions of bioenergy production from degraded land in Buntoi village in Central Kalimantan, Indonesia, and investigates sociodemographic factors affecting their preferences for bioenergy production using Firth's logistic regression model. There are several studies that analyze bioenergy production from degraded land in Indonesia (e.g., [23,29,30]). However, only a few studies focus on the owners of degraded lands, or on landowner preferences for non-food species to restore degraded lands and produce bioenergy feedstocks (e.g., [31]). Thus, only limited empirical evidence is available to elucidate factors affecting landowner preferences for bioenergy production from degraded land in Indonesia. This study attempts to reduce this knowledge gap by identifying particular factors influencing landowners in Central Kalimantan, and to contribute to our understanding of the feasibility of developing a bottom-up approach to bioenergy production from degraded land in Indonesia.

2. Bioenergy Production in Indonesia

2.1. Landowner Preferences

Several studies identify factors affecting landowners' preferences for bioenergy species such as oil palm (*Elaeis guineensis* Jacq.), jatropha (*Jatropha curcas* L.), and nyamplung (*Calophyllum inophyllum* L.) in Indonesia. Feintrenie et al. [30] argue that factors affecting smallholder preferences for palm oil in Jambi, Sumatra, may include direct profits, low technical requirements to grow oil palm, high investment return, and partnerships with large companies and banks. Anggraini and Grundmann [29] assert that cash income and loans were major motivations for smallholders to shift their rice fields to oil palm in the districts of Mandailing Natal and Labuhan Batu, Sumatra. Amir et al. [23] argue that expectations of high profits had motivated farmers to plant jatropha in their mixed gardens as well as rice fields in Mandalasari village, West Java. Uripno et al. [28] indicate that factors affecting communities' involvement in bioenergy production include bioenergy price, technology innovation, project roles, and support from local leaders in Buluagung and Patutrejo villages, Central Java. Sitompul et al. [31] indicate that the likelihood of farmers taking up bioenergy production would increase because of higher profits and shorter contract years in the districts of Maliku and Pandih Batu, Central Kalimantan. They also argue that farmers from different ethnic backgrounds would have different interests in bioenergy crops. Nurlaila et al. [32] assert that traditional cultures of landowners have impacts on their decisions to produce bioenergy. The studies mentioned here are mostly qualitative and have investigated the overall preferences of stakeholders for bioenergy, so that their results are rather limited to empirically representing various landowners who own degraded lands. Thus, there is a need for quantitative analyses focusing on these landowners to gain a more comprehensive understanding of their preferences and expectations as regards bioenergy production.

2.2. Challenges of Encouraging Landowner Participation

The Energy Sufficient Village program reveals several challenges for landowners who produce or wish to produce bioenergy feedstocks in Indonesia [24–26,28]. Although relevant to various stakeholders of bioenergy production, these challenges reflect required conditions for landowners, including: a bottom-up approach allowing their participation during program development, a stable market in which to sell bioenergy feedstocks, capacity building and technical guidelines, stable and high levels of production of bioenergy feedstocks, low cost of bioenergy production, low levels of stakeholder conflicts, technical advancement of bioenergy production, and available infrastructure. Muslihudin et al. [25] indicate that implementation of the program was challenged by low engagement of the community, inefficient machines for bioenergy feedstock processing, limited technical guidelines, high production costs, and a limited market in which to sell seed oil. Uripno et al. [28] assert that the top-down nature of the program challenged the long-term participation of location communities. Simandjuntak [26] demonstrates that the program was challenged by a limited market, unstable crop production, and limited technical research. Fatimah [24] shows that stakeholders considered low productivity and limited coordination among institutions as the main reasons for failure of the program. Amir et al. [23] argue that a complex bureaucracy at the village level and different stakeholder interests were challenges of the implementation of the program. They also claim that limited infrastructure, such as limited land for growing bioenergy crops, was a main challenge to encouraging small landowners' participation in bioenergy production. All of these challenges provide valuable lessons for testing the feasibility of a bottom-up approach to bioenergy production from degraded land in Indonesia.

3. Materials and Methods

3.1. Study Site

The research site is located in Buntoi village, Pulang Pisau District, in Central Kalimantan Province. It is located between 2°48′59.4″ S and 114°10′47.3″ E and is situated along the Kahayan, one of the main rivers in the province (Figure 1). The total area is about 16,000 ha; agriculture and forest dominate village land use, accounting for 41% and 57%, respectively. The other 2% is allocated for settlement. Rubber production has been a major economic activity of Buntoi village. The village has a tropical and humid climate with average temperature between 26.5 and 27.5 °C [33]. Consisting of 12 sub-villages, the village had a total population of 2719. Dayak (or Ngaju) was the main ethnic group in the village although other ethnic groups co-existed, including: Banjarnese, Javanese, Bataknese, Bugis, Sundanese, Madurese, Balinese, Flores, Manado, and Chinese [34].

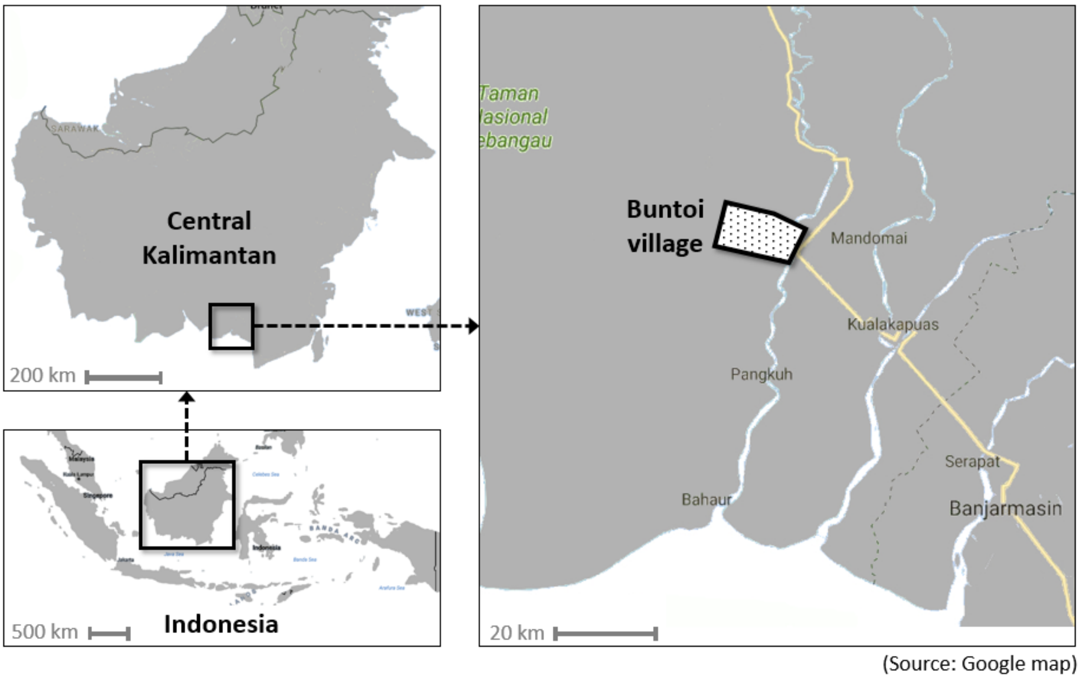

Figure 1. Location of Buntoi village, Central Kalimantan, Indonesia.

Buntoi village was selected as a study site because it has large areas of degraded lands from a forest fire and it was chosen as one of the pilot locations for Bioenergy Lestari by the central and local governments. In 2015, the village in Kalimantan experienced a massive forest fire which caused haze affecting several neighboring countries, including Singapore and Malaysia. The fire destroyed more than 400 ha of landowners' rubber plantations in the village, resulting in a loss of about Indonesian rupiah (IDR) 300 million (or USD 22,500 as of 2017) [35]. Landowners have sought ways to invest in their burned lands, and the Ministry of Energy and Mineral Resources initiated a project called the Sustainable Bioenergy Development Program (or *Program Pengembangan Bioenergi Lestari*), in collaboration with the Government of Central Kalimantan to produce bioenergy from the degraded lands in the districts of Pulang Pisau and Katingan, including Buntoi village.

3.2. Survey Design and Administration

We designed a survey to analyze landowners' preferences for restoration species for degraded lands and their perceptions of bioenergy. Before the survey design, a preparatory visit was carried out in June 2016 to observe the village conditions and to interview some key village informants about the 2015 fire and haze disaster, rubber plantations (e.g., cost and current market conditions), and landowners' restoration plans for their burned lands.

As a result of the visit, three species were selected as potential restoration species in the villages: Sengon (*Albizia chinensis* (Osb.) Merr.), rubber tree (*Hevea brasiliensis* Müll.Arg.), and nyamplung (*Calophyllum inophyllum* L.). Sengon was chosen as a species for wood production, as it has been increasingly recognized as a new species of high economic value in the village. In addition, sengon production has been supported by the social forestry program (HKM) from the Ministry of Environment and Forestry (KLHK). The program provides farmers with a license to harvest wood from the community plantation forest (IUPHHK-HTR) for 35 years. Rubber tree was selected as the species for rubber production as it has been a major activity of economic interest in the village. Traditionally, old rubber trees have been used for firewood for cooking in the village. Nyamplung was selected as a potential species for bioenergy production. Since this species was new to the village, the testing of landowners' preferences for this potential bioenergy species was considered appropriate. Nyamplung is known to produce biodiesel that is the most similar to diesel oil and has the potential to replace diesel fuel without any engine modifications [36] and adapt to degraded land including peatland [37]. Moreover, it meets the Indonesian National Standard (SNI) for fuel [14,15].

The final survey had sections of (1) demographic information, (2) land management plan, (3) fire coping strategies, and (4) perceptions on bioenergy. The first section asked essential socio-demographic information, including education level, household income, and ethnicity background. The second section asked their experiences with farm land degradation by fire. The third section asked their strategies used for management of degraded farm lands. The fourth section asked participants to choose one of the three species (Table 1) that they preferred the most as a potential species for restoration of their degraded lands. If none of the species was preferred, participants were allowed to not choose any of them. Before asking participants about their preferences, each participant received a brief presentation on the main characteristics of the species based on a literature review and expert consultations. A visual aid was also used in providing these descriptions to aid their understanding.

Table 1. Characteristics of three potential species for restoration of degraded lands in Buntoi village.

Category	Sengon	Rubber Tree	Nyamplung
Main objective	Wood production (1)	Rubber production (2)	Biodiesel production (3, 4)
Other uses	Firewood, wood box, animal feedstock (1)	Firewood (2, 8)	Medicine, cosmetic, wood, firewood, and animal feedstock (3)
Tolerable condition	Infertile and moist land (1)	Fertile (5)	Infertile and waterlogged land (6)
Disease resistance	Weak (1)	Weak (5)	Medium (1)
Capacity to improve soil	Strong (1)	Medium (2)	Strong (7)
Market availability	Available (8)	Available (8)	Limited (9)
Price risk	No influence by international market (9)	Influenced by international market (10)	No influence by international market (9)
Plantation cost per ha	IDR * 30 million (9)	IDR 12.5 million (8)	IDR 10 million (3)
Revenue per ha	IDR 120–130 million (wood) (9)	IDR 13–39 million (rubber) (8)	IDR 20–22 million (seed) (3)
First harvest after planting	5th year (9)	7th year (8)	7th year (3)
Harvest cycle	Once in 5 years (9)	Every year (8)	Every year (3)
Production period	For 5 years (9)	For 50 years (8)	For 50 years (3)

Sources: (1) Pratiwi et al. [38]; (2) Orwa et al. [39]; (3) Leksono et al. [15]; (4) Ong et al. [36]; (5) Damanik et al. [40]; (6) Martawijaya et al. [41]; (7) Friday and Okano [42]; (8) Interview key informants in the preparatory visit in 2016; (9) consultation of sengon silviculture and business experts in Kalimantan and Java; and (10) Zhengzhou Double Vigour Chemical Product Co., Ltd. [43]. * IDR indicates the Indonesian rupiah. As of September 2017, IDR 13,510 was USD 1.

From 29 January to 7 February 2017, we surveyed a total of 150 landowners with lands degraded by the forest fire in Buntoi village. We randomly selected respondents from the 10 sub-villages in which most of the landowners with forest fire experience reside. Sociodemographic variables of participants are described in Table 2.

In addition, a focus group discussion was conducted with key informants in Buntoi village in order to examine the land-use history and environmental changes the village has undergone as well as landowner plans for degraded lands. Key informants were identified and invited to the discussion based on snowball sampling. A total of 20 key informants joined the discussion, and they consisted of representatives of the sub-villages and those highly involved with village activities.

Table 2. Description of sociodemographic variables of landowners with degraded lands in Buntoi village (n = 150). Means of the dummy variables (1 or 0) represent their percentages in variable categories: male (78%) or female (22%); having business income (15%) or not (85%); farming as main jobs (76%) or additional jobs (24%); using river water (6%) or not (94%); and an ethnicity of Dayak (77%), Banjar (19%), Java (3%), and Madura (1%).

Variable	Mean	Standard Deviation
General information		
Gender (male: 1, female: 0)	0.78	0.42
Education (year)	8.77	3.09
Age (year)	47.65	13.59
Business income (yes: 1, no: 0)	0.15	0.35
Monthly household income (IDR)	3,191,512	3,489,856
River water use (yes: 1, no: 0)	0.06	0.24
Land use		
Mainly farming (yes: 1, no: 0)	0.76	0.43
Farming with another job (yes: 1, no: 0)	0.24	0.43
Burned land in 2015 (ha)	3.48	3.90
Ethnic group		
Dayak ethnic (yes: 1, no: 0)	0.77	0.42
Banjar ethnic (yes: 1, no: 0)	0.19	0.40
Java ethnic (yes: 1, no: 0)	0.03	0.16
Madura ethnic (yes: 1, no: 0)	0.01	0.08

3.3. Firth's Logistic Regression

We established a binary logistic regression model to analyze the impacts of sociodemographic variables on the landowners' decision to plant a potential bioenergy species (or nyamplung) on degraded lands. We defined $E\ (y\,|\,X)$ as an expected probability for landowners to select nyamplung (y) given their sociodemographic values (X), resulting in a logistic regression model:

$$ln\left[\frac{E(y\mid X)}{1+E(y\mid X)}\right] = \beta_0+\beta_1 x_1+\ldots+\beta_6 x_6, \quad (1)$$

where β_0 is an intercept, x_1 is "farming with another job," x_2 is "business income," x_3 is "Java ethnic," x_4 is "Bioenergy benefit for climate," x_5 is "extension to learn," x_6 is "river water use," and β_1 to β_6 represent coefficients of the six variables. The model was estimated with Firth's penalized likelihood [30] since there was only a small number of landowners selecting nyamplung (n = 12). Logistic regression models with a small number of events might result in inflated coefficients and separation indicating that dependent variables are perfectly separable using an independent variable. A solution to these problems is Firth's logistic regression, which penalizes likelihood estimation [44–47]. It penalizes inflated coefficients by using a score function:

$$U(\beta_n)^* = U(\beta_n)+0.5tr\left[I(\beta)^{-1}\frac{\partial I(\beta)}{\beta_n}\right]\ n\ =\ 1,\ldots,\ k, \quad (2)$$

where, β_n indicates the nth parameter, k is the number of parameters, tr is the trace function, and $I(\beta)$ is the Fisher's information matrix. Before finalizing the model, moreover, we tested collinearity of the selected variables and their potential interactions. For the model estimation, the study employed R version 3.4.1 software and the 'logistf' package [46].

4. Results

4.1. Landowner Perceptions of Bioenergy

Results showed that landowners in Buntoi village preferred to use conventional species for restoration of their degraded lands and had low awareness of bioenergy. They dominantly preferred sengon as a potential restoration species (57%) (Figure 2a). They selected rubber tree as the second most preferred species (19%), while nyamplung was the least preferred species (8%). When asked about the main modes of learning about selected restoration species, landowners preferred following other farmers (n = 48), searching for information by themselves (n = 35), and learning by agricultural extension (n = 30) (Figure 2b). Meanwhile, 12 landowners preferred learning by practice. Of 150 landowners, only 32 (23%) were aware of bioenergy and renewable energy before the survey. They got to know about these topics from the media (n = 12), neighbors (n = 9), non-government organizations (NGOs) (n = 9), and the government (n = 5) (Figure 2c). Many of them considered that bioenergy would provide economic benefits (n = 27) and help mitigation of climate change (n = 19), while a few considered bioenergy would conserve soil (n = 9) and water (n = 2) (Figure 2d).

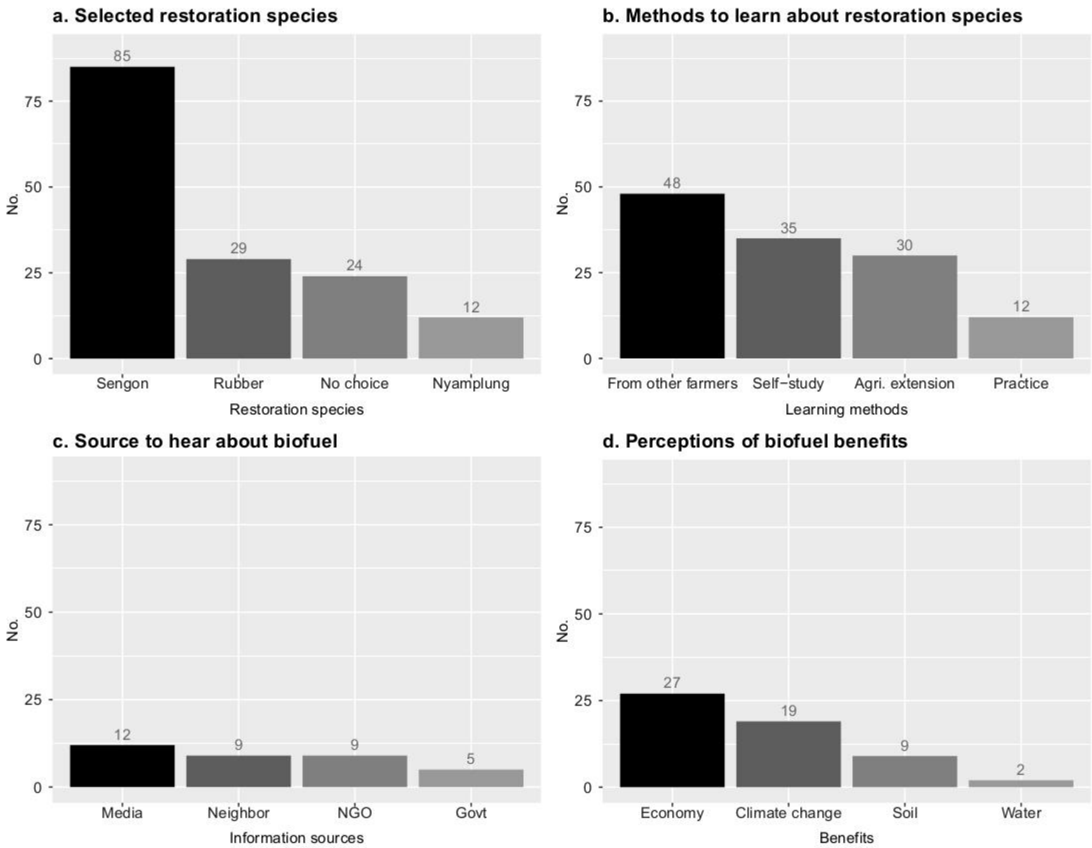

Figure 2. Landowner preferences for potential species for restoration of degraded land and their perceptions of bioenergy.

4.2. Logistic Regression Model

Two Firth's logistic regression models were established (Table 3). Model 1 obtained variables significant at the 1% level, while Model 2 obtained variables that were either statistically significant or insignificant. Since Model 2 failed to reject the null hypothesis of the Wald test (or impacts of all variables were equal to zero), Model 1 was mainly used to interpret results of the Firth's logistic regression models.

Table 3. Results of Firth's logistic model showing landowner preferences for bioenergy production on degraded lands (n = 150).

Variables	Model 1		Model 2	
	Coeff [1]	Std. error [2]	Coeff [1]	Std. error [2]
Intercept	−7.738 **	1.876	−4.303 **	2.509
Farming with another job	3.013 **	1.202	3.856 **	1.525
Business income	3.950 **	1.251	4.155 **	1.446
Java ethnic	5.776 **	2.186	6.116 **	2.444
Bioenergy benefit for climate	2.583 **	1.086	2.833 **	1.127
Agricultural extension	3.193 **	0.969	3.141 **	1.063
River water use	5.215 **	2.044	5.228 *	2.082
Age			−0.035	0.041
Gender			−0.540	0.944
Education			−0.197	0.173
Burned land area			−0.012	0.081
Likelihood ratio test	χ^2 = 48.52, p < 0.001		χ^2 = 47.91, p < 0.001	
Wald test	χ^2 = 14.59, p = 0.023		χ^2 = 13.96, p = 0.187	

** Significant at the 1% level. * Significant at the 5% level. [1] Coefficient, [2] Standard error.

Results of Model 1 revealed characteristics of landowners who had chosen to plant nyamplung as a plantation species on their degraded lands (Table 3). All variables had p-values lower than 1%. A likelihood ratio test of the model was significant at the 1% level, and a Wald test with all variables of the model was significant at the 5% level. The model only analyzed the main effects of the selected variables because none of their interactions were statistically significant. The model avoided collinearity as none of the selected variables were correlated to each other.

All variables of Model 1 achieved positive coefficients, except for the intercept, implying their positive marginal impacts on the landowners' preferences for nyamplung as a potential species on degraded lands. These results showed that a chance—or a likelihood ratio—for landowners to prefer nyamplung increased when landowners had a job in addition to farming (or the variable of "farming with another job" applied); they owned businesses providing additional income (or "business income"); migrated from the Java region (or "Java ethnic"); they considered that bioenergy supports mitigating climate change (or "bioenergy benefit for climate"); they preferred agricultural extension as a strategy to learn about species suited to degraded lands (or "agricultural extension"); and/or they used river water (or "river water use").

5. Discussion

Study results reveal lessons for bioenergy production from degraded land in Indonesia. Results of the logistic regression model and descriptive statistics of landowners imply three major lessons for building a bottom-up approach to bioenergy production from degraded land in Indonesia: (1) the bioenergy market should be stable for landowners; (2) bioenergy species should be familiar to landowners; and (3) landowners need support for their capacity building. Each item is discussed below.

5.1. Bioenergy Market Should Be Stable for Landowners

The bioenergy market should be stable for landowners, since bioenergy production was mainly preferred by those landowners who could afford a market risk of bioenergy production because they had additional jobs (or "farming with another job") and income sources (or "business income") (Table 3). In other words, landowners considered that bioenergy production still has market uncertainty, indicating a business risk. Thus, the opportunity to prefer bioenergy production was low for those landowners who relied solely on farming and had no other income sources, as they had limited capacity to cope with the risk associated with bioenergy production. This fact is also corroborated by the descriptive statistics that most landowners (88%) did not prefer bioenergy production (Figure 2) since many of them did not have additional jobs (76%) and only a few had additional incomes from business (15%) so that they were highly cautious about any market risk associated with farming (Table 2). The importance of a stable market is supported by other studies indicating that a lack of a market in which to sell bioenergy was a main cause of the failure of the Energy Sufficient Village program [25] and that farmers in the program preferred non-energy crops because they have a stable market [24]. Therefore, a stable market for bioenergy production is a key requirement to build a bottom-up approach to Bioenergy production from degraded lands in Indonesia.

5.2. Bioenergy Species Should Be Familiar to Landowners

Bioenergy species familiar to landowners would support their participation in bioenergy production than in species new to them. Results of Firth's logistic model indicate that those landowners from Java indicated a higher likelihood of them preferring nyamplung compared with other ethnic groups, such as Dayak (Table 3). Although nyamplung is new to Buntoi village, it is prevalent in Java [14] so that landowners originally from Java but now living in Buntoi village would have known the species better than the other ethnic groups and it might have encouraged their selection of nyamplung as a restoration species for their degraded lands. This ethnic impact on landowner preferences is also supported by the results that sengon or rubber tree were familiar to Buntoi villagers, where Dayak is the dominant ethnic group (77%) (Table 2); thus, these landowners mostly preferred sengon or rubber tree (76%) for restoration of their degraded lands (Figure 2). Moreover, these results support the literature emphasizing that the traditional cultures of landowners have impacts on their decisions to produce bioenergy [31,32]. Accordingly, application of bioenergy species that are culturally familiar to landowners is important for developing a bottom-up approach to bioenergy production in Indonesia.

5.3. Landowners Need Support for Capacity Building

Landowners who preferred bioenergy production indicated a need for agricultural extension support to build their technical capacity to manage bioenergy species (Table 3). A lack of landowner capacity and limited technical guidance were the main challenges for the Energy Sufficient Village program [25]. Moreover, limited technical capacity of landowners would not only increase bioenergy production costs, which excludes landowner businesses (e.g., [23]), but also make production unreliable, thereby creating an unfavorable business environment for Bioenergy refineries and companies (e.g., [24]). Therefore, a bottom-up approach to bioenergy production should be able to support capacity building of landowners (e.g., support for agricultural extension) in order to encourage their participation in bioenergy production, to make their production costs efficient and stable, and to reduce the business risk for bioenergy refineries and companies.

5.4. Study Limitations

We recognize some limitations of this study, indicating the need for future studies. First, there could be other factors affecting landowner preferences for bioenergy production, such as knowledge of other bioenergy crops. Second, this study is limited to showing factors that affect other key stakeholder preferences for bioenergy production from degraded land, including bioenergy refineries, companies, and end consumers, even though they play vital roles in establishing a bottom-up approach to bioenergy production. Third, while the study only focused on nyamplung, there are other potential bioenergy species in Indonesia, such as malapari (*Pongamia pinnata* (L.) Panigrahi), kemiri sunan (*Reutalis trisperma* (Blanco) Air Shaw), and kaliandra (*Calliandra calothyrsus* Meissner) [13]. As this study shows, different bioenergy species might generate different landowner preferences. Fourth, this study represents a case study of Buntoi village in Central Kalimantan, and landowners in other areas with different socioeconomic and sociocultural conditions might have different perceptions of bioenergy production. Fifth, the study analyzes one type of degraded land—burned land—so that landowner preferences for restoration species might differ for other types of degraded land and/ or abandoned land. All these limitations, therefore, indicate the need for future studies on a variety of potential factors affecting landowner preferences, the preferences and interests of stakeholder groups, diverse bioenergy species, other regimes in Indonesia, as well as several types of degraded lands.

6. Conclusions

This study examined landowner perceptions of bioenergy production by investigating factors affecting landowner preferences for bioenergy production on degraded lands in Central Kalimantan, Indonesia. Using Firth's logistic regression model, we analyzed 150 owners of land degraded by forest fire in Buntoi village. Results showed that most landowners (76%) preferred conventional species for restoration of their degraded lands, including sengon and rubber tree. Only a few (8%) preferred nyamplung for bioenergy production on these lands. Those who preferred bioenergy production were characterized by the capacity to handle the market risk associated with bioenergy production because they had additional jobs and incomes, were Javanese farmers and landowners familiar with nyamplung, or preferred learning about restoration species throughout agricultural extension. Our results contribute to empirically identifying three key conditions for a bottom-up approach to bioenergy production from degraded land in Indonesia: a stable bioenergy market for landowners, the application of familiar bioenergy species, and extension support for capacity building. These conditions would serve as criteria for testing the feasibility of a bottom-up approach to bioenergy production. Furthermore, further studies are required to test its feasibility, including testing a variety of potential factors affecting landowner preferences, the interests of different stakeholders, diverse bioenergy species, as well as different types of degraded lands in Indonesia.

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References

1. Ladanai, S.; Vinterback, J. *Global Potential of Sustainable Biomass for Energy*; Swedish University of Agricutural Science, Department of Energy and Technology (SLU): Uppsala, Sweden, 2009.
2. WEC (World Energy Council). *World Energy Resources: Bioenergy*; WEC: Washington, DC, USA, 2016; Available online: https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Bioenergy_2016.pdf (accessed on 16 January 2019).
3. Campbell, J.; Elliot, B.; Lobell, R.C.; Genova, R.C.; Field, C.B. The global potential of bioenergy on abandoned agriculture lands. *Environ. Sci. Technol.* **2008**, *42*, 5791–5794. [CrossRef] [PubMed]
4. Cai, X.; Zhang, X.; Wang, D. Land availability for biofuel production. *Environ. Sci. Technol.* **2011**, *45*, 334–339. [CrossRef] [PubMed]
5. Tilman, D.; Hill, J.; Lehman, C. Carbon-negative biofuels from low input high diversity grassland biomass. *Science* **2006**, *314*, 1598–1600. [CrossRef] [PubMed]
6. Fargione, J.; Hill, J.; Tilman, D.; Polasky, S.; Hawthorne, P. Land clearing and the biofuel carbon debt. *Science* **2008**, *319*, 1235–1238. [CrossRef] [PubMed]
7. GAIN (Global Agriculture Information Network). *Indonesia Bioenergy Annual 2017*; USDA Foreign Agricultural Service: Jakarta, Indonesia, 2017.

8. GOI (Government of Indonesia). *Peraturan Pemerintah Republik Indonesia no. 79 tahun 2014 tentang Kebijakan Energy Nasional*; Sekretariat Negara: Jakarta, Indonesia, 2014.
9. ICCC (Indonesia Climate Change Center). *Crops to Energy on Degraded Land as a Step toward Energy Independence, Carbon Sink Agriculture and Protection of REDD+ Designated Areas*; Indonesia Climate Change Center: Jakarta, Indonesia, 2015.
10. Jaung, W.; Wiraguna, E.; Okarda, B.; Artati, Y.; Goh, C.S.; Syahru, R.; Leksono, B.; Prasetyo, L.B.; Lee, S.M.; Baral, H. Spatial assessment of degraded lands for biofuel production in Indonesia. *Sustainability* **2018**, *10*, 4595. [CrossRef]
11. DEN (Dewan Energi National). *Indonesia Energy Outlook 2016*; Dewan Energi National: Jakarta, Indonesia, 2017.
12. Samsudin, Y.B.; Andini, S.; Baral, H.; Lee, S.M.; Rahman, S.A. *Biofuels; Growing Renewables and Restoring Degraded Land?* Center for International Forestry Research (CFIRO): Bogor, Indonesia, 2018; Available online: http://www.cifor.org/publications/pdf_files/posters/6469-infographic.pdf (accessed on 16 January 2019).
13. Borchard, N.; Artati, Y.; Lee, S.M.; Baral, H. *Sustainable Forest Management for Land Rehabilitation and Provision of Biomass-Energy*; Center for International Forestry Research (CIFOR): Bogor, Indonesia, 2017.
14. Bustomi, S.; Rostiwati, T.; Sudradjat, R.; Kosasih, A.S.; Anggraeni, I.; Leksono, B.; Irawanti, S.; Kurniaty, R.; Syamsuwida, D.; Effendi, R.; et al. *Nyamplung (Calophyllum inophyllum L.) Sumber Energi Bioenergy yang Potensial*; Kementerian Kehutanan: Jakarta, Indonesia, 2008.
15. Leksono, B.; Windyarini, E.; Hasnah, T.M. *Budidaya Tanaman Nyamplung (Calophyllum inophyllum) untuk Bioenergi dan Prospek Pemanfaatan Lainnya*; IPB Press: Jakarta, Indonesia, 2014.
16. Widayati, A.; Öborn, I.; Silveira, S.; Baral, H.; Wargadalam, V.; Harahap, F.; Pari, G. *Exploring the Potential of Bioenergy in Indonesia for Multiple Benefits*; Policy Brief no. 82; World Agroforestry Centre Southeast Asia Regional Program: Bogor, Indonesia, 2017.
17. Rahman, S.A.; Baral, H.; Sharma, R.; Samsudin, Y.B.; Meyer, M.; Lo, M.; Artati, Y.; Simamora, T.I.; Andini, S.; Leksono, B.; et al. Integrating bioenergy and food production on degraded landscapes in Indonesia for improved socio-economic and environmental outcomes. *Food Energy Secur.* **2018**. in review.
18. Blanco-Canqui, H. Growing dedicated energy crops on marginal lands and ecosystem services. *Soil Sci. Soc. Am. J.* **2016**, *80*, 845–858. [CrossRef]
19. Singh, M.K.; Astley, H.; Smith, P.; Ghoshal, N. Soil CO_2–C flux and carbon storage in the dry tropics: Impact of land-use change involving bioenergy crop plantation. *Biomass Bioenergy* **2015**, *83*, 123–130. [CrossRef]
20. Dauber, J.; Brown, C.; Fernando, A.L.; Finnan, J.; Krasuska, E.; Ponitka, J.; Styles, D.; Thrän, D.; Van Groenigen, K.J.; Weih, M.; et al. Bioenergy from "surplus" land: Environmental and socio-economic implications. *BioRisk* **2012**, *7*, 5–50. [CrossRef]
21. Liu, T.T.; McConkey, B.G.; Ma, Z.Y.; Liu, Z.G.; Li, X.; Cheng, L.L. Strengths, weaknesses, opportunities and threats analysis of bioenergy production on marginal land. *Energy Procedia* **2011**, *5*, 2378–2386. [CrossRef]
22. Ullah, K.; Sharma, V.K.; Dhingra, S.; Braccio, G.; Ahmad, M.; Sofia, S. Assessing the lignocellulosic biomass resources potential in developing countries: A critical review. *Renew. Sustain. Energy Rev.* **2015**, *51*, 682–698. [CrossRef]
23. Amir, S.; Nurlaila, I.; Yuliar, S. Cultivating energy, reducing poverty: Bioenergy development in an Indonesian village. *Perspect. Glob. Dev. Technol.* **2008**, *7*, 113–132. [CrossRef]
24. Fatimah, Y.A. Fantasy, values, and identity in Bioenergy innovation: Examining the promise of jatropha for Indonesia. *Energy Res. Soc. Sci.* **2015**, *7*, 108–116. [CrossRef]
25. Muslihudin, M.; Kusumanegara, S.; Ahdiati, T. The program implementation of energy self-sufficient village based on *Calophyllum inophyllum* in Purworejo, Central Java, Indonesia. *Proc. Eng. Int. Comm.* **2015**, *4*, 27–31.
26. Simandjuntak, D. Riding the hype: The role of state-owned enterprise elite actors in the promotion of jatropha in Indonesia. *Sustainability* **2014**, *6*, 3780–3801. [CrossRef]
27. Singh, R.; Setiawan, A.D. Biomass energy policies and strategies: Harvesting potential in India and Indonesia. *Renew. Sustain. Energy Rev.* **2013**, *22*, 332–345. [CrossRef]
28. Uripno, B.; Slamet, R.M.; Amanah, S. Implementation of demonstration plots DME Nyamplung (*Calophyllum inophyllum L*) in Buluagung and Patutrejo villages. *Int. J. Sci. Eng.* **2014**, *7*, 81–90. [CrossRef]
29. Anggraini, E.; Grundmann, P. Transactions in the supply chain of oil palm fruits and their relevance for land conversion in smallholdings in Indonesia. *J. Environ. Dev.* **2013**, *22*, 391–410. [CrossRef]

30. Feintrenie, L.N.; Chong, W.K.; Levang, P. Why do farmers prefer oil palm? Lessons learnt from Bungo District, Indonesia. *Small-Scale For.* **2010**, *9*, 379–396. [CrossRef]
31. Sitompul, R.; Brouwer, R.; Sopaheluwakan, J.; van Beukering, P. Farm household preferences and evaluation of land use change policies for agro-forestry plantations in Central Kalimantan, Indonesia: A choice experiment. *Int. J. Adv. Sci. Eng. Inf. Technol.* **2016**, *6*, 210–216. [CrossRef]
32. Nurlaila, I.; Yuliar, S.; Gharaei, R.A. Multiculturality in Indonesia's Bioenergy Innovation Initiative: Critical issues. *J. Asian Behav. Stud.* **2013**, *3*, 79–88.
33. Buntoi Village Government. *Rencana Pembangunan Desa Buntoi 2014–2024*; Buntoi Village Government: Buntoi, Indonesia, 2014.
34. Buntoi Village Government. *Monografi Desa Buntoi*; Buntoi Village Government: Buntoi, Indonesia, 2016.
35. Buntoi Village Government. *Data Kebakaran Lahan di Desa Buntoi*; Buntoi Village Government: Buntoi, Indonesia, 2015.
36. Ong, H.C.; Mahlia, T.M.I.; Masjuki HH Norhasyima, R.S. Comparison of palm oil, Jatropha curcas and *Calophyllum inophyllum* for biodiesel: A review. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3501–3515. [CrossRef]
37. Maimunah, S.; Rahman, S.A.; Samsudin, Y.B.; Artati, Y.; Simamora, T.I.; Andini, S.; Lee, S.M.; Baral, H. Assessment of suitability of tree species for bioenergy production on burned and degraded peatlands in Central Kalimantan, Indonesia. *Land* **2018**, *7*, 115. [CrossRef]
38. Pratiwi Narendra, B.H.; Hartoyo, E.; Kalima, T.; Padjadinata, S. *Altas Jenis-Jenis Pohon Adalan Setempat untuk Rehabilitasi Hutan*; FORDA Press: Bogor, Indonesia, 2014.
39. Orwa, C.; Mutua, A.; Kindt, R.; Jamnadass, R.; Anthony, S. Agroforestry Tree Database: A Tree Reference and Selection Guide Version 4.0. 2009. Available online: http://www.worldagroforestry.org/treedb/AFTPDFS/Hevea_brasiliensis.PDF (accessed on 10 January 2017).
40. Damanik, S.; Syakir, M.; Tasma, M. *Budidaya dan Pasca Panen Karet. Pusat Penelitian dan Pengembangan Perkebunan*; Kementrian Pertanian: Jakarta, Indonesia, 2010.
41. Martawijaya, A.; Kartasujana, I.; Kdir, K.; Prawira, S.A. *Atlas kayu Indonesia*; FORDA: Bogor, Indonesia, 2005.
42. Friday, J.B.; Okano, D. *Calophyllum inophyllum* (kamani). *Species Profiles of Pacific Island Agroforestry*, version 2.1; 2006. Available online: https://www.doc-developpement-durable.org/file/Arbres-Bois-de-Rapport-Reforestation/FICHES_ARBRES/Arbres-non-classes/Calophyllum-kamani.pdf (accessed on 10 January 2017).
43. Zhengzhou Double Vigour Chemical Product Co., Ltd. The Eight Factors of the Natural Rubber tree Price Fluctuations. 2013. Available online: http://www.rubbertree-accelerator.com/news/eight-factors.html#.WcsvvGiCw2y (accessed on 15 January 2017).
44. Firth, D. Bias reduction of maximum likelihood estimates. *Biometrika* **1993**, *80*, 27–38. [CrossRef]
45. Heinze, G.; Schemper, M. A solution to the problem of separation in logistic regression. *Stat. Med.* **2002**, *21*, 2409–2419. [CrossRef] [PubMed]
46. Heinze, G.; Ploner, M. *logistf: Firth's Bias Reduced Logistic Regression*, R Package, Version 1.22; 2016. Available online: https://CRAN.R-project.org/package=logistf (accessed on 15 November 2017).
47. Wang, X. Firth logistic regression for rare variant association tests. *Front. Genet.* **2014**, *5*, 187. [CrossRef] [PubMed]