CHAPTER 4

Landowner perceptions towards bioenergy production on degraded lands in Indonesia

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Abstract: Various tree species have been identified as having potential for bioenergy and restoration of degraded land. Using degraded land for bioenergy production provides Indonesia with an opportunity to meet its rapidly growing energy demand while creating productive landscapes. However, bioenergy production is not feasible without landowner participation. This study investigates factors affecting preferences for restoration tree species by analysing responses from 150 landowners with fire experience in Buntoi Village in Central Kalimantan I. Results indicate 76% of landowners preferring familiar species with readily available markets, such as *Albizia chinensis* (*sengon*) and *Hevea brasiliensis* (rubber), for restoration on degraded land, with only 8% preferring *Calophyllum inophyllum* L. (*nyamplung*) for bioenergy production. The latter group of landowners revealed a capacity to handle the uncertainty of the bioenergy market as they had additional jobs and income, had migrated from Java where *nyamplung* is prevalent, or preferred agricultural extension to improve their technical capacity. These results contribute to identifying key conditions for a bottom-up approach to bioenergy production on 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 perceptions, restoration
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4.1 Introduction

Bioenergy is a promising and most versatile form of renewable energy (Ladanai et al. 2009; WEC 2016), and its production from degraded lands has potential for helping meet global energy demand (Campbell et al. 2008; Cai et al. 2011). It might increase the supply of renewable energy (Cai et al. 2011) and improve land use efficiency (Tilman et al. 2006; Fargione et al. 2008). These benefits have encouraged many countries to promote bioenergy use and support the development of technologies and policies related to bioenergy production (Ladanai et al. 2009; WEC 2016). The Government of Indonesia, for example, has set targets to increase biodiesel and bioethanol use by 30% and 20%, respectively by 2025 (Presidential Regulation No. 12/2015) (Gain 2017) to manage the country's rapidly growing energy demand. By 2025, energy demand in Indonesia is expected to be 1.8 times higher than in 2015 (GoI 2014) due to population growth, urbanization and economic development (ICCC 2015; DEN 2017; Jaung et al. 2018).

Recently, there has been increasing interest in bioenergy production through the cultivation of non-food seed oil producing crops such as *Calophyllum inophyllum* (*nyamplung*) on degraded lands. Such practices can have multiple benefits (Samsudin et al. 2018) as some of these non-food crops can grow on degraded lands unable to support food production, thereby minimizing the trade-off between food and fuel production (Leksono et al. 2014; Borchard et al. 2017; Widayati et al. 2017; Bustomi et al. 2018). Environmental impacts can be reduced if these crops are harvested from degraded and underutilized lands that have limited value to store carbon and preserve native vegetation and biodiversity (Leksono et al. 2014; ICCC 2015; Rahman et al. 2019). In addition, such practices could support restoration of degraded lands with these bioenergy species and provide a variety of ecosystem services, such as carbon storage, soil erosion reduction and biodiversity enhancement (Singh et al. 2015; Blanco-Cangui 2016). They also create employment opportunities in rural areas, particularly in developing countries where large populations live and rely on marginal lands for farming (Liu et al. 2011; Dauber et al. 2015; Ullah et al. 2015; Widayati et al. 2017).

However, capturing the benefits of bioenergy production on degraded land is not feasible without landowner participation. Therefore, to make bioenergy production an attractive prospect for landowners, it should meet their preferences and expectations. In 2007, the Government of Indonesia launched its *Desa Mandiri Energi* or energy self-sufficient villages programme in Java (Amir et al. 2008; Singh and Setiawan 2013; Simandjuntak 2014; Uripno et al. 2014; Fatimah 2015; Muslihudin et al. 2015). The programme aimed not only at encouraging village communities to produce bioenergy for energy security, but also at creating employment and reducing poverty in rural areas. However, most pilot projects under the programme have recently been discontinued as its top-down approach failed either to engage landowners or accommodate their preferences. This failure suggests a bottom-up approach would be preferable; one that motivates landowners to participate in bioenergy production, ensures stable market demand for bioenergy feedstocks, and reflects local needs. A preliminary step in testing the feasibility of such a bottom-up approach is to investigate what would encourage or discourage owners of degraded and underutilized land to participate in bioenergy production.

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. Several studies, such as Amir et al. (2008), Feintrenie (2010) and Anggraini and Grundmann (2013), have analysed bioenergy production from degraded land in Indonesia. Though few have focused on the owners of degraded lands, or on landowner preferences for non-food species to restore degraded lands and produce bioenergy feedstocks (Sitompul et al. 2016). Thus, 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.

4.2 Bioenergy production in Indonesia

4.2.1 Landowner preferences

Several studies identify factors affecting landowners' preferences for bioenergy species such as *Elaeis guineensis* (Jacq.) (oil palm) *Jatropha curcas* (jatropha) and *Calophyllum inophyllum* L. (*nyamplung*) in Indonesia. Feintrenie et al. (2010) 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 (2013) assert that cash income and loans were major motivations for smallholders in Mandailing Natal and Labuhan Batu districts in North Sumatra in converting their rice fields for oil palm. Amir et al. (2008) argue that expectations of high profits motivated farmers in Mandalasari Village, West Java to plant jatropha in their mixed gardens and rice fields. Uripno et al. (2014) indicate that factors affecting communities' involvement in bioenergy production in Buluagung and Patutrejo villages in Central Java included bioenergy price, technology innovation, project roles and support from local leaders. Sitompul et al. (2016) indicate that the likelihood of farmers in Maliku and Pandih Batu subdistricts in Central Kalimantan taking up bioenergy production would increase with higher profits and shorter contracts. They also argue that farmers from different ethnic backgrounds would have different interests in bioenergy crops. Nurlaila et al. (2013) assert that landowners' traditions and cultures impact their decisions regarding bioenergy production.

As these studies are mostly qualitative and investigate the overall preferences of stakeholders for bioenergy, their results are limited in providing empirical representations of the various owners of degraded lands. Thus, quantitative analyses that focus on such landowners are needed to gain a more comprehensive understanding of their preferences and expectations in regard to bioenergy production.

4.2.2 Challenges in encouraging landowner participation

The Energy Self-Sufficient Villages programme reveals several challenges for landowners who produce or wish to produce bioenergy feedstocks in Indonesia (Simandjuntak 2014; Uripno et al. 2014; Fatimah 2015; Muslihudin et al. 2015). Although relevant to various stakeholders in bioenergy production, these challenges reflect required conditions for landowners, including: a bottom-up approach allowing their participation during programme 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. (2015) indicate that implementation of the programme was challenged by low levels of community engagement, inefficient machinery for bioenergy feedstock processing, limited technical guidelines, high production costs and a limited market in which to sell seed oil. Uripno et al. (2014) assert that the top-down nature of the programme challenged the long-term participation of communities. Simandjuntak (2014) demonstrates that the programme was challenged by a limited market, unstable crop production and limited technical research. Fatimah (2015) shows that stakeholders considered low productivity and poor coordination between institutions to be the main reasons for the programme's failure. Amir et al. (2008) argue that complex bureaucracy at the village level and different stakeholder interests were major challenges to programme implementation. They also claim that limited land for growing bioenergy crops was a major challenge in encouraging small landowners to participate in bioenergy production. All of these challenges provide valuable lessons for testing the feasibility of a bottom-up approach to bioenergy production on degraded land in Indonesia.

4.3 Materials and methods

4.3.1 Study site

The research site is located in Buntoi Village, Pulang Pisau District, Central Kalimantan Province at coordinates 2°48'59.4" S and 114°10'47.3" E along the Kahayan, one of the main rivers in the province (Figure 1). Buntoi Village covers a total area of approximately 16,000 ha. Agriculture and forest land use dominate the area, accounting for 41% and

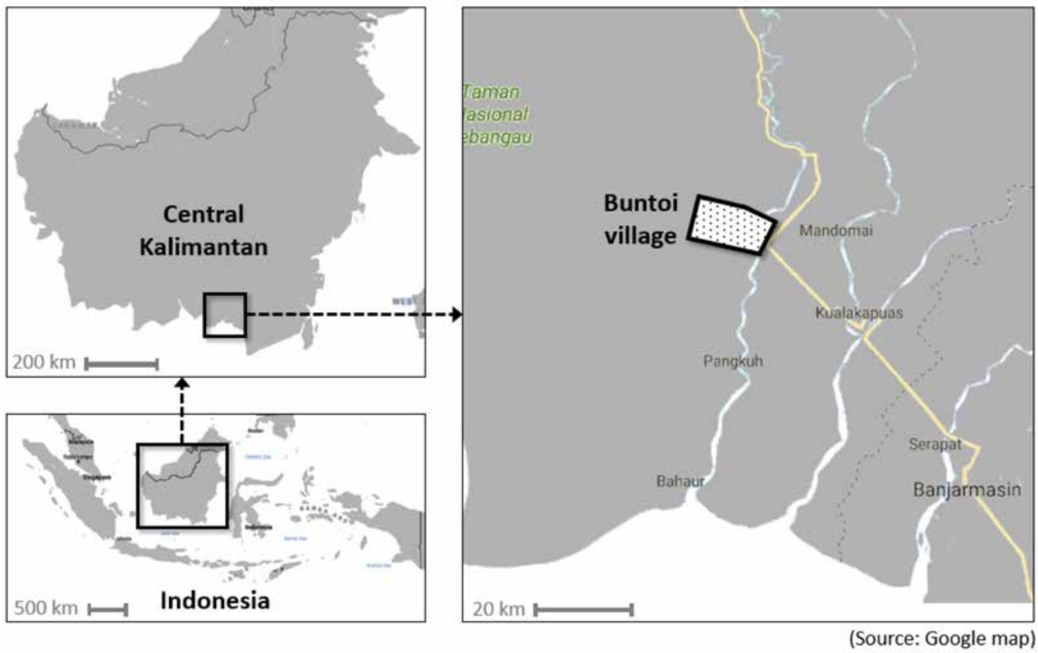

Figure 1. Location of Buntoi Village, Central Kalimantan, Indonesia

57%, respectively, while the remaining 2% constitutes settlements. Rubber production has been a major economic activity in Buntoi. The village has a tropical humid climate with average temperatures ranging from 26.5 to 27.5°C (Buntoi Village Government 2014). Consisting of 12 sub-villages, the village had a total population of 2,719 at the time of the study. The predominant ethnic group in the village is Ngaju Dayak, but other ethnicities include Banjarese, Javanese, Batak, Buginese, Sundanese, Madurese, Balinese, Florinese, Manadonese and Chinese (Buntoi Village Government 2016).

Buntoi Village was selected as a study site because it has large areas of burned degraded land and is a pilot location for the central and regional government's *Bioenergy Lestari* sustainable bioenergy programme. In 2015, the village was one of a number of areas affected by massive forest fires, the haze from which affected neighbouring countries, including Singapore and Malaysia. Fire destroyed more than 400 ha of landowners' rubber plantations in the village, resulting in losses of around IDR 300 million, equivalent to USD 22,500 in 2017 (Buntoi Village Government 2015). With landowners seeking ways to invest in their burned lands, the Ministry of Energy and Mineral Resources initiated the *Program Pengembangan Bioenergi Lestari* or Sustainable Bioenergy Development Programme in collaboration with the Central Kalimantan Provincial Government to produce bioenergy from degraded lands in the districts of Pulang Pisau and Katingan, including Buntoi Village.

4.3.2 Survey design and administration

We designed a survey to analyse landowners' preferences for restoration species for degraded lands and their perceptions of bioenergy. Prior to designing the survey, we conducted a preparatory visit in June 2016 to observe village conditions and interview key village informants about the 2015 fire and haze disaster, rubber plantation costs and current market conditions, and landowners' plans for restoring their burned lands.

As a result of the visit, three species were selected as potential restoration species for the village: *sengon* (*Albizia chinensis*), rubber tree (*Hevea brasiliensis*) and *nyamplung* (*Calophyllum inophyllum* L.). *Sengon* was chosen for timber production, as it was gaining increasing recognition in the village as a high-value species. In addition, the Ministry of Environment and Forestry was supporting *sengon* production through its *Hutan Kemasyarakatan* (HKM) social forestry programme. Through this programme, the government grants 35-year community plantation forest timber extraction permits (IUPHHK-HTR) for farmers to harvest wood. Rubber tree was selected as rubber production had been a major economic interest in the village for many years, and villagers traditionally used old rubber trees as fuelwood for cooking. *Nyamplung* was selected as a potential species for bioenergy production. As the bioenergy species was new to the village, it was considered appropriate for testing landowners' perceptions regarding potential for bioenergy production. *Nyamplung* is known to produce the biodiesel most similar to diesel oil, has the potential to replace diesel fuel without the need for engine modifications (Ong et al. 2011), and adapts well to degraded land including peatland (Maimunah et al. 2018). In addition, it meets the Indonesian National Standard (SNI) for fuel (Leksono et al. 2014; Bustomi et al. 2018).

The final survey had sections on demographic information, land management plans, fire coping strategies and perceptions on bioenergy. Questions in the first section focused on essential sociodemographic information, including level of education, household earnings and ethnic background. The second section asked respondents about their experiences with land degradation resulting from fire. The third section asked about strategies for managing degraded farmland, while the fourth section asked participants to choose which one of the three species (Table 1) they would prefer for restoration of their degraded lands. Participants were also allowed to opt for none of the three species. Before being asked about their preferences, each participant received a brief presentation on the main characteristics of the three species based on a literature review and expert consultations. Visual aids were used to increase understanding when providing species descriptions.

From 29 January to 7 February 2017, we surveyed a total of 150 owners of land in Buntoi Village degraded by the 2015 forest fire. Respondents were selected randomly

Table 1. Characteristics of the three potential restoration species for degraded land in Buntoi Village

Category	*Sengon*	Rubber tree	*Nyamplung*
Main objective	Timber production (1)	Rubber production (2)	Biodiesel production (3, 4)
Other uses	Fuelwood, wooden crates, animal feed (1)	Fuelwood (2, 8)	Medicine, cosmetics, wood, fuelwood, and animal feed (3)
Tolerable conditions	Infertile and moist land (1)	Fertile land (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	Not influenced by international market (9)	Influenced by international market (10)	Not influenced 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 every 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. 2014; (2) Orwa et al. 2009; (3) Leksono et al. 2014; (4) Ong et al. 2011; (5) Damanik et al. 2010; (6) Martawijaya et al. 2005; (7) Friday and Okano 2016 [42]; (8) Interviews with key informants in the preparatory visit in 2016; (9) consultations with *sengon* silviculture and business experts in Kalimantan and Java; and (10) Zhengzhou Double Vigour Chemical Product Co. Ltd. 2013. * IDR = Indonesian rupiah. Per September 2017, IDR 13,510 = USD 1.

from the 10 sub-villages where most landowners with forest fire experience reside. Sociodemographic variables of participants are presented in Table 2.

In addition, a focus group discussion was held with key informants in Buntoi to examine village land-use history, environmental changes the village has experienced, and landowners' plans for their degraded lands. Key informants were identified through snowball sampling and invited to the discussion. A total of 20 key informants comprising sub-village representatives and those actively involved in village activities joined the focus group discussion.

Table 2. Sociodemographic variables of landowners with degraded lands in Buntoi Village (n = 150)

Variable	Mean	Standard Deviation
General information		
Gender (male: 1, female: 0)	0.78	0.42
Education (years)	8.77	3.09
Age (years)	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 (yes: 1, no: 0)	0.77	0.42
Banjarese (yes: 1, no: 0)	0.19	0.40
Javanese (yes: 1, no: 0)	0.03	0.16
Madurese (yes: 1, no: 0)	0.01	0.08

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 income source (76%) or additional income source (24%); using river water (6%) or not (94%); and ethnicity of Dayak (77%), Banjarese (19%), Javanese (3%) and Madurese (1%).

4.3.3 Firth's logistic regression

We established a binary logistic regression model to analyse the impacts of sociodemographic variables on landowners' decisions to plant a potential bioenergy species (*nyamplung*) on their degraded land. 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:

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

where b_0 is an intercept, x_1 is "farming with another job," x_2 is "business income," x_3 is "Javanese," x_4 is "Bioenergy benefit for climate," x_5 is "extension to learn," x_6 is "river water use," and b_1 to b_6 represent coefficients of the six variables. The model was estimated with Firth's penalized likelihood (Feintrenie 2010) since only a small number of landowners selected *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 (Firth 1993; Heinze and Schemper 2002; Wang 2014; Heinze and Ploner 2016). It penalizes inflated coefficients by using a score function:

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

where, b_n indicates the *n*th parameter, *k* is the number of parameters, *tr* is the trace function, and *I(b)* is the Fisher information matrix. Before finalizing the model, we tested the 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 (Heinze and Ploner 2016).

4.4 Results

4.4.1 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. A majority (57%) preferred *sengon* as a potential restoration species (Figure 2a), while 19% chose rubber, with *nyamplung* being the least preferred species at 8%. When asked about preferred modes of learning about selected restoration species, most landowners chose following other farmers (*n* = 48), followed by searching for information themselves (*n* = 35), and learning by agricultural extension (*n* = 30) (Figure 2b). Meanwhile, 12 landowners preferred learning by practice. Of the 150 landowners, only 32 (23%) were aware of bioenergy and renewable energy before the survey, having found out from the media (*n* = 12), neighbours (*n* = 9), non-governmental organizations (NGOs) (*n* = 9), and the government (*n* = 5) (Figure 2c). Many thought bioenergy would provide economic benefits (*n* = 27), help mitigate climate change (*n* = 19), conserve soil (*n* = 9) and conserve water (*n* = 2) (Figure 2d).

4.4.2 Logistic regression model

Two Firth 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 (impacts of all variables were equal to zero), Model 1 was mainly used to interpret results.

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 analysed 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.

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

	Model 1		Model 2	
Variables	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
Javanese	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	$\chi^2 = 48.52$, $p < 0.001$		$\chi^2 = 47.91$, $p < 0.001$	
Wald test	$\chi^2 = 14.59$, $p = 0.023$		$\chi^2 = 13.96$, $p = 0.187$	

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

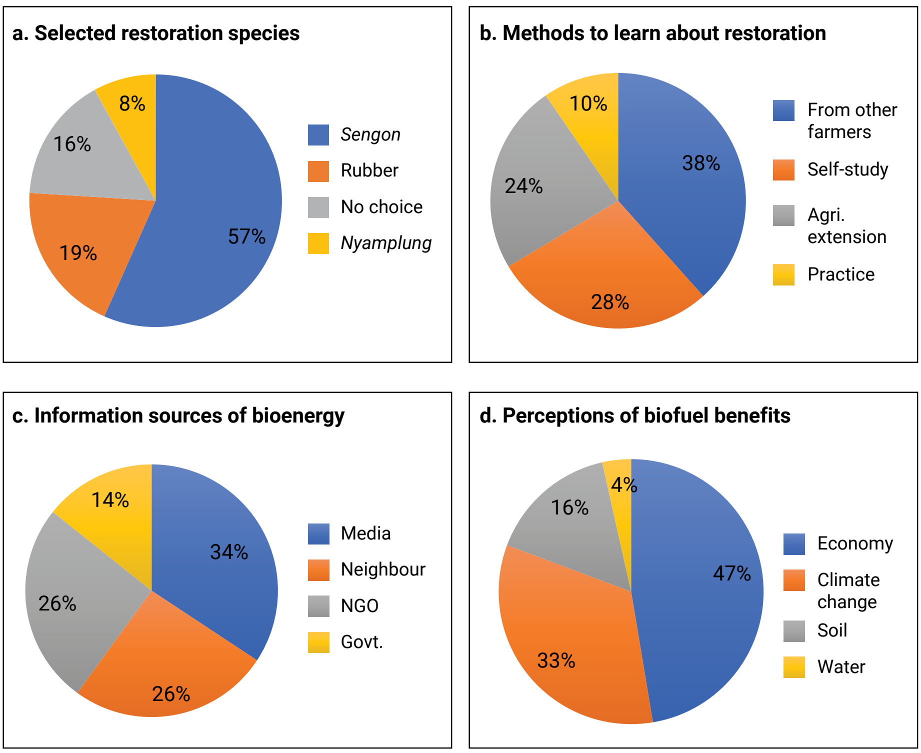

Figure 2. Landowner preferences for potential degraded land restoration species and perceptions of bioenergy

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 for restoring degraded lands. These results showed that the chance—or likelihood ratio—for landowners to prefer *nyamplung* increased when they had a job in addition to farming (the "farming with another job" variable applied); they owned businesses providing additional income ("business income"); migrated from the Java region (or "Javanese"); they thought bioenergy supports climate change mitigation ("bioenergy benefit for climate"); they preferred agricultural extension for learning about species suited to degraded lands ("agricultural extension"); and/or they used river water ("river water use").

4.5 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) landowners require a stable bioenergy market; (2) bioenergy species should be familiar to landowners; and (3) landowners need capacity building support. Each of these is discussed below.

4.5.1 Landowners require a stable bioenergy market

The bioenergy market should be stable for landowners, as bioenergy production was mainly preferred by those landowners who could afford a market risk with bioenergy production, either because they had additional jobs ("farming with another job") or had other income sources ("business income") (Table 3). In other words, landowners felt 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 source of income, as they had limited capacity to cope with the risk associated with bioenergy production. This was corroborated by descriptive statistics showing most landowners (88%) did not prefer bioenergy production (Figure 2), as many of them (76%) had no additional jobs while only a few (15%) had additional incomes from business. This made them extremely wary of any market risks associated with farming (Table 2). The importance of a stable market is supported by other studies suggesting the lack of markets in which to sell bioenergy feedstocks was a major reason for the Energy Self-Sufficient Villages programme failing (Muslihudin et al. 2015), and that farmers involved in the programme preferred non-energy crops because they have stable markets (Fatimah 2015). Therefore, a stable market is a key requirement for a bottom-up approach to developing bioenergy production on degraded lands in Indonesia.

4.5.2 Bioenergy species should be familiar to landowners

Landowners would be more likely to participate in bioenergy production with species they are familiar with rather than species that are new to them. Results of the Firth logistic regression model showed landowners originally from Java being more likely than other ethnicities to opt for *nyamplung* (Table 3). Though *nyamplung* is new to Buntoi, it is prevalent in Java (Bustomi et al. 2018), so Javanese landowners now living in Buntoi would be more familiar with the species than other ethnic groups, which might have encouraged their selection of *nyamplung* as a restoration species for their degraded lands. This notion of familiarity influencing landowner preferences is supported by results showing *sengon* and rubber – species familiar to Buntoi villagers – being preferred choices for 76% of landowners for restoration of their degraded lands (Table 2), while indigenous ethnic Dayaks make up 77% of the population (Figure 2). Moreover, these results support literature suggesting landowners' traditions and cultures influence their decisions to cultivate bioenergy crops (Nurlaila et al. 2013; Sitompul et al. 2016). Therefore, using bioenergy species that are culturally familiar to landowners is important for developing a bottom-up approach to bioenergy production in Indonesia.

4.5.3 Landowners need capacity building support

Landowners who preferred bioenergy production indicated a need for agricultural extension support to build their technical capacity for cultivating bioenergy species (Table 3). A lack of capacity in landowners and limited technical guidance were major challenges for the energy self-sufficient villages programme (Muslihudin et al. 2015). Limited technical capacity would not only increase bioenergy production costs for landowners (Amir et al. 2008), but would also make production unreliable, thereby creating an unfavourable business environment for bioenergy refineries and companies (Fatimah 2015). Therefore, any bottom-up approach to bioenergy production should be able to support capacity building and provide agricultural extension for landowners in order to encourage participation in bioenergy production, ensure production costs remain efficient and stable, and reduce business risks for bioenergy refineries and companies.

4.5.4 Study limitations

We recognize this study has limitations, and acknowledge the need for further investigation. First, other factors such as knowledge of other bioenergy crops may well affect landowner preferences for bioenergy production. Second, this study does not discuss factors that may affect the preferences of other key stakeholders such as bioenergy refineries, companies and end consumers for bioenergy production on degraded land, even though these stakeholders would also play vital roles in establishing a bottom-up approach to bioenergy production. Third, while the study focused only on *nyamplung*, other potential bioenergy species in Indonesia include *Pongamia pinnata* (*malapari*), *Reutalis trisperma* (Blanco), Air Shaw (*kemiri sunan*) and *Calliandra calothyrsus* Meissner (calliandra) (Borchard et al. 2017), and 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, whereas landowners in other areas with different socioeconomic and sociocultural conditions might hold different perceptions towards bioenergy production. Fifth, this study analyses only one type of degraded land; burned farmland, whereas landowner preferences for restoration species might differ for other types of degraded and/or abandoned land. These limitations indicate the need for future studies on a variety of factors with the potential to affect landowner preferences, on the preferences and interests of different stakeholder groups, on different bioenergy species and regimes in Indonesia, and on different types of degraded lands.

4.6 Conclusions

This study examined landowner perceptions towards 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 analysed responses from 150 owners of land degraded by fire in Buntoi Village. Results showed that most landowners (76%) preferred conventional species – *sengon* and rubber – for restoration of their degraded lands, while only a few (8%) preferred *nyamplung* for bioenergy production. Those opting for bioenergy production were characterized by their 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 through agricultural extension. Our results contribute empirically to identifying three key conditions for a bottom-up approach to bioenergy production on 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. Further studies are required to test the feasibility of such an approach, including testing a variety of factors with the potential to affect landowner preferences, the interests of different stakeholders, diverse bioenergy species, and different types of degraded lands in Indonesia.

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