A Sustainable Way of Agricultural Livelihood: Edible Bird's Nests in Indonesia

Yutaka Ito
Akita University: Akita Daigaku
Yuki Yamamoto (y-yamamoto@nagasaki-u.ac.jp)
Nagasaki Daigaku https://orcid.org/0000-0002-6222-4566
Aswin Usup
Palangkaraya University: Universitas Paramadina
ken'ichi Matsumoto
Nagasaki University: Nagasaki Daigaku

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A sustainable way of agricultural livelihood: Edible bird's nests in Indonesia

Yutaka Ito [1], Yuki Yamamoto [2,]*, Aswin Usup [3], and Ken'ichi Matsumoto [2]

[1] Graduate School of International Resource Sciences, Akita University, 1-1 Tegatagakuen-machi, Akita, 010-8502, Japan; utaka.ito@gipc.akita-u.ac.jp
2 Graduate School of Fisheries and Environmental Sciences, Nagasaki University, 1-14 Bunkyo-machi, Nagasaki, 852-8521, Japan; y-yamamoto@nagasaki-u.ac.jp; kenichimatsu@nagasaki-u.ac.jp (K.M.)
3 Faculty of Agriculture, University of Palangka Raya, 74874 Jl. Yos Sudarso, Kota Palangka Raya, Kecamatan Jekan Raya, Central Kalimantan; aswin@agr.upr.ac.id
* Correspondence: y-yamamoto@nagasaki-u.ac.jp

Abstract: Edible bird's nests (EBNs) have been traditionally produced in Southeast Asia and consumed in China. Indonesian farmers construct buildings for swiftlet birds and harvest their nests. Farming EBNs does not directly degrade forest resources and is therefore considered as a sustainable farming product, while the expansion of other agricultural activities often relies on the degradation of natural resources. This study examines how natural resources and agricultural livelihood are associated, focusing on Indonesian EBN farmers. Using our survey data combined with satellite information on the forest extent of Central Kalimantan, Indonesia, we measure production efficiency and identify the natural and social factors that enhance production performance. The results show that natural factors, such as forest extent and the existence of ponds, are positively associated with the production efficiency of EBNs. These natural resources could help swiftlets in collecting food and building nests. On the contrary, while farming EBNs is a sustainable and profitable option, the initial costs necessary for constructing a building to house the swiftlets may negatively impact farmers' participation in the process.

Keywords: Edible bird's nest; Swiftlet; Indonesia; Forest; Natural habitat; Ecosystem services; Satellite data

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1. Introduction

Edible bird's nests (EBNs) are created by some swiftlet species and harvested by farmers for home consumption such as food and medicine. *Aerodramus fuciphagus* (white-nest swiftlet) and *Aerodramus maximus* (black-nest swiftlet) species are the species producing EBNs in Southeast Asia (Hao et al., 2015; Chua and Zukefli, 2016). The nests are produced in Indonesia, Malaysia, Vietnam, as well as in China.[1] This natural product has been used as a luxury ingredient, traditional medicine, and most often as bird's nest soup, particularly in China, for more than 400 years. (Hobbs, 2004). EBNs are one of the most valuable animal by-products (Marcone, 2005), and its market value is around USD 1,000–10,000/kg depending on its grade, shape, type, and origin (Hao and Rahman, 2016).

Male swiftlet birds build most EBNs over 35 days during the breeding season. Traditionally, the nests were harvested from caves, particularly the enormous limestone caves at Gomantong and Niah in Borneo. With the increase in demand for EBNs since the late-1990s, these sources have been replaced by purposely-built nesting houses, which are usually reinforced concrete structures (House Of Bird's Nest, 2020). These nesting houses are typically found in urban areas near the sea because the birds tend to flock in such places.[2] The EBN production industry has been expanding, which is evident in such places as the province of North Sumatra or the Pak Phanang District in Thailand. The nests are mostly exported from those places to the markets in Hong Kong, which is the center of the world trade of EBNs. Annual EBN sales in Hong Kong are valued at approximately HKD 2 billion (An economic nesting ground, 2020), although most of the final consumers are

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[1] Three main genera (*Aerodramus, Hydrochous,* and *Collocalia*) consist of 26 species of swiftlets have been observed in Southeast Asia. For more detailed information on swiftlet species recorded in Southeast Asia, see https://avibase.bsc-eoc.org/checklist.jsp?region=SEA

[2] This study focuses on rural areas Pulang Pisau district. There, farmers construct buildings to collect EBNs by letting swiftlet birds build the nests in the buildings. The buildings are shown in Section 2.2.

in mainland China. China is the world's largest consumer of EBNs, accounting for more than 90% of their consumption (An economic nesting ground, 2020). According to Peluso (1992), the extraction of non-timber forest products in East Kalimantan has an important role of providing a means of livelihood for rainforest dwelling people and the regional economy. Many forest products were collected for their use value or for local trade and were integrated into the broad regional exchange networks. In terms of EBN, Mardiastuti (2011) summarized that the history of swiftlet farming started in East Java in 1880. The practice of swiftlet farming in Indonesia can be categorized into three periods: the first period, in the 1900s to 1950s, when farmers rely on chance and good luck; the second period, in the 1950s to 1990s, in which individual farmers and house owners developed some management methods that they had kept secret from each other; and the third period, in the 1990s to the present, now with existing EBN management methods that are more intensive and open among house owners.

Throughout those periods, Indonesia become the largest bird's nest producer in Southeast Asia, exporting around 2,000 t/year, followed by Malaysia at 600 t/year, and Thailand at 400 t/year (An economic nesting ground, 2020). Estimates suggest that the EBN industry accounts for 0.5 percent of the Indonesian Gross Domestic Product (GDP), equivalent to about a quarter of the country's fishing industry. In Thailand, the trade value of EBNs, including both natural and farmed ones, is estimated at around THB 10 billion per year (An economic nesting ground, 2020). Globally, the industry scale is estimated at around USD 5 billion (Vietnam Seeks Millions for Edible Bird Spit Industry - Bloomberg, 2013). Hong Kong and the United States are the largest importers of the nests.

This paper examines the association between natural resources and agricultural livelihood, focusing on Indonesian EBN farmers. While there is ecological evidence that natural resources provide habitats for insects that swiftlets feed on, there is no evidence that quantifies the effects of natural resources on EBN production. Using our survey data combined with satellite information on forest extent in Central Kalimantan, Indonesia, we measure production efficiency and then identify the natural and social factors that enhance production performance. The results show that natural factors, such as forest extent and the existence of ponds, are positively associated with the production efficiency of EBNs.

This study is the first attempt to investigate the relationship between EBN production efficiency and natural resources and social factors. Most of the previous studies on EBNs were in multiple fields of natural sciences, including genetics (Jamalluddin et al., 2019; Guo et al., 2017; Lee et al., 2017; Quek et al., 2018), ecology (Phach and Voisin, 1998; Hobbs, 2004; Marcone, 2005; Fullard et al., 2010; Connolly, 2017; Quek et al., 2018), chemistry (Lee et al., 2017; Jamalluddin et al., 2019), pharmaceutical sciences (Haghni et al., 2016) and nutrition sciences (Guo et al., 2017).[3] As swiftlets can repeatedly create EBNs with their sputum without harm, EBN farming can be a sustainable agribusiness for rural farmers.[4] However, researchers have paid little attention to the effects of natural resources such as forest extent around the nests and social factors such as farmers' characteristics and the material of the buildings built for farming, on EBN production. An evaluation of the impact of natural resources and social factors on EBN production is essential for three reasons.

First, quantifying the positive effect of natural resources (such as forests) on agricultural production helps to enhance forest conservation. Generally, forest conservation tends to be considered as an opportunity cost for

[3] While Indonesia is a major producer of EBNs, the increasing global demand for nests leads to the issues on food fraud such as fraudulent production of countries and constituents around the world. Therefore, scientists developed various techniques based on genetics, immunochemistry, spectroscopy, and chromatography to identify origins and ingredients of EBNs (Jamalluddin et al., 2019; Lee et al., 2017). For example, Quek et al. (2018) successfully developed the sequencing technology used to identify the origins of raw and commercial EBNs. Similarly, Guo et al., (2017) identified the geographical origin of EBNs by using protein band data. Connolly (2017) investigated the recent EBN farming phenomenon by conducting walking interviews in urban areas in Malaysia. The author explored how residents perceived this burgeoning industry, and how they deemed the practice appropriate within the political, economic, and cultural landscape of the city.

[4] The recent increase in demand for EBN production has led to several emerging concerns about farming EBNs, such as the decline in swiftlet population (Sankaran, 2001), and birds making loud crying noises (Awang et al., 2015). Awang et al. (2015) also suggested that the construction of concrete swiftlet houses in urban areas, in place of conventional types, has negatively affected the built environment's authenticity as traditional building materials and techniques were replaced.

agricultural extension.[5] For example, in recent decades, deforestation has been at least partly attributed to the expansion of oil palm plantations and selective logging in Indonesia (Austin et al., 2019; Matangaran et al., 2019). Therefore, examining the potential existence of a positive effect from natural resources on agricultural production can contribute to the forest conservation policy in the context of sustainable development in rural areas. Specifically, if the forest extent could boost the EBN production, forest conservation thus increases regional economic development. This economic value of forest ecosystems might be a substitute for agricultural revenue and help mitigate the expansion of agriculture in forest land.

Second, improving farmers' income potential is vital for poverty alleviation in developing nations such as Indonesia. The majority of the poor population settle in rural areas and engage in agricultural activities. Farmers can easily collect EBNs, yet there remains the problem of the lack of access to the initial investment necessary to begin operations. In Indonesia, the agricultural sector plays a significant role, employing 70% of the labor force in rural areas (McCulloch et al., 2011). Therefore, improving efficiency in agricultural production using actual data from rural farmers is an important contribution to the context of rural development and poverty alleviation.

Third, this study based its empirical results on the original EBN production data collected by our field survey. While the importance of EBN exports is increasing, its socioeconomic effects on farmers have not been documented. The analysis in this paper helps elucidate how EBN collection contributes to farmers' income and is essential information for policymakers to utilize when planning sustainable development projects in the rural areas of developing countries.

2. Research design

We adopted a two-stage approach to investigate the effect of social and natural resource factors on the efficiency of edible bird nest products. In this section, we first describe our data envelopment analysis (DEA) to measure the performance of EBN production based on productive efficiency in Central Kalimantan, Indonesia. The efficiency scores were then regressed by social and natural resource factors to investigate associations between the factors.

2.1. Data Envelopment Analysis to Measure EBNs Production Performance

We employed output-oriented DEA to assess EBN production efficiency. DEA has been used as a tool for measuring and evaluating performance in various fields of science (Cooper et al., 2011). The main advantage of DEA is that it does not require any prior assumptions about the underlying functional relationships between inputs and outputs (Seiford and Thrall, 1990). Output-oriented DEA measures the productivity efficiency of the decision-making unit (DMU) as the relative distance to possible production frontier to the output expansion. Each DMU has several inputs and outputs. Inputs represent the resource consumption and monetary investment levels of each DMU. The outputs represent effects on DMUs. The relative efficiency of DMUs can also be calculated. The DMU ranges from 0 to 1 and DMUs are higher when the evaluated object is relatively efficient. The efficiency of k-th DMU can be defined as the maximum value of D_i in the following linear problem:

$$
\begin{aligned}
&\max D_k \\
s.t.\ &\sum_{k=1}^{K} \lambda_k y_{ik} \geq D_k y_{ik} \\
&\sum_{k=1}^{K} \lambda_k x_{jk} \leq x_{jk} \\
&\lambda_k \geq 0 \\
&\textstyle\sum_{k=1}^{K} \lambda_k = 1,
\end{aligned}
\tag{1}
$$

[5] To prevent the conversion from forest land to agricultural land, farmers must need to give up the expected revenue from the land. This foregone revenue is considered as an opportunity cost of forest conservation. On the other hand, recent studies found that forest ecosystems positively affect rural livelihood (Costanza et al., 2014; Ickowitz et al., 2014; Yamamoto et al., 2019). These findings could help mitigate the opportunity costs of forest conservation.

Where D_k denotes the efficiency score of k-th DMU, λ_k denotes the weight for k-th DMU, y_{ik} denotes i-th output for k-th DMU, and x_{jk} denotes j-th input for k-th DMU. When evaluating the k-th DMU, the relative efficiency is set as the objective function with constraints to other DMUs efficiencies. The last line in Equation (1) indicates the assumption of a variable return to scale (VRS) of production. This model employs the ratio of the VRS efficiency to obtain scale efficiency. Our DMU is at the building level. Building owners made various decisions regarding the inputs for EBN production. In our analysis, we set two inputs in each building to calculate the efficiency. The inputs are construction cost and the dimensions of the building, whereas the output is the yearly production of EBNs.

2.2. Natural Resources and Social Factors

In this subsection, we explain how the DEA approach calculates the social and natural resource factors associated with the efficiency scores. Since the obtained efficiency scores take between 0 (lowest) and 1 (highest), we employ a Tobit regression model for the estimation:

$$\widetilde{ES_i} = \beta' X_i + \epsilon_i$$
$$ES_i = \begin{cases} 1 & \text{if } \widetilde{ES_i} \geq 1 \\ \widetilde{ES_i} & \text{if } \widetilde{ES_i} < 1, \end{cases} \tag{2}$$

where ES_i is the latent dependent variable for building i, X_i is the vector of independent variables, including the social and natural resource factors, and $\widetilde{ES_i}$ is the observed efficiency score obtained from the DEA. The model can be estimated by the maximum likelihood method.

2.3. Data

The data on EBNs and social factors for the analyses were obtained through a field survey conducted in December 2016 in five villages in the Pulang Pisau district, Central Kalimantan province, Indonesia (Figure 1).[6] The district is bordered by the Katingan district in the West, Kapuas district in the East, Gunung Mas district in the North, and the Java Sea in the South. The district's tropical climate is characterized by high relative humidity (75–87.4%) and a temperature range of 20 °C to 35.8 °C. Almost 30% of the total land area is covered by peat swamp forests. The ecosystem's carbon storage potential and rich biodiversity makes it the most important land cover type for conservation in the district. The typical land use pattern in the district is oil palm plantations and farmland, each covering almost 10% of the district area.

The Government of Indonesia implemented the *Mega Rice Project* between 1996 and 2000 to increase national rice production, which encouraged migration of people from other islands; however, the project had failed. After the project was abandoned, EBNs have been harvested as an alternative source of income in the Pulang Pisau district (Jagau et al., 2008). The situation allows us to investigate how EBNs are sustainable and are related to farmers' livelihood. We randomly chose 50 EBN buildings and conducted face-to-face interviews with their owners in Central Kalimantan in January 2017. In the interviews, we asked the owners for information on the quantity of EBNs they harvested in the previous year, the type of the building, the harvesting technique, and their demographic characteristics.[7]

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[6] The survey was conducted in a joint program between the local institute, The Centre for International Cooperation in the Sustainable Management of Tropical Peatland at the University of Palangka Raya, and Nippon Koei to understand the socioeconomic situation of rural farmers in the Pulang Pisau district in accordance with the local regulations. They hired and trained five investigators from the University of Palangkaraya to conduct the training. They were able to communicate with farmers using Indonesian and Dayak languages.

[7] While this study focuses on the quantitative association between EBN and natural resources, qualitative information such as the background of farmers' settlements and forest management methods is also important in determining their use of natural resources and assessing their livelihood.

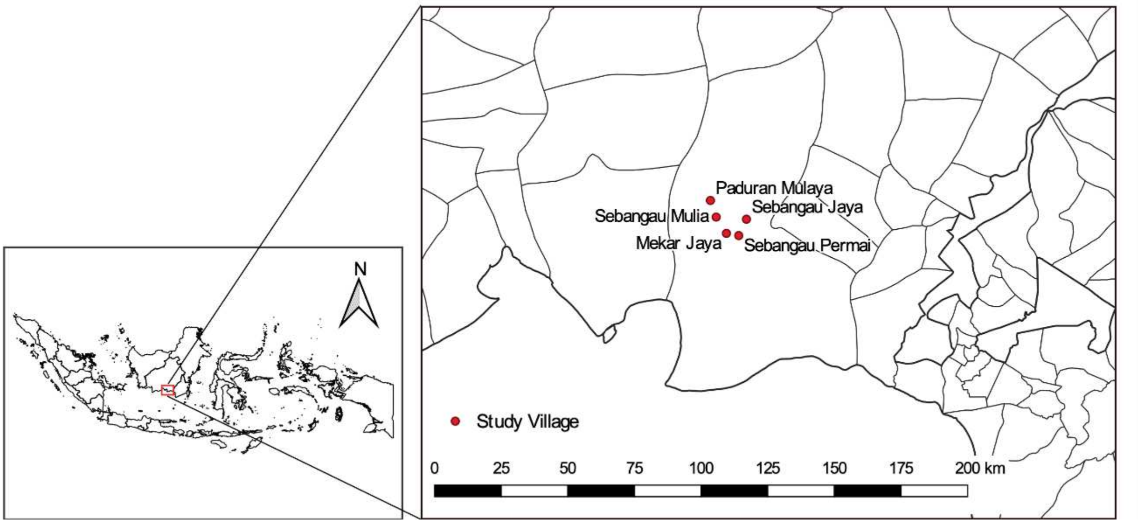

Figure 1. Study sites: Pulang Pisau district, Central Kalimantan province.

Table 1 summarizes the descriptive statistics of our sample. The total number of observations is 50 building farmers. The variables of outcome considered in this study are the annual harvest from each building. The variables affecting the efficiency of products include natural resource factors such as forest areas and ponds, and social factors such as construction materials, number of windows, maintenance costs, and pesticides used by farmers.

Table 1. Descriptive statistics of the samples.

Variables	Mean	S.D.	Min.	Max.
Price of production per kg (/1000 Rupiah)	7,794	660.7	6,000	9,800
Annual harvest (kg)	13.94	13.26	0.20	60.0
Construction cost (/1000 Rupiah)	104,400	669,49.87	20,000	400,000
Dimension (m^3)	458.604	255.768	36	1500
Debt	0.660	0.479	0	1
Forest area within 5000m radius	104.8	7.272	83.10	112.3
Pond	0.400	0.495	0	1
Concrete material	0.480	0.505	0	1
One window	0.073	0.260	0	1
Two windows	0.121	0.327	0	1
Three windows	0.008	0.090	0	1
Construction year	4.680	2.684	1	14
Annual maintenance cost (/1000 Rupiah)	1,971	1,957	0	10,000
Pesticide	0.520	0.505	0	1
Spray smell	0.940	0.240	0	1
Tape recorder	0.780	0.418	0	1
Rubber cultivation	0.200	0.404	0	1
Rice cultivation	0.220	0.418	0	1
Male owner	0.860	0.351	0	1

The natural resource factors we considered included forest cover extent and the existence of ponds surrounding the nesting area. Forest data was obtained from satellite observations provided by Hansen et al. (2013); the portion of forest cover area was calculated within a radius of 5,000 meters.[8] This dataset is publicly open and available online.[9] The data are a compilation of records on the global forest extent at the spatial resolution of 30 meters obtained from multi-spectral satellite images. Similarly, the variable *pond* is a dummy variable that takes the value of one when there is a pond in the EBN production area and zero otherwise[10]. A total of 40% of farmers have a pond near their buildings, and 24 out of 50 buildings (48% of total sampling buildings) were made from concrete materials. In Kalimantan, there are two types of buildings, either made from concrete or wood. Figure 2 shows examples. The concrete buildings tend to be taller than the wooden buildings. However, concrete buildings cost more to build than wood buildings. It might be valuable to shed light on whether the construction material affects rural welfare productivity. The annual harvest is the sum of the monthly harvests from December 2015 to November 2016.

The variable *construction year* represents the average age of buildings, the data shows that 4.68 years has passed since the building was established. A total of 43 out of 50 building owners (86%) were male, and 10 (20%) and 11 (22%) of them engage in rubber and rice cultivations as their sources of income. We investigate whether the gender of the owner and alternative agricultural activities affect the performance of EBN production.

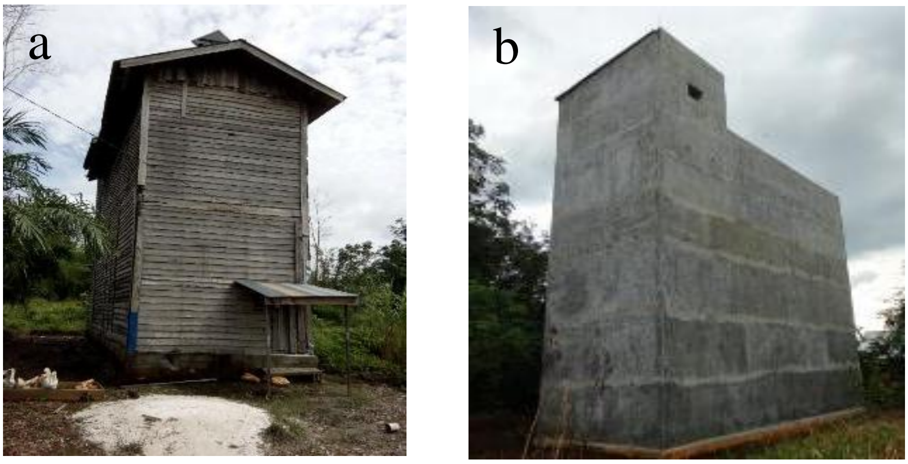

Figure 2. Photos of EBN buildings constructed of wood (a) and of concrete (b).

3. Results

3.1. Descriptive Analysis of the Farming Revenue from EBN

Table 1 reports the data on production and selling price of EBNs reported by the farmers. The average annual revenue from EBN farming, roughly calculated by multiplying annual production 14 (kg) with selling price 7,794,000 (Indonesian rupiah (IRP) / kg), was IRP 109 million (USD 7,638)[11]. This revenue is more than two times larger than the average agricultural revenue in Central Kalimantan, which is USD 3,476.5 (Yamamoto and Takeuchi, 2012).[12] Thus, EBN farming is profitable, so it attracts farmers in rural areas.

However, two problems relating to entry costs and stable production remain. The initial cost for constructing a building is IRP 104 million, which is financially infeasible for many ordinary farmers in Indonesia. In our sample, 33 out of 50 (66%) building owners have borrowed money to construct their buildings. The high initial cost for farming EBNs is a barrier for farmers to start EBN harvesting, and affected the growth

[8] Forest cover map around study area is presented in Figure A1.
[9] https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html
[10] We assume that ponds can play a similar role with forests because both these natural resources provide habitats for various living organisms including insects as a food for swiftlets and materials used for the EBNs.
[11] Indonesian Rupiah (IDR) 10,000 equal to USD 0.07
[12] Yamamoto and Takeuchi, (2012) estimated the average income of rice and rubber farmers in Central Kalimantan.

of the EBN farming industry. In addition, generally, farmers have several partners who invest jointly in the construction of the buildings. In these cases, farmers do not receive all the profit, but they share the profit.

In addition, 10 out of 50 (20%) building owners reported that their total production was less than 3 kg for the period from December 2015 to November 2016. This low production implies that farmers may receive minimal income or zero income in several months. For the farmers who rely on their income from agriculture, lower production degrades their living standards. Therefore, the unstable production outcomes also discourage farmers from participating in EBN farming. Productivity and stability issues should be addressed to make EBN farming a more viable and sustainable livelihood method.

3.2. DEA Efficiency Scores for EBN Production

We measured the EBN production efficiency in terms of the actual building production relative to other building production. As previous studies suggested, the EBN production efficiency is associated with the existence of natural resources. Figure 3 shows the results of the output-oriented DEA scores. The estimated mean and standard deviation of the DEA scores are 0.381 and 0.316. The results indicate that many buildings have a lower EBN production efficiency, while 5 out of 50 DMUs are 100% efficient. The inefficiencies scores under 0.5 account for 72% of our sample. However, this inefficiency measure does not control for the characteristics of the buildings, such as construction material and natural factors such as forest extent around buildings.

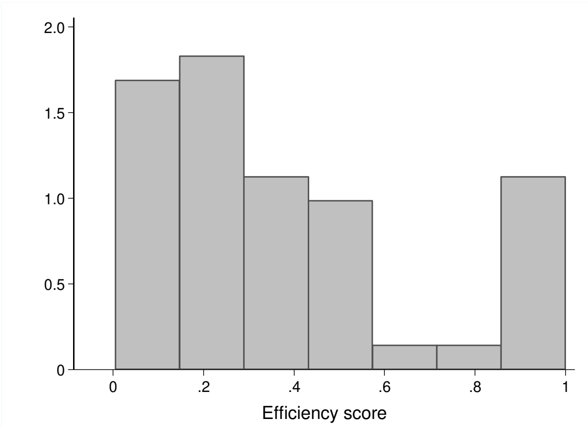

Figure 3. Histogram of efficiency score

3.3. Effects of Natural Resources and Social Factors on EBN Production

As mentioned in section 3.2, we employed a Tobit regression to the output-oriented efficiency scores shown in section 3.2. The results of the Tobit regression are shown in Table 2. In Column (1), we explored the relationship between efficiency and forest extent without controlling for inputs and farmers' characteristics. We then included the building's characteristics in Column (2), farmer's characteristics in Column (3), farmer's other agricultural production in Column (4). Both natural resource factors, i.e., forest extent and the existence of ponds, showed that there were significant positive coefficients on the efficiency score of EBN production in every model specifications.

Among the social factors, the number of gates and concrete materials for the building has a positive effect on the efficiency score. These results indicate that the building's construction material and structure are positively associated with production efficiency. Specifically, buildings constructed with concrete materials increase the efficiency score by 0.242 in Column (3).

We include the characteristics of farmers such as their main production outputs (rice and rubber) and gender. Column (4) reports the result and indicate that there are no significant associations between the characteristics of farmers and the efficiency scores.

Table 2. Results of Tobit regression.

	(1)	(2)	(3)	(4)
Forest area	0.059*	0.053*	0.051*	0.047*
within 5000m radius	(0.033)	(0.028)	(0.029)	(0.028)
Pond		0.302**	0.342**	0.382**
		(0.140)	(0.145)	(0.169)
Concrete material		0.231*	0.242*	0.251
		(0.124)	(0.141)	(0.150)
Two windows		0.183	0.168	0.158
		(0.154)	(0.162)	(0.166)
Three windows		-0.183	-0.210	-0.241
		(0.221)	(0.219)	(0.254)
Construction year		-0.010	-0.008	-0.008
		(0.051)	(0.051)	(0.056)
Construction year squared		0.003	0.003	0.003
		(0.004)	(0.004)	(0.005)
ln(maintain cost)		-0.001	-0.001	0.001
		(0.009)	(0.009)	(0.011)
Pesticide			-0.240	-0.241
			(0.254)	(0.240)
Spray smell			-0.191	-0.186
			(0.196)	(0.168)
Tape recorder			-0.181	-0.180
			(0.242)	(0.223)
Rice farmer				0.029
				(0.161)
Rubber farmer				-0.035
				(0.123)
Male owner				-0.067
				(0.143)
Constant	-6.081*	-5.780*	-5.105	-4.707
	(3.591)	(3.001)	(3.306)	(3.155)
Observation	50	50	50	50
Pseud R-squared	0.164	0.452	0.467	0.475
Log-likelihood	-18.816	-12.324	-12.008	-11.816

Note: (1) The dependent variable is the efficiency score.
(2) Robust standard errors in parentheses.
(3) All estimates include village dummies.
(4) * p < .1, ** p < .05, *** p < .01

4. Discussion

Our estimation results reported in Table 2 indicate that forest extent and the existence of ponds around buildings improve EBN production efficiency. This efficiency increase might be attributed to the fact that natural resources, including forests and ponds, provide nest material and food for the swiftlets (Quang et al., 2002; Tylianakis et al., 2005; Petkliang et al., 2017). The swiftlets nesting in areas near forests, such as the Homoptera, can catch a larger amount of food compared to urban and rural areas (Lourie and Tompkins, 2008). This is consistent with considerable ecological evidence that the forest plays a vital role as they are natural habitats for living organisms. For example, data on butterfly diversity shows that the biodiversity in a primary forest is estimated to be five times higher than other landscapes, such as plantations (Koh et al., 2011; Koh and Wilcove, 2008). In addition, *A. fuciphaga* prefers forests and wetlands rather than dry lands (Fullard et al., 2010; Phach and Voisin, 1998).

Regarding construction materials used, the use of concrete is positively associated with the efficiency score. This increase might be attributed to the swiftlet's (*A. fuciphaga*) traditional behavior of nest building in caves. They prefer caves with high humidity and low temperature (Phach and Voisin, 1998). Using concrete in construction might help with maintaining humidity and lower temperatures vs. the outside environment. In addition, concrete buildings can save on construction costs, improving efficiency in terms of the input of construction costs.

The gender of the owner and alternative agricultural income sources are both insignificant in Column (4). If the farmers engage in other agriculture, there might be a possibility that labor inputs for EBN production decrease. However, the performance of EBN production was not associated with engagement in other agricultural activities and the gender of the owner. This implies that the labor intensity of EBN production is not high and there is the potential that farmers could engage in EBN production as an alternative income source, regardless of gender and farming conditions.

Our results indicate that forest ecosystem services could benefit farmers through the increase of EBN productivity. This might affect farmers' forest conservation behavior. Some previous studies found that farmers provide more effort to forest protection when the perceived monetary value of forests becomes higher, by using the statistical approach (Bowman et al., 2008; Yamamoto et al., 2020).

5. Conclusions

This study investigates how natural resources and social factors influence the efficiency of EBN production. Our sample shows that on average, the EBN farming revenue is 109 million Indonesian rupiahs. Although a co-investor or owner would share the amount, the income might be beneficial for rural farmers. However, the initial construction costs and production stability must be considered for sustainable development.

We found that the presence of nearby forests and ponds increased EBN production efficiency. Our findings have important implications for the expansion of sustainable policies in developing countries. Improving the production of EBNs can contribute to the increase in farmers' income as well as improved natural resource management in rural areas. In many developing countries, natural resource conservation and rural development is mutually exclusive, such as in the context of with forest conservation and agricultural extension. However, our findings show that EBN production makes natural resource conservation and regional development possible. Because our results show that forest cover area has a positive impact on EBN productivity, spreading an efficient management of EBN could promote forest conservation efforts by residents because they recognize it would be a beneficial for them. In that case, it could be necessary to introduce a mechanism to secure stable income or opportunities, such as trainings, to increase productivity.

Finally, several limitations to this study should be mentioned. First, natural resource variables used in the Tobit estimation might be correlated with the efficiency score calculated in the first stage. In other words, several unobserved variables to control for EBN production are excluded from our estimates due to limitations on the data. For example, we omitted regional economic circumstances. Building costs and forest extent might be simultaneously associated with the condition of the regional economy. Unfortunately, information on the village economy is not available. Second, we cannot clearly identify the mechanism between EBN production and natural resources. Although there is considerable ecological evidence on forests and natural habitats, we cannot examine the detailed effect of natural resources on Indonesian swiftlets. Future studies should attempt to address these issues.

Author Contributions: Yuki Yamamoto conceptualized the study; Aswin Usup and Yuki Yamamoto designed the survey and performed the data collection; Yutaka Ito and Yuki Yamamoto analyzed the data; Yutaka Ito, Ken'ichi Matsumoto, and Yuki Yamamoto wrote the manuscript.

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References

Austin, K.G., Schwantes, A., Gu, Y., Kasibhatla, P.S., 2019. What causes deforestation in Indonesia? Environ. Res. Lett. 14, 24007. doi:10.1088/1748-9326/aaf6db

Awang, K.W., Hassan, M., Abdullah, A.R., 2015. Tourism landscape: understanding the swiftlet "Hotel" phenomenon. Sains Humanika 2, 51–56.

Bowman, M.S., Amacher, G.S., Merry, F.D., 2008. Fire use and prevention by traditional households in the Brazilian Amazon. Ecol. Econ. 67, 117–130. doi:10.1016/j.ecolecon.2007.12.003

Chua, L.S., Zukefli, S.N., 2016. A comprehensive review of edible bird nests and swiftlet farming. J. Integr. Med. 14, 415–428. doi:10.1016/S2095-4964(16)60282-0

Connolly, C., 2017. Landscape political ecologies of urban 'swiftlet farming' in George Town, Malaysia. Cult. Geogr. 24, 421–439. doi:10.1177/1474474016684128

Cooper, W.W., Seiford, L.M., Zhu, J. 2011. Handbook on data envelopment analysis. Springer Science & Business Media.

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., Turner, R.K., 2014. Changes in the global value of ecosystem services. Glob. Environ. Chang. 26, 152–158. doi:10.1016/j.gloenvcha.2014.04.002

Fullard, J.H., Barclay, R.M.R., Thomas, D.W., 2010. Observations on the behavioural ecology of the Atiu Swiftlet Aerodramus sawtelli. Bird Conserv. Int. 20, 385–391. doi:10.1017/S095927091000016X

Guo, L., Wu, Y., Liu, M., Wang, B., Ge, Y., Chen, Y., 2017. Determination of edible bird's nests by FTIR and SDS-PAGE coupled with multivariate analysis. Food Control 80, 259–266. doi:10.1016/j.foodcont.2017.05.007

Hansen, M.C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G., 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342, 850–853. doi:10.1126/science.1244693

Hao, L.Q., Ideris, A., Bin Abu Bakar-Zakaria, M.Z., Bin Omar, A.R., 2015. Morphology comparison of swiftlet species from natural and man-made habitats in Malaysia. Sains Malaysiana 44, 497–502. doi:10.17576/jsm-2015-4404-03

Hao, Q., Rahman, A., 2016. Swiftlets and Edible Bird's Nest Industry in Asia. PJSRR Pertanika J. Sch. Res. Rev. 2, 32–48.

Hobbs, J.J., 2004. Problems in the harvest of edible birds' nests in Sarawak and Sabah, Malaysian Borneo. Biodivers. Conserv. 13, 2209–2226. doi:10.1023/B:BIOC.0000047905.79709.7f

House Of Bird's Nest, n.d. Hello Mcwell VIP, Friends or Customers! URL https://web.archive.org/web/20140109182511/http://houseofbirdsnest.com/uncategorized/hello-mcwell/ (accessed 1.28.20).

Ickowitz, A., Powell, B., Salim, M.A., Sunderland, T.C.H., 2014. Dietary quality and tree cover in Africa. Glob. Environ. Chang. 24, 287–294. doi:10.1016/j.gloenvcha.2013.12.001

Jagau, Y., Noor, M., Verhagen, J., 2008. Master plan for the rehabilitation and rehabilitation of the ex-mega rice project area in Central Kalimantan. (Technical Report Number 5)

Jamalluddin, N.H., Tukiran, N.A., Ahmad Fadzillah, N., Fathi, S., 2019. Overview of edible bird's nests and their contemporary issues. Food Control 104, 247–255. doi:10.1016/j.foodcont.2019.04.042

Koh, L.P., Miettinen, J., Liew, S.C., Ghazoul, J., 2011. Remotely sensed evidence of tropical peatland conversion to oil palm. Proc. Natl. Acad. Sci. 108, 5127–5132. doi:10.1073/pnas.1018776108

Koh, L.P., Wilcove, D.S., 2008. Is oil palm agriculture really destroying tropical biodiversity? Conserv. Lett. 1, 60–64. doi:10.1111/j.1755-263X.2008.00011.x

Lee, T.H., Wani, W.A., Koay, Y.S., Kavita, S., Tan, E.T.T., Shreaz, S., 2017. Recent advances in the identification and authentication methods of edible bird's nest. Food Res. Int. 100, 14–27. doi:10.1016/j.foodres.2017.07.036

Lourie, S., A., Tompkins, D., M., 2000. The diets of Malaysian swiftlets. Ibis (Lond. 1859). 142, 596–602. doi:10.1111/j.1474-919x.2000.tb04459.x

Marcone, M.F., 2005. Characterization of the edible bird's nest the "Caviar of the East." Food Res. Int. 38, 1125–1134. doi:10.1016/j.foodres.2005.02.008

Mardiastuti, A. 2011. Swiftlet farming in Indonesia: Opportunity, challenge, and sustainability. The Proceedings of the 2011 International Conference & Training on Swiftlet Ranching.

Matangaran, J.R., Putra, E.I., Diatin, I., Mujahid, M., Adlan, Q., 2019. Residual stand damage from selective logging of tropical forests: A comparative case study in central Kalimantan and West Sumatra, Indonesia. Glob. Ecol. Conserv. 19, e00688. doi:10.1016/j.gecco.2019.e00688

McCulloch, N.A., Timmer, P., Weisbrod, J., 2011. Pathways out of poverty during an economic crisis: An empirical assessment of rural Indonesia. SSRN Electron. J. 1–50. doi:10.2139/ssrn.980328

Panyaarvudh, J. 2018. An economic nesting ground [WWW Document], URL https://www.nationthailand.com/business/30356222 (accessed 1.28.20).

Peluso, N.L., 1992. The political ecology of extraction and extractive reserves in East Kalimantan, Indonesia. Dev. Change 23, 49–74.

Petkliang, N., Gale, G.A., Brunton, D.H., Bumrungsri, S., 2017. Wetland, forest, and open paddy land are the key foraging habitats for Germain's swiftlet (Aerodramus inexpectatus Germani) in southern Thailand. Trop. Conserv. Sci. 10. doi:10.1177/1940082917698467

Phach, N.Q., Voisin, J.-F., 1998. Influence of cave structure, microclimate and nest harvesting on the breeding of the White-nest Swiftlet Collocalia fuciphaga germani in Viêtnam. Ibis (Lond. 1859). 140, 257–264. doi:10.1111/j.1474-919X.1998.tb04387.x

Quang, P.N., Quang, Y.V., Voisin, J.F., 2002. The white-nest swiftlet and the black-nest swiftlet: a monograph: with special reference to Vietnamese populations. Société nouvelle des éditions Boubée.

Quek, M.C., Chin, N.L., Tan, S.W., Yusof, Y.A., Law, C.L., 2018. Molecular identification of species and production origins of edible bird's nest using FINS and SYBR green I based real-time PCR. Food Control 84, 118–127. doi:10.1016/j.foodcont.2017.07.027

Sankaran, R., 2001. The status and conservation of the Edible-nest Swiftlet (Collocalia fuciphaga) in the Andaman and Nicobar Islands. Biol. Conserv. 97, 283–294. doi:10.1016/S0006-3207(00)00124-5

Seiford, L.M., Thrall, R.M., 1990. Recent developments in DEA: The mathematical programming approach to frontier analysis. J. Econom. 46(1–2): 7–38.

Tylianakis, J.M., Klein, A. and Tscharntke, T., 2005. Spatiotemporal variation in the diversity of hymenoptera across a tropical habitat gradient. Ecology 86, 3296–3302. doi:10.1890/05-0371

Bloomberg, 2013. Vietnam seeks millions for Edible Bird Spit industry. URL https://www.bloomberg.com/news/articles/2013-08-18/vietnam-seeks-millions-for-edible-bird-spit-industry (accessed 1.28.20).

Yamamoto, Y., Ishimura, Y., Shigetomi, Y., Hattori, M., 2019. Forest change and agricultural productivity: Evidence from Indonesia. World Dev. 114, 1–14.

Yamamoto, Y., Takeuchi, K., 2012. Estimating the break-even price for forest protection in Central Kalimantan. Environ. Econ. Policy Stud. 14, 289–301. doi:10.1007/s10018-012-0030-x

Yamamoto, Y., Takeuchi, K., Köhlin, G., 2020, Preventing peatland fires in Central Kalimantan, Indonesia: The role of economic incentives and social norms, J. Forest Econ. 35. http://dx.doi.org/10.1561/112.00000509

Appendix

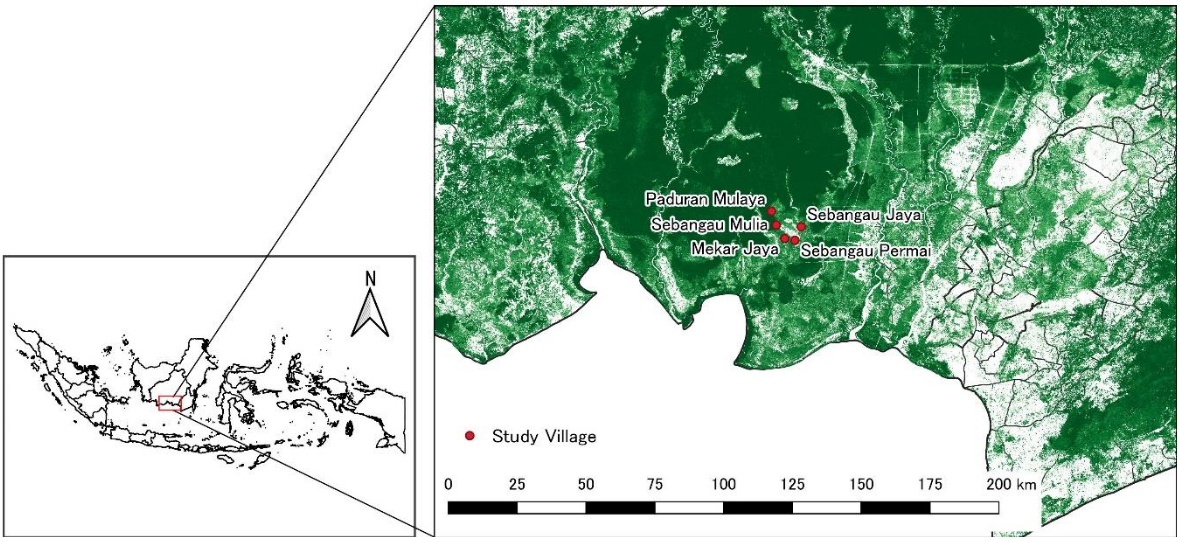

Figure A1. Forest cover map observed by remote sensing in Pulang Pisau district. *Source: Hansen et al. (2013)*

Figures

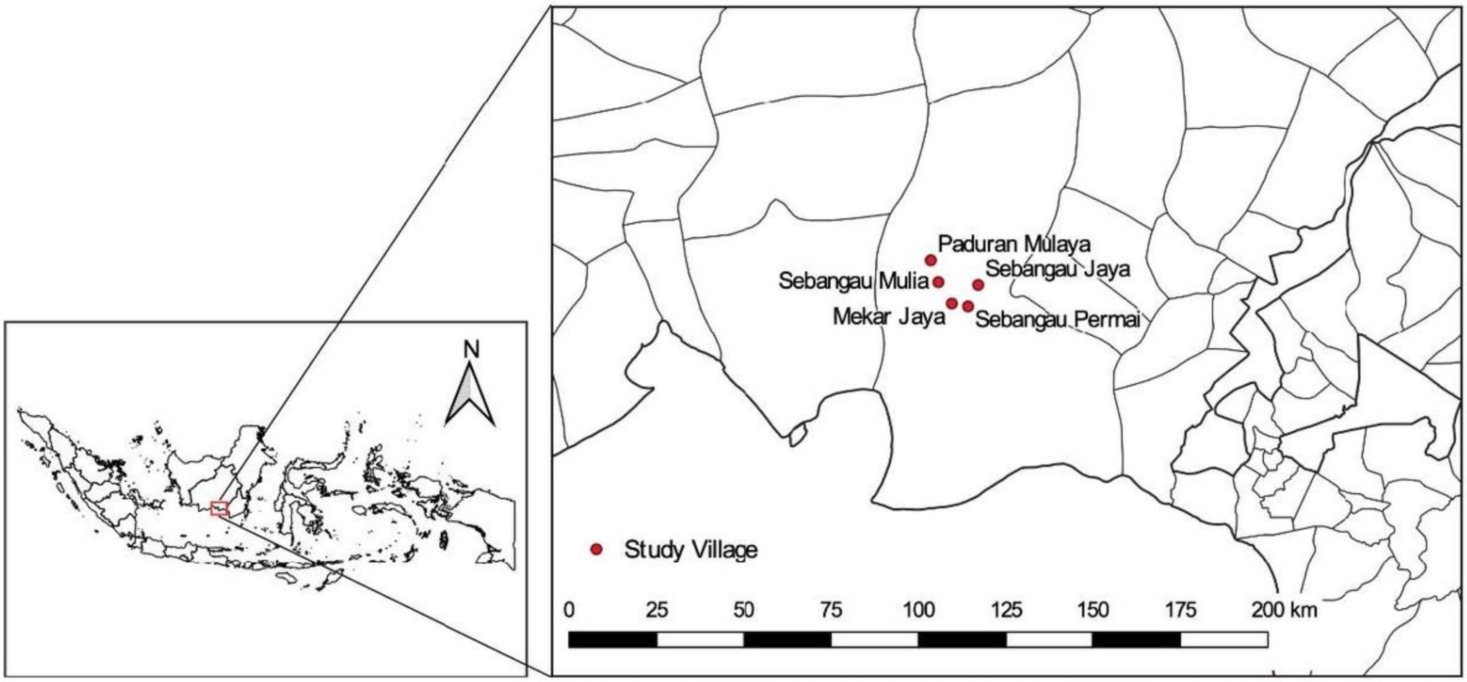

Figure 1

Study sites: Pulang Pisau district, Central Kalimantan province. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

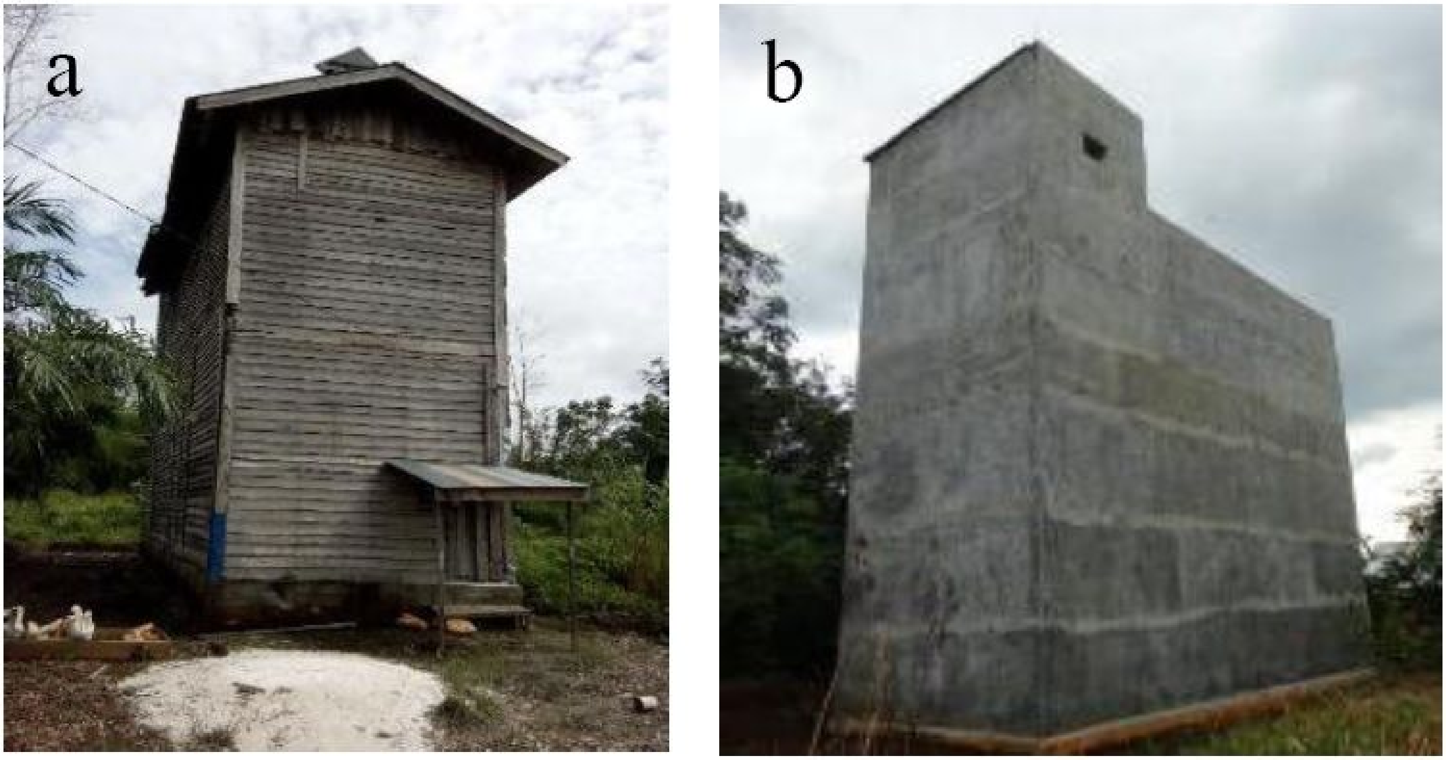

Figure 2

Photos of EBN buildings constructed of wood (a) and of concrete (b).

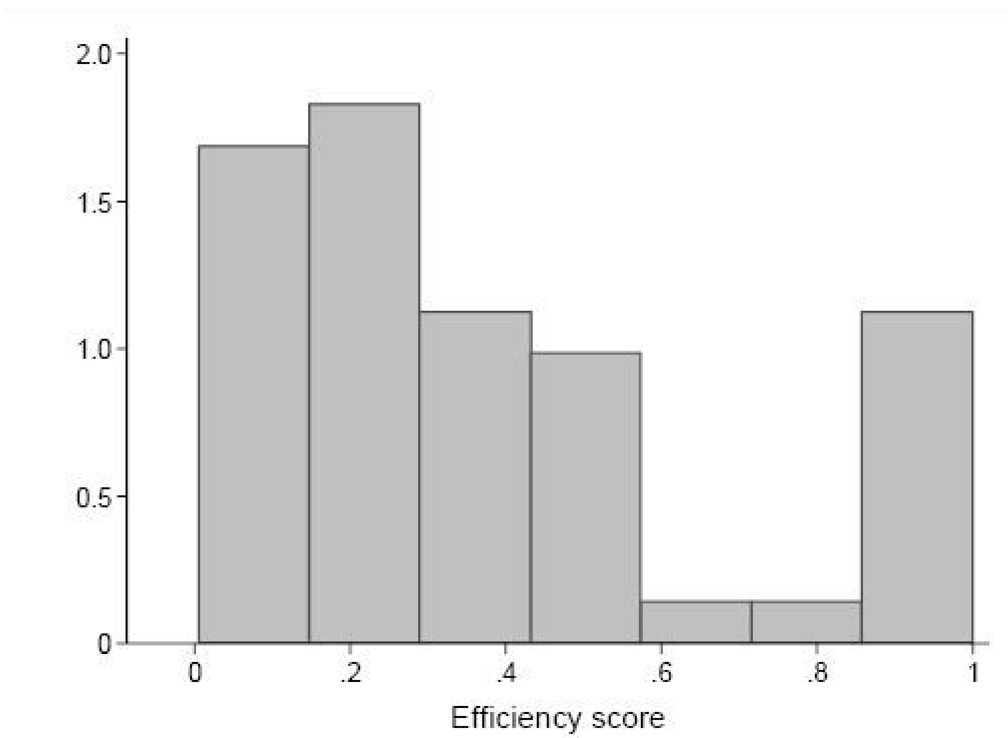

Figure 3

Histogram of efficiency score

Supplementary Files

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- FigureA1.jpg