sciendo

Folia Forestalia Polonica, Series A – Forestry, 2024, Vol. 66 (2), 72–88

METHODOLOGICAL ARTICLE

DOI: 10.2478/ffp-2024-0007

Deforestation as a catalyst for natural disaster and community suffering: A cycle in the socioecological system

Golar Golar[1] ✉, *Hasriani Muis*[1], *Isrun Isrun*[2], *Wahyu Syahputra Simorangkir*[1], *Fadhliah Fadhliah*[3], *Muhammad Nur Ali*[3], *Muhammad Basir-Cyio*[2]

[1] Tadulako University, Faculty of Forestry, Palu 94118, Central Sulawesi, Indonesia, e-mail: golar.tadulako@gmail.com

[2] Tadulako University, Faculty of Agriculture, Palu 94118, Central Sulawesi, Indonesia

[3] Tadulako University, Faculty of Social and Political Science, Palu 94118, Central Sulawesi, Indonesia

Abstract

Lore Lindu National Park (LLNP) is a conservation area that contains a lot of wood resources. Various illegal community activities have become widespread, such as illegal mining and illegal logging. So, this research aims to determine the involvement of communities around forest areas in material and wood theft from June to October 2021. To determine forest encroachment, we find explanatory variables, using qualitative description integrated with perceptual tests and Classification and Regression Tree (CART) analysis. Based on the results of the 10-fold cross-validation analysis with the smallest Rcv (x-Val relative error) value of 0.428, with a classification accuracy of 68.6%, a four-node optimum tree was obtained, which explained that as many as 86 forest encroachers were victims of a vast landslide disaster along with flood and whirlwind, due to which there was no longer any property left for them. Their encroachment affected the condition of land cover. The data on the land cover change, from 2010 to 2020, showed a reduction of 15,369.20 ha or 6.90%, which indicated a severe threat to the sustainability of LLNP as a biodiversity conservation area that should be protected. The involvement in illegal logging by communities living around the forest areas resulted from the loss of their agricultural land for their livelihoods due to natural disasters such as flood, landslide and whirlwind that destroyed infrastructure and community settlement facilities. As a result, these losses and destruction were a catalyst for forest destruction. Initially being in the frontline for preserving the forest, however, the community has now turned into silent partners with licensed wood businesspeople. The community eventually becomes a subsystem in the social ecology system (SES), which negatively affects the destruction of forest resources, production and conservation forests.

Key words

forest encroachment, illegal logging, natural disaster

Received 10 January 2023 / Accepted 26 January 2024

BY-NC-ND

© 2024 Author(s). This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Introduction

Globally, especially in Indonesia, anthropogenic activities in and near forest regions have accelerated degradation of forests (Cattau et al. 2016; Eddy et al. 2021). Ecological functions that should have been maintained to preserve natural resources, the environment and human safety are ultimately destroyed by those who care more about the wood industry than their responsibility for preserving natural resources and promoting sustainable development (Golar et al. 2021; Safe'I et al. 2022). The greed of businesspeople and big investors has created people's powerlessness in forest areas. People are forced to become victims of businesspeople who cover companies licensed to use forest products (Gerber and Haller 2021; Nandi and Sarkar 2021). Communities living around forests and along watersheds have lost their agricultural businesses due to various natural disasters (Ali et al. 2020), ranging from extreme climate change to floods and landslides (Dalagnol et al. 2022). Natural disasters occur one after another; in addition to floods, landslides and whirlwinds have devastated agricultural land, infrastructure, transportation infrastructure and lost settlements (Basir-Cyio 2021; Kiely et al. 2021).

Flash flooding is caused by surface water runoff. Unbalanced infiltration capacity and soil percolation in forested regions are responsible for the accumulation of huge water discharges (Chen J. et al. 2021; Hasyim et al. 2021). Climate change is one of the most threatening and risky factors that impact human life, especially those living around forest areas today (Dyderski et al. 2018; Golar et al. 2022; Qu et al. 2018). In the last 5 years, human involvement (anthropogenic) in accelerating forest destruction has been very prominent in Indonesia (Feng et al. 2021). The high rate of forest destruction and land degradation in the area is one factor that triggers extreme weather accompanied by high rainfall outside the rainy season and drought outside the dry season, in whichthe Meteorology, Climatology, and Geophysical Agency (Badan Metereologi dan Geofisika [BMKG]) in Indonesia feels difficult to predict (Santika et al. 2020).

Weather parameters that have been an indicator so far have experienced deviations due to extraordinary extreme conditions. Therefore, flash floods, whirlwinds and heavy rains with strong winds are not in line with disaster mitigation known to the public. Floods inundate agricultural land, which may be the only livelihood of farming communities (Hovis et al. 2021). Floods can submerge settlements up to 3 m deep for weeks and disrupt the use of houses as a gathering place for family members. The suffering felt by the affected communities is difficult to describe, but can only be felt, not only because of the loss of property and agricultural land but also due to the loss of enthusiasm for life after dealing with the reality that torments them in only a relatively short time (Clayton and Karazsia 2020); they had slowly built simple houses from agricultural produce over decades, but all were destroyed in just a few hours. The poverty they feel is not only from the physical–material aspect, but also from the psychosocial dimension, which leads to confusion and despair, and therefore, positive reasoning sometimes does not exist, except for only one: having to survive by any means, including logging into the forest (Baldassini et al. 2020; Golar et al. 2020) and stealing wood to fulfil basic family needs (Parhusip et al. 2020).

People who were previously victims of natural disasters as part of the socioecological cycle are now motivated to assist in accelerated forest destruction due to this condition (Giatti et al. 2021). The loss of their agricultural land, the difficulties of obtaining alternate forms of income and the absence of government support have shifted the community's focus from preserving forest resources to operating a licensed wood business (Mustalahti et al. 2020). The socioeconomic powerlessness of the community is exploited by timber businesspeople and owners of licensed companies to jointly commit unlawful acts using uncontrolled logging, which can be categorisedas criminal acts (Boakye 2020).

Under normal circumstances, people living around forest areas of various ethnicities have positioned themselves as the guardians of forest safety (Anugrahsari et al. 2020; Pham et al. 2020) and to supervise licensed wood businesses when logging outside the area permitted by the government (Hos et al. 2021). Over time, forest damage continues to increase, which is indicated by the decreasing land cover (Silva Junior et al. 2018); the community's motivation has changed as a silent partner for wood businesspeople (Resosudarmo et al. 2019).

Almost all forests in Indonesia have been damaged, which has caused the loss of ecological functions to become production and business functions (Maryudi 2015). Those involved in forest destruction in Indonesia, directly or indirectly, are businesspeople who seem to be protected by regulations. The government has a significant role because it issues policies that favour businesspeople compared to the safety and sustainability of natural resources, especially those in forest areas (Race et al. 2019; Yovi and Nurrochmat 2018). The negative impact currently happening is the result of these two main factors. Socially, the impact significantly weakens the spirit of community life. Economically, the community loses its source of livelihood, which causes structural poverty (Miyamoto 2020) and triggers the birth of motivations for criminal acts of forest encroachment and wood theft (Rohayu and Absori 2019).

Globally, 15%–30% of logging is estimated to be illegal (Nellemann 2012), while wood theft in developing countries accounts for over 50% of all logging (Kleinschmit et al. 2016). Even in Indonesia, more than 70% of logging is considered illegal, as is the case in other developing countries such as Bolivia, Cambodia, Ecuador, Gabon, Ghana, Laos, Liberia, Papua New Guinea, Peru and the Democratic Republic of Congo (Kleinschmit et al. 2016; Nellemann 2012). Incidents of wood theft occur in developing countries such as Indonesia and in developed countries such as USA and European countries. However, it is realised that research on wood theft is very rarely carried out in Indonesia.

The crime rate of forest destruction and wood theft increases, indicated by forest cover changes. Changes in forest cover area towards forest destruction, especially in the Lore Lindu National Park (LLNP) area from 2010 to 2020, reached 6.90% or 15,369.20 ha. This change in the area indicates a significant threat of forest destruction occurring in LLNP. Legal action is inversely proportional to the rate of forest encroachment, wood theft, and illegal mining. Very few perpetrators of theft of wood reach the judicial process because most are resolved out of court (Iqbal 2018).

This approach contributes to criminal acts of forest encroachment and wood theft. The scale of wood theft varies depending on the perpetrator (Szulecka et al. 2016). Communities that are victims of natural disasters are generally only able to reach the outskirts of the forest. However, capital owners and wood businesspeople with sophisticated and heavy equipment can reach the forest's heart in the conservation area (Crockatt 2012; Loury et al. 2021).

Wood theft in forest areas is driven by three factors: (i) perceived personal pressure, (ii) opportunities and (iii) rationalisation that the action is natural. This view is called the theft triangle (Mackevičius and Giriūnas 2013), which is described in terms of 10–80–10, which means that 10% of people will never commit theft, 80% will steal depending on the circumstances and 10% are actively involved in theft. In Indonesia, especially in the Central Sulawesi province, it is generally in the 80% category, meaning they will enter the forest and steal wood if the situation compels them. Natural disasters have changed people's motivation from protecting forest resources to being part of the wood business (Baldassini et al. 2020; Golar et al. 2020; Velo and Zafitsara 2020).

The scope of research related to forestry is usually limited to empowering communities living around forest areas, watersheds and other zones with access to forest areas. Whereas forest encroachment cannot be separated from wood theft as a series of criminal acts. The licensed wood business is the leading actor in forest destruction because the government is complicated to supervise the activities performed by wood businesspeople. This links wood businesses at the upstream level in collaboration with forest-squatting communities affected by natural disasters and wood businesses working downstream to exporters (Hughes 2018).

The interaction between society and ecology is a system that is built as a socioecological system (SES). The components built into SES consist of external subsystems, including extreme weather that can catalyse natural disasters such as heavy rains, flash floods and whirlwinds. These external factors are estimated to interact with internal factors such as the age of the community, health conditions and the number of dependent families living around the forest area and along the watershed. LLNP as a conservation area is part of an ecological system that includes the Palu and Jeneberang watersheds, whose rivers cross the provinces of Central and West Sulawesi.

Based on the background above, this research was undertaken in locations of Central and West Sulawesi to look at the external and internal factors in SES that influence the opportunities for disaster-affected communities to turn into forest encroachers who collaborated with large investors to commit criminal acts from the legal aspect, both in non-conservation and conservation areas of LLNP.

Material and methods

This research implemented two approaches to obtain comprehensive data and information in the designated study area, including Palu and Jeneberang watersheds (Fig. 1). The first approach was a survey involving Forest Management Unit (FMU), active young foresters (students and alumni of the Faculty of Forestry of Tadulako University) and forest-concerned non-governmental organisations (NGOs). The data collected from related parties were the information they already had, which was reconciled with geographical data to estimate the level of encroachment and wood theft by juxtaposing the land cover map (Fig. 1), which decreased over time. Secondly, data were collected by conducting interviews (face to face and by cellphone) with people living around the forest areas and along the Palu and Jeneberang watersheds.

In addition, government officials, who understood the ins and outs of forest management and the types of actions that could be categorised as criminals, such as forest encroachment and wood theft, were interviewed (Frimadani et al. 2020; Guisan et al. 2013). The names of companies owned by businesspeople were also collected from agencies relevant to the issuance of licences or legal letters in the use of forest products, especially the companies operating in Donggala, Sigi and Poso regencies.

The distributed questionnaires (in physical and electronic forms) were validated according to scientific principles from the methodological and statistical aspects. The number of questions in the questionnaire was 25, which contained five questions per category. The categorisations were (i) the income of the affected people who lived around the forest areas and along the Palu and Jeneberang watersheds, before and after being affected by various types of disasters; (ii) alternative work chosen after being affected by the disaster; (iii) concern for government officials; (iv) experience in logging and wood theft and (v) perception and consideration of risks in encroaching on the forest related to unlawful acts. The research sites were the regencies of Sigi, Donggala, Poso and parts of the West Sulawesi region, especially the Pasangkayu Regency.

The survey activities were preceded by Focus Group Discussion (FGD) activities from the parties on a representative basis to obtain input and primary data that supported the objectives of this research. This started in June 2021; then, in July 2021, all research teams carried out their duties according to the divisions set by the head of the research team. This whole series of activities ended in September 2021 and was followed by the data sorting phase, information reconciliation and the final FGD in October 2021.

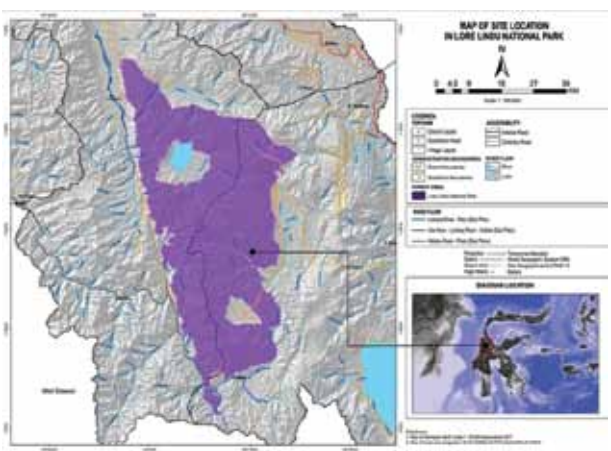

Figure 1. Map of the research implementation site, which includes the Palu and Jeneberang watersheds that are are located in the Central and West Sulawesi provinces, Indonesia

Data Collection

This research used secondary data as the initial information before collecting primary data. The secondary data were obtained from the previous research and related institutions or agencies, including the Ministry of Environment and Forestry of the Republic of Indonesia. To strengthen the secondary data, a library and repository search was carried out in the university libraries, especially of Tadulako University. The secondary data obtained were adapted and reconciled with related data, so that the resulting information

could answer and solve problems and the research objectives. The most relevant secondary data were (i) the number of companies owned by businesspeople licensed to utilise forest products, (ii) the level of forest destruction in the last 4 years, (iii) land cover change, (iv) the type and number of natural disasters that occurred in the last 4 years and (v) handling cases of criminal acts of forest encroachment and wood theft by various parties who went to court or law enforcement agencies.

The primary data were obtained through observation, interviews and questionnaires. Key informants and communities around the forest areas were the main sources (Sabariah et al. 2014). Two hundred respondents were determined to represent the entire community living around the forest area based on their ethnicity and distribution along the Palu and Jeneberang watersheds. Those who were interviewed and given the questionnaire were:

a) two forestry officials,
b) five FMU leaders,
c) 10 young foresters,
d) 10 scientists and
e) community representatives living around the forest area.

Table 1. Variables of forest damage level (Y) and explanatory/independent (X) variables in CART analysis

Response variable		
Encroachment rate by community (Y)	1	Quite severe
	2	Severe
	3	Really severe
Explanatory variable		
Number of family (people) (X_1)	1	1–3
	2	>3
Age of the head of family (years) (X_2)	1	36–45
	2	>45
Health of the head of family (X_3)	1	Supporting
	2	Not supporting
Flood (X_4)	1	Heavy
	2	Really heavy
Landslide (X_5)	1	Wide
	2	Very wide
Whirlwind (X_6)	1	Speedy
	2	Very speedy
Earthquake/liquefaction (X_7)	1	High
	2	Very high

Data Analysis

The analytical method used for secondary data was descriptive qualitative analysis (Dronkers et al. 2018) performed after the data were tabulated and reconciled. The tabulation results were then rationalised and correlated with the suitability of the research objectives (Bendtsen et al. 2021; Soler et al. 2021). In addition, some of the data were plotted into pictures to facilitate the discussion. The primary data from interviews and questionnaires were presented as frequency and percentage, including statistical tests for perceptual data.

Simple Correlation Analysis

The primary data collected from the questionnaire distributed for 200 respondents selected purposively from the people living around LLNP and along the Palu and Jeneberang watersheds were analysed by Chi-square test to find the relationship between the response variable (Y) and the explanatory variable (Xn). Alpha values <0.05 or 95% accuracy level was used to determine a significant relationship.

Descriptive Qualitative Analysis

The secondary data were obtained through literary searches and repositories in libraries and reports on the results of previous research. Both were obtained from government agencies and companies and the results of NGO studies. The data were analysed descriptively by compiling ratios and dynamics in time series–based increases and decreases. The ratios and compilations were presented in a numeric format and as frequencies and percentages, making it easier to integrate one data with the other data.

Classification and Regression Tree Analysis

Data analysis using the Classification and Regression Tree (CART) instrument was a follow-up analysis of Chi-square analysis to find the explanatory variables in stages through the pruning stages (Shabani 2017; Zuccolotto et al. 2023). The response variable in the CART

analysis was the rate of forest encroachment and wood theft (Y) by people living around the forest areas, where the explanatory variable was a natural disaster (Xn), as presented in Table 1.

Table 1 identifies the response variable Y (rate of forest encroachment) with three categories, namely, quite severe (1), severe, (2) and really severe (3), with the explanatory variable (Xn) analysed by Chi-square test to determine the relationship between the two variables (Boccia and Sarnacchiaro 2020; Shan and Gerstenberger 2017). The response variable (Y), which had a relationship with the explanatory variable (Xn), was then analysed by CART (Breiman et al. 2017) to obtain a complex maximal tree.

Furthermore, we proceeded with pruning using the partitioning rule based on the Goodness of Split criteria to evaluate the sorting performed by the sorter s at node t. Suppose there is a sorter s that divides t into a left node tL with a proportion of pL and a right node tR with a proportion of pR (Gocheva–Ilieva et al., 2022). In that case, n the Goodness of Split ϕ(s, t) is defined as the decrease in heterogeneity using Equation 1:

$$\phi(s, t) = \Delta i(s, t) = i(t) - p\_L\ i(t\_L) - p\_R\ i(t\_R) \quad (1)$$

Sorting the node t1 is carried out through expansion, so that in the end, we get sorter s*, which can produce heterogeneity values with the highest decrease in height (Eq. 2).

$$\Delta i(s^{\wedge}*, t\_1) = \max\neg(s \subset S) \square \Delta i(s, t\_1) \quad (2)$$

It is important to prune large and complex classification trees to avoid overfitting or underfitting. This can be overcome by taking these steps: (i) determination of the full complex regression tree and then carrying out iterative pruning to form smaller and nested tree sequences and (ii) the best tree is selected from this sequence using a test sample cross-validation sample, followed by determining the size of the classification tree and a proper regression by looking at the minimum cost complexity (Breiman et al., 2017). For any tree T, which is a subtree of the largest tree Tmax where T < Tmax has a cost complexity pruning measure, the resubstitution of a tree T at complexity α uses Equation 3.

$$R_\alpha(T) = R(T) + \alpha\,|\tilde{T}| \quad (3)$$

Cost complexity pruning determines the subtree that minimises Rα(T) over the entire subtree for each value of α. The value of the complexity parameter α will slowly increase during the trimming process. Furthermore, the search for the subtree T(α) < Tmax which can minimise Rα(T) is:

$$R_\alpha(T(\alpha)) = \min_{T<T\max} R_\alpha(T) \quad (4)$$

A very large regression tree gives the smallest replacement estimator value, so this tree is preferred to estimate the response value. The test sample estimator and the V-fold cross-validation estimator are two kinds of substitute estimators that can obtain the optimal classification tree (Eq. 5).

$$R^{ts}(T_t^{(v)}) = \frac{1}{N_v} \sum_{(x_n, j_n) \in L_v}^{N} X(d^{(v)}(x_n) \neq j_n) \quad (5)$$

Nv =N/V is the total observation in Lv.

The same procedure is carried out using all L, then the V-fold cross-validation estimator for Tt(v) is:

$$R^{cv}(T_t) = \frac{1}{N} \sum_{v=1}^{V} R^{ts}\left(T^{(v)}\right) \quad (6)$$

The terminal node t either becomes a terminal node or not. It will be resorted if the node t does not significantly decrease heterogeneity or n has a minimum limit, such as only one observation at each node. According to Dan (2009), the number of cases contained in a homogeneous terminal node is generally <10 cases, but the minimum number of cases should be five cases to stop the pruning process (Breiman et al. 1984).

Results and discussion

Correlation Analysis of Forest Encroachment (Y) with Natural Disaster Variables (Xn)

Forest encroachment and wood theft (Y) as response variables were affected by seven explanatory variables (Xn) of two categories:

1) internal variables, consisting of the number of family dependents (X_1), age of the head of the family (X_2) and the health condition of the head of the family (X_3) and
2) external explanatory variables such as flood (X_4), landslide (X_5), whirlwind (X_6) and earthquake (X_7).

All variables of response and explanation are described in Table 1.

The results of Chi-square analysis at the alpha level of 0.05 showed that the only internal explanatory variable was the age of the head of the family (X_2), which had a relationship with the level of forest encroachment and wood theft (Y) by people around the forest area (Yunis, 2023). The external explanatory variables consisting of flood (X_4), landslide (X_5), whirlwind (X_6) and earthquake (X_7), all had a relationship with the level of forest encroachment and wood theft (Y) at the alpha level <0.05, and (i) number of the family dependents (X_1) and (ii) the health of the head of the family (X_3) were the only internal variables that were ignored because they did not correlate with the rate of forest encroachment and wood theft (Y). The results of the Chi-square analysis are presented in Table 2. Consequently, of the seven explanatory variables, five had a relationship with the response variables of forest encroachment and wood theft (Y) by people living around the forest areas.

Table 2. Result of relationship analysis between response variable (community encroachment rate) and explanatory variables

Explanatory variables	Variable response (Y)			*P*-value
	quite severe	severe	really severe	
Number of family members				0.919
1–3 People	10	21	20	
>3 People	33	61	55	
Age of the head of the family				<0.001
36–45 years	20	14	8	
>45 years	23	68	67	
Health of the head of the family				0.517
Not supporting	7	19	19	
Supporting	36	63	56	
Flood				<0.001
Heavy	30	17	3	
Really heavy	13	65	72	
Landslide				<0.001
Wide	30	16	5	
Really wide	13	66	70	
Whirlwind				<0.001
Speedy	43	71	28	
Really speedy	0	11	47	
Earthquake/liquefaction				<0.001
High	15	62	58	
Really high	28	20	17	

Source: Result of Chi-square analysis (alpha level < 0.05)

Data in Table 2 were followed by the CART analysis as presented in Figure 2.

Analysis of CART Community Encroachment Rate (Y) with Disaster Variable (Xn)

The initial CART analysis obtained classification trees and regression of 13 nodes (Fig. 2a). To get the optimum node, the analysis was continued to the pruning stage by focusing on the minimum cost complexity value using the 10-fold cross-validation with the smallest R^{CV} (x-Val relative error) value as an impossible condition to continue pruning the classification tree and regression anymore.

Considering the smallest R^{CV} (x-Val reactive error) value from the results of pruning the classification tree and regression, the smallest optimum node was four nodes (Fig. 2b). From the optimum node, it can be seen that the topology of the classification tree and the maximum regression with 13 nodes for the response variable of forest encroachment and wood theft (Y) have changed to the topology of the classification tree and the optimum regression of four nodes (Fig. 2b).

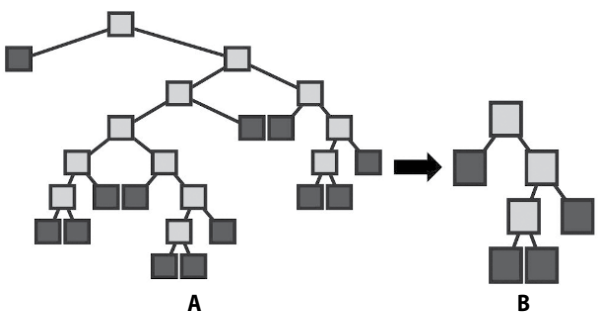

Figure 2. Maximum regression tree topology for Y (A) and optimal regression tree topology for Y (B)

From the 10-fold cross-validation analysis results, the smallest R^{CV} value was 0.428 with a classification accuracy of 68.6% (Fig. 3). Description of the optimum classification tree resulting from pruning and description of the information in stages were presented in the optimum CART as shown in Figure 4. The classification

tree showed that the first sorting variable was a whirlwind (X_6). The main explanatory variable was flooded (X_4), in with from the respondents amounted to 142 people (n = 142).

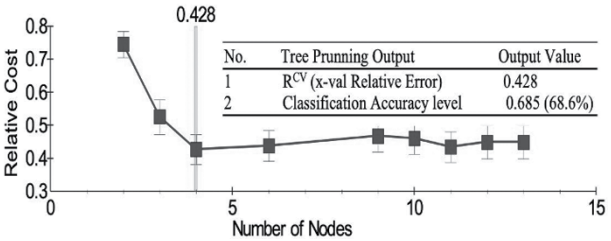

Figure 3. R^{CV} (x-Val relative error) plot of community encroachment rate (Y) response variable

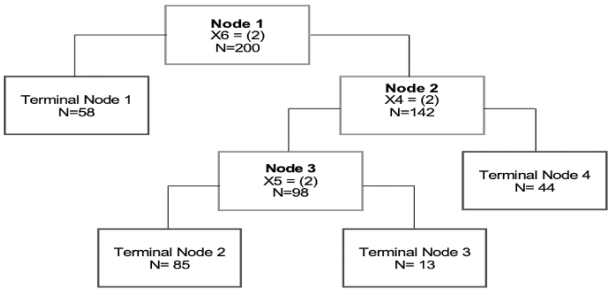

Figure 4. Optimum classification tree with four final terminals on the community encroachment rate (Y) response variable

Of the 142 respondents, 44 stated that they were affected by the heavy flood category ($X_{4\text{-}1}$) and 98 respondents stated that they were affected by the really heavy flood category ($X_{4\text{-}2}$). Furthermore, of the 98 respondents affected by the really heavy flood category, as many as 85 respondents were affected by the really wide landslide ($X_{5\text{-}2}$) and 13 other respondents were affected by the wide landslide category ($X_{5\text{-}1}$).

Based on the classification of the optimum tree with the smallest R^{CV} value (0.428) at the classifier level of 68.6% in Figure 3, it can be explained that the natural flood disaster accompanied by landslides and whirlwinds had afflicted those who lived around the forest area and along the Palu and Jeneberang watersheds. Floods and landslides were the two most powerful external explanatory variables impacting people's lives around the forest areas.

The community dominated by the Kaili ethnic group believed that wood businesspeople who owned a company licensed by the government only thought about profit and did not care about the safety of the community and the sustainability of their lives. It was very difficult to get food when hit by floods and landslides due to logging in the upstream areas. Those businesspeople were not responsible on the pretext that their companies were licensed by the government. People who expected concern from the government were also not optimal. Of the 200 respondents representing communities living around the forest areas, almost 100% stated that they were neglected and did not receive attention from all parties when a natural disaster hit them.

The Cycle of Natural Disasters and Their Impact on Forest Encroachment

According to the Regional Disaster Management Agency (Badan Pengendalian Bencana Daerah [BPBD]) of Sigi), in 2019–2020, the frequency of flash floods and landslides was 17 times, with details five

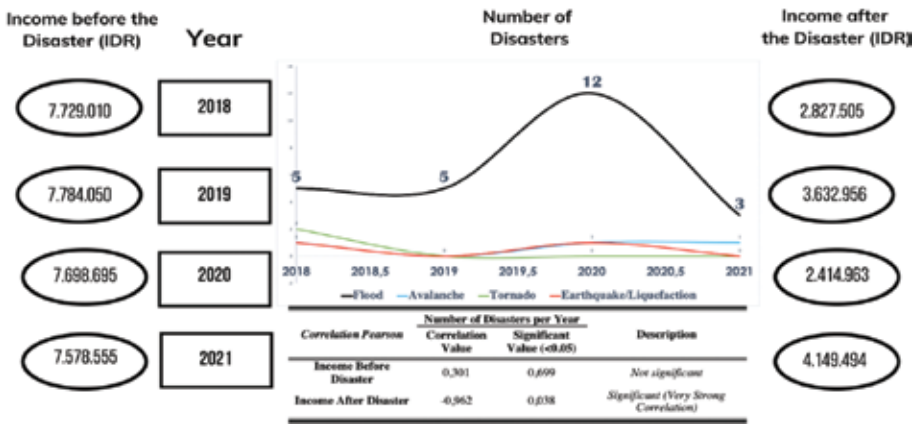

Figure 5. Integration of time series, flood disaster, incomes before and after disaster, and Chi-square correlation test

times in 2019 and 12 times in 2020. The location is directly adjacent to the LLNP area (Suni et al. 2023). The impact was the occurrence of very wide inundation, both in agricultural areas and in community settlements around the forest areas and along the Palu and Jeneberang watersheds (Fig. 5). Figure 5 shows that when flood (X_4) and landslide (X_5) hit the community's agricultural land, along with whirlwind (X_6), all farming activities stopped completely. There was a very strong correlation between the level of forest encroachment and the intensity of natural disasters (R = 0.96). The value of the determinant coefficient showed that 92% of forest encroachment and wood theft occurred due to natural disasters. Only about 8% were not due to logging.

In a very dilemmatic position during a disaster, those living around the forest areas are also looking for alternative jobs, apart from saving themselves, looking for safer places at higher elevations. During the 2019 flood disaster, their income fell greatly from IDR 7.78 million in 2018 to IDR 3.63 million in 2019. In 2020, the intensity and frequency of disasters increased by 12 times, which had a very large socioeconomic impact. The flood-impacted community experienced a decrease in its income, from IDR 3.63 million to IDR2.41 million.

In situations of panic and stress facing natural disasters, there is no other choice, but to look for sources of life in the forest as a social network. The community existing as forest encroachers, together with wood businesspeople in the upstream sector, have participated in illegal logging (Figure 6B). Before being hit by floods and landslides, where their agricultural land was still possible to cultivate, the community supervised licensed companies in carrying out their activities (Fig. 6A).

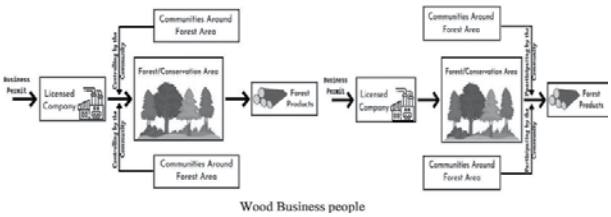

Figure 6. The cycle of the socioecological system before the community is involved (A) and after the community is involved in forest encroachment (B) as a silent partner for the wood businesspeople

It was found that the wood businesspeople had taken advantage of the suffering of the community affected by natural disasters as partners in forest encroachment, and so, the community became part of the SES that took on a negative role. The people living around the forest area were ethnic Kaili. They were forced to leave their agricultural land because it was impossible to cultivate it. Floods, landslides and

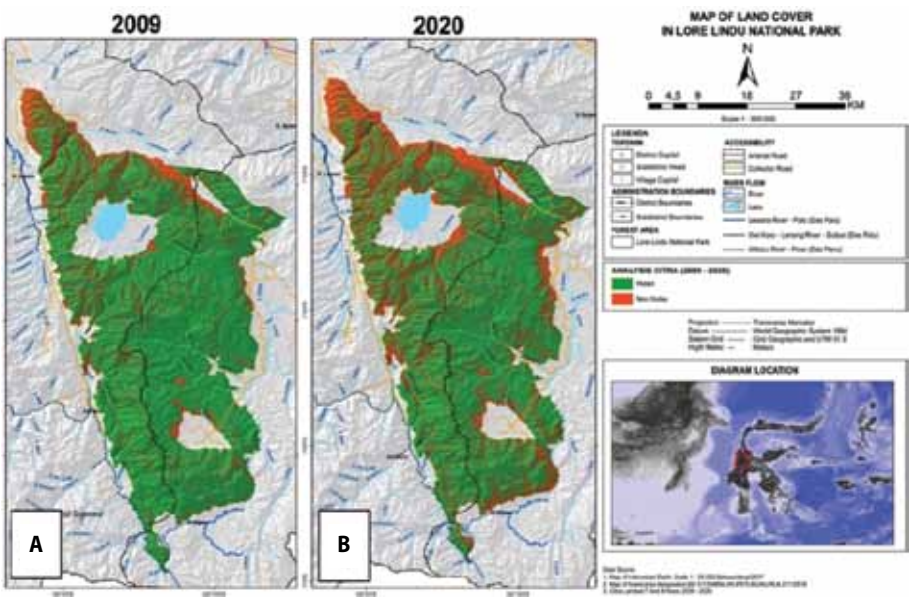

Figure 7. Integration of 2019 flood, wood business partnerships and flood victims of various ethnicities, and the level of deforestation

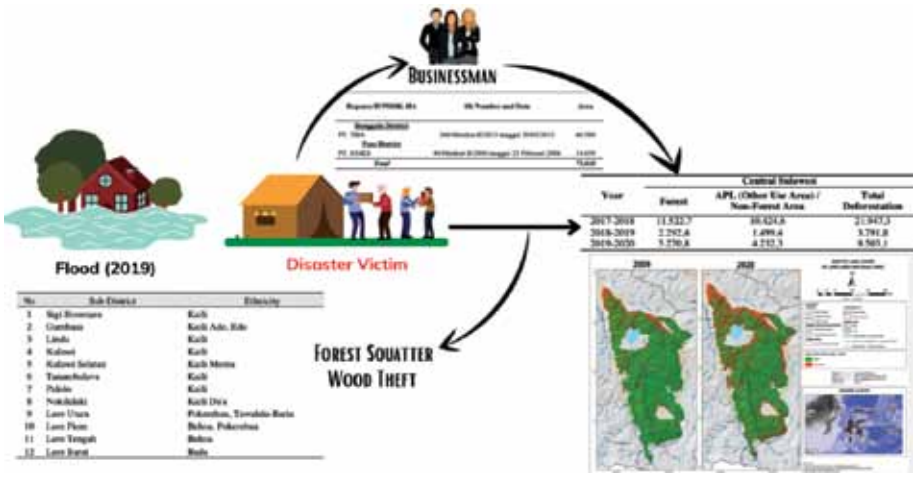

Figure 8. Changes in land cover from 2009 to 2021

heavy rains accompanied by whirlwinds are the rational reasons.

Their involvement as forest encroachers with licensed businesspeople has accelerated land cover decline to indicate forest destruction. The total deforestation in 2019–2020 in Central Sulawesi was 9,503.1, sharply increasing compared to that in 2018–2019, when it was only 3,791.8 ha (an increase of about 60.1%) (Fig. 7). Field facts that occurred in LLNP show that there has been a significant reduction in forest cover in the last 10 years.

The decrease in primary and secondary dryland forest cover and other small spots reached an area of 15,369.20 ha or 6.90% of the total area of LLNP. In terms of percentage, it is relatively small. However, the damage to conservation forests can be a serious threat to the preservation of biodiversity. This condition requires comprehensive handling and attention from the government (Fig. 8).

Decrease in land cover is an authentic evidence of violation of the law between a licensed timber company and the government from the aspect of encroachment outside the designated area (Basil Ewane 2022; Kant and Vertinsky 2022). However, it also indicates the community's involvement around the forest area in forest encroachment (Mbuvi and Kungu 2021). Wood theft attempts by many parties have used smuggling routes, which are very difficult to detect by the forest police.

However, some of the routes that have been detected so far are by carrying stolen wood into the Jeneberang river, which empties into West Sulawesi Province, an area with a different locus of the forest area, where the wood is cut and smuggled.

Biodiversity in LLNP is a resource that should be preserved. However, with forest encroachment that continues to increase, in the next 20 years, it is estimated that there will be a loss of ecological function and conservation functions.

Forest encroachment by businesspeople and communities around forest areas is a powerful source of a threat if there are no law enforcement efforts for perpetrators of forest encroachment and wood theft as protective measures from the government. Figure 8b shows reduced forest cover compared to Figure 8a as evidence if logging activities continue, both legal and illegal.

Discussion

Destruction of forests due to encroachment and illegal logging not only impacts the environment, but also destroys human values (Sahide et al. 2016; Wardani 2021). Destruction of protected forests and loss of ecological functions as catchment areas will lead to natural disasters of floods and landslides (Pham et al. 2020). Surface runoff water is difficult to control in forest areas when the rainfall volume is above normal (Newbold et al. 2015; Rascón-Ramos et al. 2021), where the infiltration and percolation capacity of the soil is not balanced with the volume of surface runoff (Appels et al. 2011; Boisson et al. 2014).

The acceleration of land cover decline due to forest encroachment and wood theft by businesspeople who have companies licensed from the government leads to initiation of natural disasters such as floods and landslides (Cronkleton et al. 2017; Kelly et al. 2012). Disasters due to forest destruction will occur continuously because restoration efforts cannot keep up with the rate of forest destruction due to forest encroachment (Farooq et al. 2020; Washaya et al. 2018). People's suffering due to natural disasters causes their motivation to change in living their daily lives (Benevolenza and DeRigne 2019; Maki et al. 2019), even though initially, they were very much concerned about forest safety. Changes in a person's intentions and motivations, both personally and communally, depend on the situation they face (Castelló et al. 2017; Righetti and Impett 2017).

Several community groups never intended to become forest encroachers and wood thieves. However, with economic pressure, psychosocially, they eventually turned into forest encroachers (Vasile 2019). Encroaching forests for any reason is against the law because it damages natural resources and the environment (Chaudhary et al. 2016; Chirenje et al. 2013). The state generally forgives criminal acts with a humanitarian dimension for their actions (Hauser et al. 2021). The government also has a role in forest destruction which causes various natural disasters (Rosselló et al. 2020), including floods and landslides that have eliminated people's livelihoods leading to economic poverty (Tasri et al. 2022) and have damaged infrastructure and other public facilities (Chen Z. et al. 2021).

The perpetrators of theft of wood by the community have never entered the judiciary due to the lack of coordination between agencies and the weak human resources of law enforcement agencies in handling criminals of illegal forest harvesting (Alusiola et al. 2021; Arsyad et al. 2020; Hos et al. 2021). Government-licensed companies are the main players in the level of forest destruction that is getting out of control from year to year (McEwan et al. 2020; Resosudarmo et al. 2019).

Data released by the Ministry of Environment and Forestry of the Republic of Indonesia shows that land cover has decreased as a cause of various natural disasters (Fisher et al. 2017; Maryudi et al. 2022; Rahayu et al. 2020). In 2019–2020, the frequency of flash floods and landslides was 17 times with details, in 2019 as many as five times and in 2020 as many as 12 times. The impact is wide scale flodding in agricultural areas and community settlements around the forest areas and along the Palu and Jeneberang watersheds. Forest damage is a catalyst for natural disasters (Velo and Zafitsara 2020), whose impact can extend to various aspects and dimensions of people's lives (Martínez-Espinosa et al. 2020).

Businesspeople whose companies are licensed have a great responsibility in protecting the balance of nature, so that forest sustainability is maintained. People are part of SES due to coercion and economic pressure (Melnykovych et al. 2018). The process of accelerating deforestation is motivated by circumstances that make people take illegal methods (Baldassini et al. 2020; Miyamoto 2020). They made a warning addressed to the local government, which in terminology is called 'Forbidden to Prohibit'. This means that the local government should not prohibit people from encroaching, because the goal is not to destroy the forest, but to utilise the forest to sustain life.

The situation is interpreted as a triangle category '10–80–10', which means that there is 10% of the people who care about forest safety, 80% carry out forest encroachment and timber theft because they are forced, and another 10% because indeed from the beginning there was an intention and motivation to encroach (Conrad and Grove 2020). Functionally, LLNP is a conservation area that protects the world's biodiversity (Blicharska et al. 2020; Corlett 2020; Fredericksen 2021). Forest encroachment and wood theft are long-term threats. Conservation areas are shown by the increasing intensity of law violations (Kumeh et al. 2022). The forest cover continues to decline, esspecialy in the upstream region, that as a catchment area. There is under threat of destruction accompanied by loss of ecological function, because it turns into an economic function (Endreny et al. 2019). The weakness of the government and the inability of the forest police to deal with large-capital timber businesspeople are due to the lack of concern for forest safety. Law enforcement does not work, criminals are not deterred from committing violations, so the rules issued by the government are not effective in their application in the field (Fatem et al. 2018; Van der Muur 2018).

Conclusion

1. Wood businesspeople legally have a licence to operate in the use of forest products; however, weak supervision from government institutions, especially the Ministry of Environment and Forestry of the Republic of Indonesia, has resulted in logging that is not following the agreements and licences issued by the government.
2. There is a reduction in land cover from year to year, indicating the high intensity of forest encroachment. There was a decline in land cover of up to 60.1%, as happened in 2019–2020, along with the exodus of people living around the forest areas and watersheds heading into the forest to participate in forest encroachment. From this dilemmatic condition emerged the term from the community addressed to the local government, 'Forbidden to Prohibit'.
3. Increasing forest encroachment is the main catalyst for natural disasters as well as a drop in their income by 70% compared to before the floods and landslides occurred.

Acknowledgement

This research was conducted in collaboration with colleagues from different academic background, including Professor Timothy Roberts from the Hunter Innovation and Science Hub of the University of Newcastle, Australia. We also wish to acknowledge Melanie Ball for the English editing of the manuscript.

Conflict of interest

No potential conflict of interest was reported by the author(s).

References

Ali, R., Kuriqi, A., Kisi, O. 2020. Human–environment natural disasters interconnection in China: a review. *Climate*, 8 (4), 48. DOI: 10.3390/cli8040048

Alusiola, R.A., Schilling, J., Klär, P. 2021. REDD+ Conflict: Understanding the Pathways between Forest Projects and Social Conflict. *Forests*, 12 (6), 748. DOI: 10.3390/f12060748

Anugrahsari, I., Sardjono, M.A., Fitriyah, N., Golar, G. 2020. Social contracts: Pillars of community conservation partnerships in Lore Lindu national park, Indonesia. *Forest and Society*, 4 (1), 115–126. DOI: 10.24259/fs.v4i1.8682

Appels, W.M., Bogaart, P.W., van der Zee, S.E. 2011. Influence of spatial variations of microtopography and infiltration on surface runoff and field scale hydrological connectivity. *Advances in Water Resources*, 34 (2), 303–313. DOI: 10.1016/j.advwatres.2010.12.003

Arsyad, M. et al. 2020. Agricultural development: poverty, conflict and strategic programs in country border. *IOP Conference Series: Earth and Environmental Science*, 575 (1), 12091. DOI: 10.1088/1755-1315/575/1/012091

Baldassini, P., Bagnato, C.E., Paruelo, J.M. 2020. How may deforestation rates and political instruments affect land use patterns and Carbon emissions in the semi-arid Chaco, Argentina? *Land Use Policy*, 99, 104985. DOI: 10.1016/j.landusepol.2020.104985

Basil Ewane, E. 2022. Forest Governance Effectiveness of Community- and Government-managed Forests in Cameroon. *International Journal of Environment and Climate Change*, 12 (9), 83–102. DOI: 10.9734/ijecc/2022/v12i930741

Basir-Cyio, M. 2021. The impact of liquefaction disaster on farming systems at agriculture land based on technical and psychosocial perspectives. *PloS One*, 16 (1), e0245591. DOI: 10.1371/journal.pone.0245591

Bendtsen, E.B., Clausen, L.P. W., Hansen, S.F. 2021. A review of the state-of-the-art for stakeholder analysis with regard to environmental management and regulation. *Journal of Environmental Management*, 279, 111773. DOI: 10.1016/j.jenvman.2020.111773

Benevolenza, M.A., DeRigne, L. 2019. The impact of climate change and natural disasters on vulnerable populations: A systematic review of literature. *Journal of Human Behavior in the Social Environment*, 29 (2), 266–281. DOI: 10.1080/10911359.2018.1527739

Blicharska, M. et al. 2020. Between biodiversity conservation and sustainable forest management–A multidisciplinary assessment of the emblematic Białowieża Forest case. *Biological Conservation*, 248, 108614. DOI: 10.1016/j.biocon.2020.108614

Boakye, J. 2020. Enforcement of logging regulations in Ghana: Perspectives of frontline regulatory officers. *Forest Policy and Economics*, 115, 102138. DOI: 10.1016/j.forpol.2020.102138

Boccia, F., Sarnacchiaro, P. 2020. Chi-squared automatic interaction detector analysis on a choice experiment: An evaluation of responsible initiatives on consumers' purchasing behavior. *Corporate Social Responsibility and Environmental Management*, 27 (2), 1143–1151. DOI: 10.1002/csr.1873

Boisson, A. et al. 2014. Comparison of surface and groundwater balance approaches in the evaluation of managed aquifer recharge structures: Case of a percolation tank in a crystalline aquifer in India. *Journal of Hydrology*, 519, 1620–1633.

Breiman, L., Friedman, J.H., Olshen, R.A., Stone, C.J. 2017. Classification and regression trees. Routledge.

Castelló, M., Pardo, M., Sala-Bubaré, A., Suñé-Soler, N. 2017. Why do students consider dropping out of doctoral degrees? Institutional and personal factors. *Higher Education*, 74 (6), 1053–1068.

Cattau, M.E., Harrison, M.E., Shinyo, I., Tungau, S., Uriarte, M., DeFries, R. 2016. Sources of anthropogenic fire ignitions on the peat-swamp landscape in Kalimantan, Indonesia. *Global Environmental Change*, 39, 205–219. DOI: 10.1016/j.gloenvcha.2016.05.005

Chaudhary, R.P., Uprety, Y., Rimal, S.K. 2016. Deforestation in Nepal: Causes, consequences and responses. *Biological and Environmental Hazards, Risks, and Disasters*, 335–372.

Chen, J., Liu, W., Zhao, W., Jiang, T., Zhu, Z., Chen, X. 2021. Magnitude amplification of flash floods caused by large woody in Keze gully in Jiuzhaigou National Park, China. *Geomatics, Natural Hazards and Risk*, 12 (1), 2277–2299. DOI: 10.1080/19475705.2021.1961882

Chen, Z. et al. 2021. Transfer of heavy metals in fruits and vegetables grown in greenhouse cultivation systems and their health risks in Northwest China. *Science of the Total Environment*, 766, 142663. DOI: 10.1016/j.scitotenv.2020.142663

Chirenje, L.I., Giliba, R.A., Musamba, E.B. 2013. Local communities' participation in decision-making processes through planning and budgeting in African countries. *Chinese Journal of Population Resources and Environment*, 11 (1), 10–16. DOI: 10.1080/10042857.2013.777198

Clayton, S., Karazsia, B.T. 2020. Development and validation of a measure of climate change anxiety. *Journal of Environmental Psychology*, 69, 101434. DOI: 10.1016/j.jenvp.2020.101434

Conrad, J.L., Grove, P.M. 2020. Timber Security Practices, Vulnerabilities, and Challenges in the Southern United States. *Society and Natural Resources*, 33 (7), 842–858. DOI: 10.1080/08941920.2020.1725988

Corlett, R.T. 2020. Safeguarding our future by protecting biodiversity. *Plant Diversity*, 42 (4), 221–228. DOI: 10.1016/j.pld.2020.04.002

Crockatt, M.E. 2012. Are there edge effects on forest fungi and if so do they matter? *Fungal Biology Reviews*, 26 (2/3), 94–101.

Cronkleton, P. et al. 2017. How do property rights reforms provide incentives for forest landscape restoration? Comparing evidence from Nepal, China and Ethiopia. *International Forestry Review*, 19 (4), 8–23. DOI: 10.1505/146554817822330506

Dalagnol, R. et al. 2022. Extreme rainfall and its impacts in the Brazilian Minas Gerais state in January 2020: Can we blame climate change? *Climate Resilience and Sustainability*, 1 (1), e15. DOI: 10.1111/gcb.13925

Dronkers, E.A.C., Hoesseini, A., de Boer, M.F., Offerman, M.P.J. 2018. Communication of prognosis in head and neck cancer patients; a descriptive qualitative analysis. *Oral Oncology*, 84, 76–81.

Dyderski, M.K., Paź, S., Frelich, L.E., Jagodziński, A.M. 2018. How much does climate change threaten European forest tree species distributions? *Global Change Biology*, 24 (3), 1150–1163.

Eddy, S., Milantara, N., Sasmito, S.D., Kajita, T., Basyuni, M. 2021. Anthropogenic drivers of mangrove loss and associated carbon emissions in South Sumatra, Indonesia. *Forests*, 12 (2), 187. DOI: 10.1111/1752-1688.12777

Endreny, T.A., Kwon, P., Williamson, T.N., Evans, R. 2019. Reduced soil macropores and forest cover reduce warm-season baseflow below ecological thresholds in the upper Delaware River Basin.

JAWRA Journal of the American Water Resources Association, 55 (5), 1268–1287. DOI: 10.1111/1752-1688.12777

Farooq, F. et al. 2020. A comparative study of random forest and genetic engineering programming for the prediction of compressive strength of high strength concrete (HSC). *Applied Sciences*, 10 (20), 7330.

Fatem, S.M. et al. 2018. Camouflaging economic development agendas with forest conservation narratives: A strategy of lower governments for gaining authority in the re-centralising Indonesia. *Land Use Policy*, 78, 699–710. DOI: 10.1016/j.landusepol.2018.07.018

Feng, Y. et al. 2021. Upward expansion and acceleration of forest clearance in the mountains of Southeast Asia. *Nature Sustainability*, 4 (10), 892–899.

Fisher, L.A., Kim, Y.-S., Latifah, S., Mukarom, M. 2017. Managing forest conflicts: Perspectives of Indonesia's forest management unit directors. *Forest and Society*, 1, 8–26.

Fredericksen, T.S. 2021. Biodiversity conservation in managed forests. *Forests*, 12 (8), 1054. DOI: 10.3390/f12081054

Frimadani, M.R., Yonariza, Y., Yuerlita, Y. 2020. The implementation of community-based forest management (CBFM) schemes within the protection forest management unit (PFMU) Sijunjung, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 583 (1), 1–10. DOI: 10.1088/1755-1315/583/1/012035

Gerber, J.-D., Haller, T. 2021. The drama of the grabbed commons: anti-politics machine and local responses. *The Journal of Peasant Studies*, 48 (6), 1304–1327.

Giatti, L.L., Ribeiro, R.A., Nava, A.F.D., Gutberlet, J. 2021. Emerging complexities and rising omission: Contrasts among socio-ecological contexts of infectious diseases, research and policy in Brazil. *Genetics and Molecular Biology*, 44. DOI: 10.1590/1678-4685-gmb-2020-0229

Gocheva-Ilieva, S., Ivanov, A., Stoimenova-minova, M. 2022. Prediction of Daily Mean PM10 Concentrations Using Random Forest, CART Ensemble and Bagging Stacked by MARS. *Sustainability (Switzerland)*, 14 (2). DOI: 10.3390/su14020798

Golar, G., Malik, A., Muis, H., Herman, A., Nurudin, N., Lukman, L. 2020. The social-economic impact of COVID-19 pandemic: implications for potential forest degradation. *Heliyon*, 6 (10), e05354.

Golar, G., Muis, H., Herman, A., Simorangkir, W.S. 2022. Effectiveness of community based-collaborative on forest management of the forest programme III in Central Sulawesi. *IOP Conference Series: Earth and Environmental Science*, 1114 (1). DOI: 10.1088/1755-1315/1114/1/012028

Golar, G. et al. 2021. Can forest management units improve community access to the forest? *International Journal of Design and Nature and Ecodynamics*, 16 (5), 565–571.

Guisan, A. et al. 2013. Predicting species distributions for conservation decisions. *Ecology Letters*, 16 (12), 1424–1435. DOI: 10.1111/ele.12189

Hasyim, S., Abdullah, R., Ibrahim, H. 2021. Forest damage and preservation through forest resources management in Indonesia. *GeoJournal*, 86 (5), 2183–2189. DOI: 10.1007/s10708-020-10177-5

Hauser, C., Simonyan, A., Werner, A. 2021. Condoning corrupt behavior at work: What roles do Machiavellianism, on-the-job experience, and neutralization play? *Business and Society*, 60 (6), 1468–1506. DOI: 10.1177/0007650319898474

Hos, J., Kusujiarti, S., Upe, A., Arsyad, M., Dharta, F.Y., Natanson, J. 2021. Conflict management in multiethnic communities: a case study in Southeast Sulawesi, Indonesia. *Journal of International Migration and Integration*, 23, 1963–1985. DOI: 10.1007/s12134-021-00923-0

Hovis, M. et al. 2021. Natural infrastructure practices as potential flood storage and reduction for farms and rural communities in the North Carolina coastal plain. *Sustainability*, 13 (16), 9309. DOI: 10.3390/su13169309

Hughes, A.C. 2018. Have Indo-Malaysian forests reached the end of the road? *Biological Conservation*, 223, 129–137. DOI: 10.1016/j.biocon.2018.04.029

Iqbal, M. 2018. Effective implementation of the opportunity principle in Indonesia based on public interest. *Jurnal Surya Kencana Satu: Dinamika Masalah Hukum Dan Keadilan*, 9 (1), 87–100. DOI: 10.32493/jdmhkdmhk.v9i1.1178

Kant, S., Vertinsky, I. 2022. The anatomy of social capital of a Canadian indigenous community: Implications of social trust field experiments for commu-

nity-based forest management. *Forest Policy and Economics*, 144 , 102822.

Kelly, P.M., Lien, T.V., Hien, H.M. (2012). Managing environmental change in Vietnam. In Living with environmental change. Routledge, 57–80.

Kiely, L. et al. 2021. Assessing costs of Indonesian fires and the benefits of restoring peatland. *Nature Communications*, 12 (1), 1–11. DOI: 10.1038/s41467-021-27353-x

Kleinschmit, D., Mansourian, S., Wildburger, C., Purret, A. 2016. Illegal logging and related timber trade-dimensions, drivers, impacts and responses. A global scientific rapid response assessment report. IUFRO World Series Volume 35, IUFRO, Vienna.

Kumeh, E.M., Bieling, C., Birner, R. 2022. Food-security corridors: A crucial but missing link in tackling deforestation in Southwestern Ghana. *Land Use Policy*, 112 , 105862. DOI: 10.1016/j.landusepol.2021.105862

Loury, E.K. et al. 2021. Communicating for aquatic conservation in Cambodia and beyond: lessons learned from in-person and media-based environmental education and outreach strategies. *Water*, 13 (13), 1853. DOI: 10.3390/w13131853

Mackevičius, J., Giriūnas, L. 2013. Transformational research of the fraud triangle. *Ekonomika*, 92 (4), 150–163.

Maki, A., Dwyer, P.C., Blazek, S., Snyder, M., González, R., Lay, S. 2019. Responding to natural disasters: Examining identity and prosociality in the context of a major earthquake. *British Journal of Social Psychology*, 58 (1), 66–87. DOI: 10.1111/bjso.12281

Martínez-Espinosa, C., Wolfs, P., Vande Velde, K., Satyanarayana, B., Dahdouh-Guebas, F., Hugé, J. 2020. Call for a collaborative management at Matang Mangrove Forest Reserve, Malaysia: An assessment from local stakeholders' view point. *Forest Ecology and Management*, 458, 117741. DOI: 10.1016/j.foreco.2019.117741

Maryudi, A. 2015. The political economy of forest landuse, the timber sector, and forest certification. In: The context of natural forest management and FSC certification in Indonesia. CIFOR, Bogor Barat, 9–34.

Maryudi, A. et al. 2022. Holding social forestry hostage in Indonesia : Contested bureaucracy mandates and potential escape pathways. *Environmental Science and Policy*, 128 (1), 142–153. DOI: 10.1016/j.envsci.2021.11.013

Mbuvi, M.T.E., Kungu, J.B. 2021. A transforming traditional community based forest management: the case of Loita community forest, Kenya. *Heliyon*, 7 (6). DOI: 10.1016/j.heliyon.2021.e07380

McEwan, A., Marchi, E., Spinelli, R., Brink, M. 2020. Past, present and future of industrial plantation forestry and implication on future timber harvesting technology. *Journal of Forestry Research*, 31 (2), 339–351. DOI: 10.1007/s11676-019-01019-3

Melnykovych, M., Nijnik, M., Soloviy, I., Nijnik, A., Sarkki, S., Bihun, Y. 2018. Social-ecological innovation in remote mountain areas: Adaptive responses of forest-dependent communities to the challenges of a changing world. *Science of the Total Environment*, 613, 894–906. DOI: 10.1016/j.scitotenv.2017.07.065

Miyamoto, M. 2020. Poverty reduction saves forests sustainably: Lessons for deforestation policies. *World Development*, 127, 104746. DOI: 10.1016/j.worlddev.2019.104746

Mustalahti, I., Gutiérrez-Zamora, V., Hyle, M., Devkota, B.P., Tokola, N. 2020. Responsibilization in natural resources governance: A romantic doxa? *Forest Policy and Economics*, 111, 102033. DOI: 10.1016/j.forpol.2019.102033

Nandi, D., Sarkar, S. 2021. Non-timber forest products based household industries and rural economy – a case study of Jaypur Block in Bankura District, West Bengal (India). In: Spatial modeling in forest resources management. Springer, Cham, 505–528.

Nellemann, C. 2012. Green carbon, black trade: illegal logging, tax fraud and laundering in the world's tropical forests. UNEP, Nairobi, Kenya.

Newbold, T. et al. 2015. Global effects of land use on local terrestrial biodiversity. *Nature*, 520 (7545), 45–50. DOI: 10.1038/nature14324

Parhusip, S.B., Hirose, Y., Matsumura, N. 2020. Community involvement in forest resource utilization: case study of rural communities in Japan and Indonesia. *FORMATH*, 19, 2–19. DOI: 10.15684/formath.19.002

Pham, N.T.T., Nong, D., Sathyan, A.R., Garschagen, M. 2020. Vulnerablitiy assessment of households to flash floods and landslides in the poor upland re-

gions of Vietnam. *Climate Risk Management*, 28 (100215), 1–4.

Qu, S., Wang, L., Lin, A., Zhu, H., Yuan, M. 2018. What drives the vegetation restoration in Yangtze River basin, China: climate change or anthropogenic factors? *Ecological Indicators*, 90, 438–450. DOI: 10.1016/j.ecolind.2018.03.029

Race, D. et al. 2019. Smallholder forestry: the role of commercial forestry in rural livelihoods in Indonesia. *International Forestry Review*, 21 (2), 225–237. DOI: 10.1505/146554819826606568

Rahayu, S. et al. 2020. Bureaucratizing non-government organizations as governmental forest extension services in social forestry policy in Indonesia. *Forests Trees and Livelihoods*, 29 (2), 119–129. DOI: 10.1080/14728028.2020.1753585

Rascón-Ramos, A.E. et al. 2021. Soil moisture dynamics in response to precipitation and thinning in a semi-dry forest in Northern Mexico. *Water*, 13 (1), 105.

Resosudarmo, I.A.P., Tacconi, L., Sloan, S., Hamdani, F.A.U., Alviya, I., Muttaqin, M.Z. 2019. Indonesia's land reform: Implications for local livelihoods and climate change. *Forest Policy and Economics*, 108, 101903. DOI: 10.1016/j.forpol.2019.04.007

Righetti, F., Impett, E. 2017. Sacrifice in close relationships: Motives, emotions, and relationship outcomes. *Social and Personality Psychology Compass*, 11 (10), e12342.

Rohayu, R., Absori, A. 2019. Utilizing the values of local wisdom: a solution for illegal logging conflict in Sumbawa Forest. *International Journal of Social Sciences and Humanities*, 3 (1), 91–101.

Rosselló, J., Becken, S., Santana-Gallego, M. 2020. The effects of natural disasters on international tourism: A global analysis. *Tourism Management*, 79, 104080. DOI: 10.1016/j.tourman.2020.104080

Sabariah, M.K., Hanifah, A., Siti, S. 2014. Early detection of type II Diabetes Mellitus with random forest and classification and regression tree (CART). In: Proceedings of International Conference of Advanced Informatics: Concept, Theory and Application (ICAICTA), 20–21 August 2014, Bandung, Indonesia, 238–242. DOI: 10.1109/ICAICTA.2014.7005947

Safe'i, R., Puspita, E.N., Hilmanto, R. 2022. Assessment of tree vitality as an indicator of monitoring the health condition of community forest in agroforestry patterns. *Folia Forestalia Polonica, Series A – Forestry*, 64 (4), 206–213. DOI: 10.2478/ffp-2022-0020

Sahide, M.A.K., Maryudi, A., Supratman, S., Giessen, L. 2016. Is Indonesia utilising its international partners? The driving forces behind Forest Management Units. *Forest Policy and Economics*, 69, 11–20. DOI: 10.1016/j.forpol.2016.04.002

Santika, T. et al. 2020. Interannual climate variation, land type and village livelihood effects on fires in Kalimantan, Indonesia. *Global Environmental Change*, 64, 102129. DOI : 10.1016/j.gloenvcha.2020.102129

Shabani, S. 2017. Modelling and mapping of soil damage caused by harvesting in Caspian forests (Iran) using CART and RF data mining techniques. *Journal of Forest Science*, 63 (9), 425–432.

Shan, G., Gerstenberger, S. 2017. Fisher's exact approach for post hoc analysis of a chi-squared test. *PloS One*, 12 (12), e0188709. DOI: 10.1371/journal.pone.0188709

Silva Junior, C.H.L., Aragão, L.E.O.C., Fonseca, M.G., Almeida, C.T., Vedovato, L.B., Anderson, L.O. 2018. Deforestation-induced fragmentation increases forest fire occurrence in central Brazilian Amazonia. *Forests*, 9 (6), 305. DOI: 10.3390/f9060305

Soler, R. et al. 2021. The politics behind scientific knowledge: Sustainable forest management in Latin America. *Forest Policy and Economics*, 131, 102543. DOI: 10.1016/j.forpol.2021.102543

Suni, M.A., Mappatoba, C.A., Maarif, F. 2023. Spatial analysis of flood vulnerability in buffer village Lore Lindu National Park. *Jurnal Analisis Kebijakan Kehutanan*, 20 (2), 91–101.

Szulecka, J., Obidzinski, K., Dermawan, A. 2016. Corporate–society engagement in plantation forestry in Indonesia: Evolving approaches and their implications. *Forest Policy and Economics*, 62, 19–29. DOI: 10.1016/j.forpol.2015.10.016

Tasri, E.S., Karimi, K., Muslim, I. 2022. The effect of economic variables on natural disasters and the impact of disasters on economic variables. *Heliyon*, 8 (1), e08678. DOI: 10.1016/j.heliyon.2021.e08678

Van der Muur, W. 2018. Forest conflicts and the informal nature of realizing indigenous land rights in In-

donesia. *Citizenship Studies*, 22 (2), 160–174. DOI: 10.1080/13621025.2018.1445495

Vasile, M. 2019. Fiefdom forests: Authoritarianism, labor vulnerability and the limits of resistance in the Carpathian Mountains. *Geoforum*, 106, 155–166. DOI: 10.1016/j.geoforum.2019.08.001

Velo, N.M.A., Zafitsara, J. 2020. The management of forest and deforestation, mitigation, and adaptation of climate change in Madagascar. *Open Access Library Journal*, 7 (6), 1–19. DOI: 10.4236/oalib.1106451

Wardani, W.I. 2021. How can the law protect the forest? *Journal of Law and Legal Reform*, 2 (4), 527–538. DOI: 10.15294/jllr.v2i4.48757

Washaya, P., Balz, T., Mohamadi, B. 2018. Coherence change-detection with sentinel-1 for natural and anthropogenic disaster monitoring in urban areas. *Remote Sensing*, 10 (7), 1026. DOI: 10.3390/rs10071026

Yovi, E.Y., Nurrochmat, D.R. 2018. An occupational ergonomics in the Indonesian state mandatory sustainable forest management instrument: A review. *Forest Policy and Economics*, 91, 27–35. DOI: 10.1016/j.forpol.2017.11.007

Yunis, R. 2023. Optimizing Random Forest Classification using Chi-Square and SMOTE-ENN on student drop-out data. Proceedings of Eighth International Conference on Informatics and Computing (ICIC), 08–09 December 2023, Manado, Indonesia, 1–5. DOI: 10.1109/ICIC60109.2023.10382055

Zuccolotto, P., Sandri, M., Manisera, M. 2023. Spatial performance analysis in basketball with CART, random forest and extremely randomized trees. *Annals of Operations Research*, 325 (1), 495–519.