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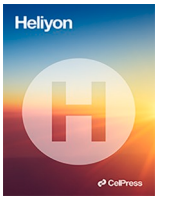

Research article

Devolution of forest management to local communities and its impacts on livelihoods and deforestation in Berau, Indonesia

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A R T I C L E I N F O

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A B S T R A C T

Law 11/2020 on job creation has changed a partial forest business license to a multi-purpose forest business and devolved some authorities in forest management to local communities. Studies on common-pool resources demonstrate that devolution of common property is one of the most important factors for sustainability. This study aims to analyze the factors that influence reducing deforestation and focuses on two different village forest organizations in East Kalimantan: first, village forests under the management of the Forest Management Unit of Berau Barat -forests managed by a provincial government (Long Duhung and Merapun village forests), and second, devolution of village forest managed by a local village institution (Merabu village forest). Recent evidence from these study sites indicates that the devolution of forest management associated with village forests has not consistently reduced forest cover loss. There was a complex interaction between the passage of robustness of the institutional settings and economic preferences linked to deforestation. The forest governance systems, including rules that determine property rights, can promote forest conservation when people's interests are served by forest land use. Conversely, economic preferences also control deforestation. This study confirms that the institutional robustness of forest governance systems and actors' economic preferences play an important role in controlling deforestation. This study suggests the devolution of rights for forest management and incentivizing economic alternatives for using forest resources to reduce deforestation.

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1. Introduction

Indonesia faced a severe deforestation problem due to complex factors of economic, social, cultural, and policy [1–7]. There is an urgent need to evaluate the implication of devolution in forest management to achieve sustainable forest management to reduce deforestation. One of the most important components of devolution is delivering property rights, which refer to the legal and social recognition of resource allocation, including the authority to carry out particular actions in a specific domain [8,9]. When property rights are enforced, effective, and complete, they control illegal or extra-legal deforestation. Without property rights, it is difficult to manage forests sustainably or distinguish legal forest loss from illegal activity [1]. Indonesia has numerous laws and regulations related to forest property rights. Still, the extent to which these formal rules have been implemented to provide a clear legal basis for national forest management remains uncertain (see Ref. [10]).

Since transitioning to democracy in 1998, the Government of Indonesia (GoI) has implemented many programs for collaborative, decentralized, and devolved forest management [11]. Though these policies demonstrate an enhanced commitment to conserving forest areas [12], they have failed to resolve some disputes over forest property rights [13]. One of the problems faced in collaboration and partnership management is improving access structures and benefit-sharing mechanisms limited to forests (see Ref. [14]). The GoI promotes initiatives such as forest management units (FMUs) and village forests [15]. Both play important roles in enforcing forest property rights at the site level. FMUs are now Indonesia's mainstream forest management mechanism [16]. FMUs were first implemented in 2008 [17], founded by the Ministry of Forestry in 2012 [18], and came under provincial authority after the latest Regional Governance Law 23/2014. FMUs have faced several problems, including unrecognized spatial planning, incomplete forest boundary demarcation, competing claims by villagers within the forest area, forest encroachment (particularly by oil palm plantations), and overlapping land permits (mining, forest concession, and community claims) [18,19]. Meanwhile, the village forest program in Indonesia was established in 2008 as a new devolution approach premised on community-based forest management [20,21].

Many factors affect the effectiveness of property rights in controlling deforestation. The GoI introduced devolution schemes to improve property rights for community forests through forest land reform [22,23] and social forestry programs [24,25]. Those schemes of land reform and social forestry programs aimed to improve property rights as an important precondition for successful forest governance. However, there is no theoretical or empirical reason to believe that government-administered property rights are universally superior, to collective or locally negotiated property rights, for sustaining forest resources [26,27–29], and [30]. No significant differences in the mean values of tree species diversity between the two types of forest land ownership (communal and private) in the Sierra Madre Occidental, Mexico [31]. Another study on the number of stems, diameter at breast height, and basal area of 42 forests in India, Kenya, Nepal, Uganda, and the USA, also found no differences between different types of land ownership [28].

In Indonesia, economic drivers are the most immediate drivers of forest loss [32]. As is common in other countries, deforestation in Indonesia occurs with the rising conversion of forests for agriculture and industrial logging [20,33–36]. Therefore, to examine the role of devolution in forest management, different property regimes must be compared in forests with the same likelihood for infrastructure development and conversion. This study aims to analyze the factors that influence the relationship between property rights and reducing deforestation that shares similar floristic, economic, and social characteristics. It focuses on two types of local forest management organizations that use property rights to identify and delineate forest resources and improve their management as well as protection. The study contributes to the debate concerning the efficacy of devolution in promoting better forest management. It also lends insight into what processes determine the efficacy of forest management and conservation by improving property rights.

2. Conceptual background

Empirical research on the effects of different property regimes within Indonesia remains limited. This research explores influencing factors for controlling forest cover loss in area-specific in East Kalimantan, Indonesia. Scholars provide two general perspectives on how property rights contribute to reducing deforestation: (i) by providing a clear foundation for sustainable forest management and (ii) by providing a clear foundation for economic exchange. The first perspective sees property rights as critical to a system of rule-based regulation. This perspective has been adopted by Refs. [37–41]. [37] compared the processes and outcomes of decentralization initiatives directed toward forests in South Asia. They investigated two main issues: the role of local populations in ensuring that property rights and decision-making are devolved and the types of property rights that must be devolved to local populations for effective decentralization. A comparison between the ability of publicly protected and common-property forest institutions is required to control outside encroachment into frontier forests in Honduras and Nicaragua [38]. Another study assessed institutional performance in forest management as an institution's capacity to reduce forest degradation (objective function) and an institution's internal functioning mechanisms (operational function) [39]. This study investigated the roles of local institutions in fostering forest management in Cameroon. Combining institutional analysis and the sustainable livelihoods framework is used to map the relationship between property rights and forest institutions [40]. They described the influence of institutional forest property rights on livelihoods and forest performance. It adopted this perspective to understand how formal and informal local institutions interact in Ghana [41].

Some scholars have focused explicitly on the direct influence of property rights on forest resources through the enforcement of laws and regulations (formal and informal). Adopted approaches of [42–46], [47] analyzed how distorted policies, laws, and regulations on agrarian, forest, and environmental matters explain insecure property rights over land and timber (see Refs. [30,48]). Property rights transcend a narrow sense of ownership and grant state-issued titles to resources [42]. In some cases, state law has less relevance than the practice of the village, ethnic community, or user group in determining property rights in a specific region [44]. focused on forest tenure reforms and identified three types of regulations: rules that limit the areas available to local communities; rules that delineate conservation areas and impose related limits on use; and bureaucratic requirements for permits and management plans that restrict the

commercial use and marketing of valuable forest products [46]. explored the relationship between national and local issues and revealed that Indonesia had low national–local integration.

Under the second perspective, property rights will effectively protect the forest if there are no economic pressures to convert forests to other land uses or if deforestation costs are higher than the benefit. This perspective was adopted by (among others) [49–51], and [52]. [49] revealed that local people's interests in forests are tied mainly to the forests' direct role in providing or protecting their income (see also [53]). Sustainable forest management is unlikely where tenure security is strong. Still, communities are interested in economic opportunities that result in forest cover loss and are not a risk of sanctioning (see Refs. [50,51]). If the forest is more valuable as timber than standing forest, trees will be cut down, regardless of the potential costs to society [51]. Deforestation is considered a risk management strategy. It includes landowners clearing the forest preventively to assert the productive use of land and reduce the expropriation risk, squatters invading land plots, and clearing the forest. It may subsequently gain official recognition through formal property titles [52].

3. Methodology

3.1. Research framework

The effects of devolution in forest management, particularly the arrangement of forest property rights, are determined by interactions between institutional arrangements and economic preferences. However, studies often examine one perspective or the other. The current research seeks to integrate an analysis of institutional robustness and economic preferences to understand how property rights and forest cover change are related. Fig. 1 advances a framework for this research. To render it useable across forest contexts, the framework accounts for specific characteristics of the forest resources that can also influence the relationship between property rights and forest cover change. Such forest characteristics include accessibility level, forest products, and the scale and scope of the production process. Fig. 1 illustrates that natural resource management, institutional robustness, and forest-related economic preferences have reciprocal consequences for property rights. The situation approaches a stable equilibrium as conflicting claims over forests and/or land use decrease. A stable equilibrium, in this context, indicates that since it could be the case that property rights are pretty unjust, but because they are enforceable, there are minimal conflicts.

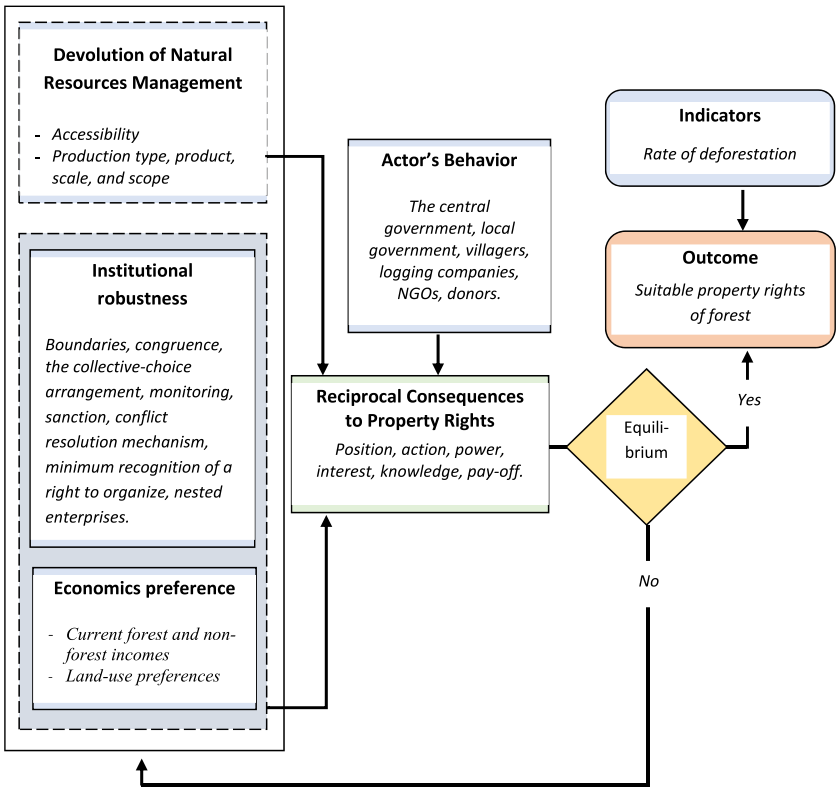


Fig. 1. Research framework.

3.2. Research sites

This research examined two forest management organizations in Berau, East Kalimantan, i.e., the village forest (Merabu) has been devolved to the village government and managed by a village institution. Two villages (Long Duhung and Merapun) under the Forest Management Unit of Berau Barat were used to provide comparison areas for controlling compounding factors and also establishing counterfactual forest loss rate as an approach used by Refs. [54,55]. This research analyzes the Berau Barat FMU and the Merabu Village Forest in three villages selected because of their proximity and dependence on forest resources. The three villages include Long Duhung and Merapun under the Berau Barat FMU and Merabu under the Merabu Village Forest (Fig. 2).

The Berau Barat FMU is a provincial institution that manages a 768,021-ha state forest that comprises approximately one-third of the total forest area in the Berau district. 97% of the FMU is forested, including 57% primary and 40% secondary forests. It illustrates the timber potency within the Berau Barat FMU's area. Primary forests are in protected areas within the FMU, and secondary forests are mostly in forest production areas. Logging companies manage 80% of the secondary forest area within the Berau Barat FMU. The forest boundaries of the Berau Barat FMU are primarily natural (e.g., rivers), but some are artificial (e.g., roads). The Berau Barat FMU is divided into four regions, as reported in Table 1.

Indonesia's village forests are part of the government forest area but are managed by villages. In 2014, the GoI granted Merabu village management rights over 8245 ha of protected forest area for 35 years through the Ministry of Forestry Decree 28/2014. The village authorities formed the *Kerima Puri* as the institution responsible for managing the daily activities of the Merabu Forest Village. *Kerima Puri* implemented four programs: forest patrol, ecotourism development, economic empowerment through agroforestry, and utilization of non-timber forest products. Many tangible resources within the village forest area include timber and non-timber forest products (such as honey, rattan, bird nests, and wild meat). Furthermore, the lake, caves (featuring unique handprint patterns of immense archaeological value), and endemic wild animals (especially the *bekantan* and several bird species) attract visitors to Merabu village. As a result of ecotourism activities, there are several emerging sources of income for villagers, such as homestays, guided tours, and boat rentals.

The forest resources in the Berau Barat FMU and Merabu Village Forest consist of a common pool as well as public goods. Common-pool goods from these forests are non-excludable and rivalrous. They include timber, non-timber forest products, wild meat, and bird nests, among other goods. The public goods provided by these forest areas are non-excludable and non-rivalrous. They include services such as the provision of water, protection against erosion, and improved air quality. This analysis focuses primarily on the common-pool goods provided by forest resources.

The forest around Long Duhung Village is a Production Forest area managed by the logging company (HPH) PT Mahardika Insan Mulia. Based on participatory mapping in 2004, around Long Duhung there is also a cultivation area of 2571.7 ha and protection of water sources covering an area of 124.8 ha. The Long Duhung people used forests for hunting and gathering non-timber forest products, such as honey, sago, fruits, fish, and small-scale gold mining. Within the production forest, there is 1958.8 ha which is recognized by the Long Duhung community as a forbidden forest (referred to as Wugun Forest) essential to them for hunting and territorial protection, including protecting their ancestral graves. The community recognizes that the area is a customary forest that must be preserved. Since 2010, the Nature Conservancy (TNC) has facilitated a collaborative forest management process between the village community and the company.

The forest around Merapun Village is also a Production Forest, which HPH has managed since 1997–2000. Since 2005, in Merapun Village, there have been oil palm plantation companies. Until the research was conducted, four oil palm companies were operating, and two companies were in the licensing process. Because the condition of the forest around the village is fragmented, the community no longer depends on the forest. However, some Merapun communities are carrying out forest-related activities, including protection of certain forest trees in the forest to increase natural regeneration, such as mangosteen, *tengkawang,* fig, *jelemu*, fruit trees, formation of a group of forest honey collectors, and drafting village regulations related to tree cutting permits.

3.3. Data collection

Primary data were collected with a preliminary survey (September 2014), inception survey (July 2015), household survey, and observation (August 2016). Secondary data were obtained from the District Forestry Office, Berau REDD + Task Force, NGOs, FMU of Berau Barat, village forest authorities, three village authorities, villagers, and other kinds of literature (2016–2020). An unstructured questionnaire was used in surveying key informants, while a structured questionnaire was used for the household interviews.

Key informants and households were selected purposively to provide information on forest management and use. In-depth interviews were conducted with 15 key informants representing the Local government (the District Forestry Service and the District REDD + Task Force), FMU authorities (the Head of the Berau Barat FMU, forest rangers, and field assistants), development organizations (GIZ-Forclim, TNC, Yakobi, GLIM, Pena Buluh Segah Sub-District Forum), and local leaders (Village Head Office personnel, village council representatives). Households in the three villages were selected intentionally to provide variation in livelihood variation, gender, social status, and spatial distribution. The purposive sample includes 146 respondents, comprising 24 households in

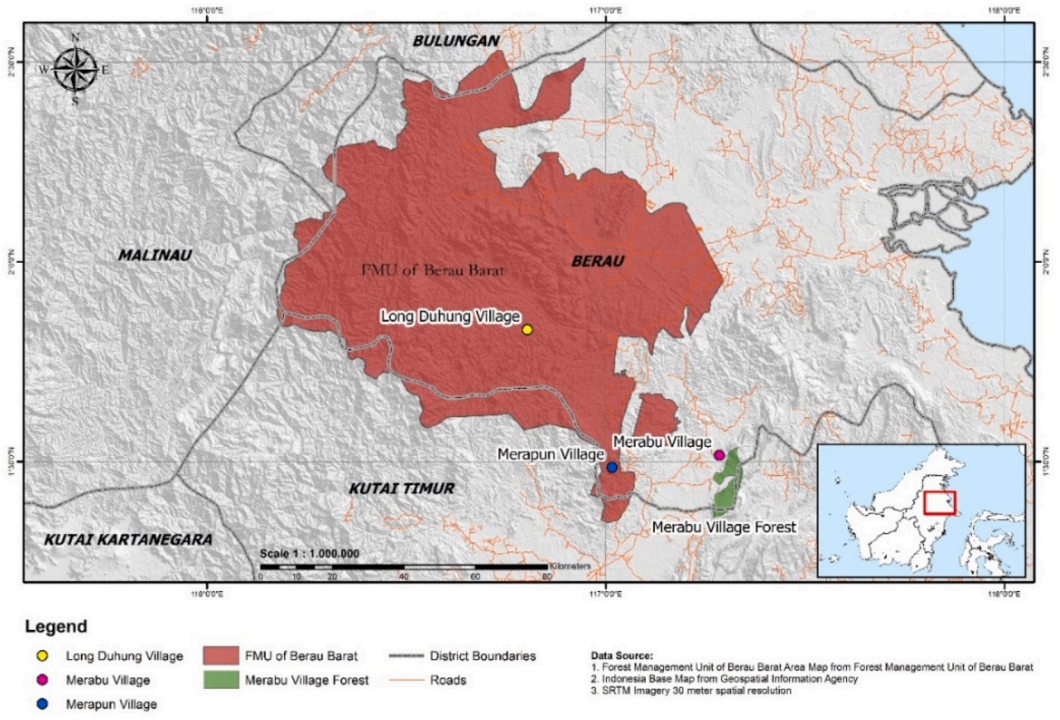


Fig. 2. Map of the research sites.

Table 1
Management region in FMU of Berau Barat.

No.	Region	Area	
		(Ha)	(%)
1.	Area of natural forest utilization permit (IUPHHK-HA)	478,914.44	60.94
2.	Area of plantation forest utilization permit (IUPHHK-HT)	15,430.66	1.96
3.	Area of oil palm plantation permit (conversion forest area)	2740.64	0.35
4.	Area without permit	288,935.26	36.75
Total		786,021.00	100.00

Source [19].

Long Duhung Village, 76 in Merapun Village, and 46 in Merabu Village. We investigated institutional robustness, arrangement, information, power, and economic interests at the organizational level.[1]

We analyzed institutional robustness by reviewing laws and regulations for forest property rights to understand contemporary forest property rights in the FMU and village forest. Analysis of institutional arrangements included the assessment of forest and forest land security in FMU and Village Forest areas. Assessment of these arrangements includes considering acceptable forest boundaries, collaborative planning, monitoring, sanction, conflict resolution mechanisms, and the right of outside actors to organize. We assessed the amount of information within each organization, their ability to enforce regulation (power), and economic preferences using policy documents and field observations.

3.4. Examining the forest characteristics and historical deforestation

The initial step of this study was to investigate the characteristics of forest resources based on biophysical attributes, such as accessibility levels, forest products and services, and the scale and scope of production processes. We used a rapid assessment technique and village-level survey approach, the results of which are reported in Section 3.1.

[1] The field survey and data collection in this study are in accordance with the research procedures and ethics, as acknowledged by the Head of the Forest Management Science Study Program, IPB University (Dr. Budi Kuncahyo) and the Director of Environment, Maritime, Natural Resources and Nuclear Policy, National Research and Innovation Agency/BRIN (Dr. Ing. M. A. Kholiq). All data and information have obtained direct approval and/or no objections (informed consent) from all key informants and respondents.

The second step consisted of spatial analysis to understand historical forest cover change in the study sites. Forest cover change was examined using multiple methods. The surveys described in Section 3.2 gathered local perceptions of current deforestation rates. However, quantitative data was the primary information for historical deforestation analysis. Deforestation was primarily measured, through spatial analysis, based on satellite imagery from Landsat TM 5, Landsat 7 ETM+, and Landsat 8 OLI. We used temporal land cover data from 2015 to 2019 issued by the Indonesian Ministry of Environment and Forestry. Previous studies have demonstrated significant and positive relationships between the Indonesian forest cover data and publicly available forest cover datasets [56]. The Indonesian forest includes approximately 20 land cover types [57]. These periodical data were selected to illustrate historical deforestation in the study sites over the last 15 years by overlaying the maps and identifying changes from forest to other land covers.

Quantification of deforestation is based on the definitions of "forest" issued by several scientific and formal institutions. This study referred to the formal definition of forest in Indonesia's Forest Reference Emission Level submitted to the United Nations Framework Convention on Climate Change (UNFCCC). It defined forest as an area of land spanning more than 0.25 ha with trees higher than 5 m at maturity and a canopy cover of more than 30% or trees able to reach these thresholds in situ [58]. For this study, deforestation is a permanent alteration of a forested area to a non-forested area due to human activities.

3.5. Examining the influencing factors of the property rights–deforestation link

The third step was to examine the factors (institutional robustness and economic preferences) influencing the relationship between property rights and deforestation. The institutional arrangement of forest governance was identified using common-pool resources [59], comprising eight attributes: clearly defined boundaries, congruence, collective-choice arrangement, monitoring, graduated sanctions, conflict resolution mechanism, minimal recognition of rights to organize, and nested enterprises. The variables used for assessing the institutional arrangement of forest rights are described in Table 2.

In this variable's scoring system: 1 means no demonstrable evidence; 2 means well-defined evidence, but further development is required, and 3 means significant evidence. The economic preferences were identified qualitatively and quantitatively by investigating the main source of income or funding for relevant key stakeholders and villagers and their preferred forest land use. The economic preferences were examined through a livelihood approach [61] to assess forest and non-forest incomes and land-use preferences.

The last step was an integrative analysis of the influencing factors (institutional robustness and economic preferences) for different stakeholders to elaborate on how the key actors treat the forest based on their knowledge, position, power, and interests, referring to Ref. [62]. The criteria, categories, and indicators used in the stakeholder analysis are presented in Table 3.

4. Results

4.1. Historical deforestation of the study sites

Spatial analysis indicates that the current deforestation rate in the Merabu Village Forest area was confined to one period (2006–2009), followed by reforestation from shrubland to a secondary forest (Table 4). The contrast occurred in the forest in Merapun Village, which showed deforestation from 2003 to the end of the 2017 observation. While the forest in Long Duhung Village was in an intermediate condition, deforestation was observed in the 2006–2012 and 2017–2019 periods.

Forest cover loss di Long Duhung was driven by the conversion of forest area for agriculture. However, in Merapun, forests are commonly converted into mixed dryland agriculture and plantations.

Table 2
Variables used in the assessment of institutional robustness.

No.	Variables	Description
1.	Clearly defined boundaries	The resource and users are clearly defined or not
2.	Congruence	a. The distribution of benefits from appropriation rules is roughly proportionate to the costs imposed by provision rules. b. Appropriation rules restricting the time, place, technology, and/or quantity of resource units are related to local conditions.
3.	Collective-choice arrangement	Most individuals affected by operational rules can participate in modifying these rules.
4.	Monitoring	Monitors who actively audit CPR conditions and appropriator behavior are accountable to the appropriators and/or are the appropriators themselves.
5.	Graduated sanctions	Appropriators who violate operational rules will likely receive graduated sanctions from other appropriators, officials accountable to these appropriators, or both.
6.	Conflict-resolution mechanisms	Appropriators and their officials have rapid access to low-cost, local arenas to resolve conflict among appropriators or between appropriators and officials.
7.	Minimal recognition of rights to organize	External government authorities do not challenge the rights of appropriators to devise their institutions.
8.	Nested enterprises (for CPRs that are part of larger systems)	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

Sources: adapted from [59,60].

Table 3
Criteria, category, and indicator of stakeholder analysis.

Criteria	Category	Indicator
Knowledge of forest property rights	Low	Key actor does not know or has a piece of unclear information on forest ownership and management rights holder, the existence of FMU and Village Forest, and the role of FMU and Village Forest
	High	The key actor knows clear information about forest ownership and management rights holders, the existence of FMU and Village Forest, and the role of FMU and Village Forest.
Position to support or against the existing forest property rights	Support	Key actor indicates support for formal forest ownership and forest rights enacted in the FMU of Berau Barat and Village Forest
	Opposition	Key actor against formal forest ownership and forest rights in the FMU and Village Forest
Power (ability) to affect forest rights policy	Low	Cannot decide to mobilize resources (human, financial, technology) to affect forest rights policy
	High	Can make a decision, or part of other systems which can decide to mobilize resources to affect forest rights policy
Interest relates to forest	Forest stand	The key actor prefers to keep the forest as their source of cash and in-kind income
	Other land uses	The key actor prefers to convert forest and use the land for other purposes

Table 4
Historical deforestation in Merabu, Long Duhung, and Merapun Villages 2000–2019.

No.	Unit	Description	Period						
			2000–2003	2003–2006	2006–2009	2009–2012	2012–2015	2015–2017	2017–2019
1	Merabu Village Forest	Deforestation (ha)	0	0	1429.92	0	(805.17)	0	0
		Annual deforestation (ha/year)	0	0	476.64	0	(268.39)	0	0
		Type of land-use change			From forest to shrub		Reforestation from shrub to secondary forest		
2	Forest area of Long Duhung Village	Deforestation (ha)	0	0	412.65	371.72	0	0	45.16
		Annual deforestation (ha/year)	0	0	137.55	123.91	0	0	22.58
		Type of land-use change			From forest to shrub	From forest to shrub			From forest to shrub
3	Forest area of Merapun Village	Deforestation (ha)	0	153.69	4345.58	2924.60	687.54	1699.69	1405.71
		Annual deforestation (ha/year)	0	25.61	1448.53	974.87	229.18	849.84	702.86
		Type of land-use change		From forest to shrub and mixed-cropland	From forest to shrub, bare land, and mixed-cropland	From forest to estate crop and bare land	From forest to estate crop	From forest to shrub, estate crop, bare land, and mixed-cropland	From forest to shrub, estate crop, bare land, mixed-cropland, and swamp shrub

4.2. Institutional arrangement and economic preference

Regarding institutional arrangements, robust institutional governance was found in the Merabu Village Forest, particularly in boundary, congruence, collective-choice arrangement, graduated sanction, and minimal recognition of the right to organize. While improvement is needed for monitoring and conflict resolution mechanisms within the village forest, the institutional setting of Merabu Village Forest demonstrated better overall robustness than that of the two other villages managing the forest. In Long Duhung Village, good institutional performance was found on boundaries' and graduated sanctions' attributes and other attributes of moderate value (except for low congruence). Meanwhile, Merapun was identified as having weak institutional performance in almost all attributes (Table 5).

As a short historical overview before the establishment of FMU and Village Forest, those three forest areas were previously managed under the District Forestry Office (DFO). DFO is the forest institution under the district government as a regulatory agency. To some extent, it also acts as an executing agency (such as forest rehabilitation and forest protection). However, the DFO had no right to manage the forest for a commercial business. The central government defined forest area boundaries under the DFO authority but did not install them completely on the ground. The collaborative arrangement and recognition of a right to organize were also low, where the central government developed the rule of forest management, and some rules were incompatible with local conditions and

Table 5
Performance of institutional setting in forest management in Merabu, Long Duhung, and Merapun Villages.

Attribute	Merabu		Long Duhung		Merapun	
	Score	Evidence	Score	Evidence	Score	Evidence
Boundaries	3	The central government clearly defined resource and user boundaries of Village Forest based on a bottom-up process. The village authority and the villagers received sufficient information concerning Village Forest. Most physical boundaries have been installed on the ground (75%).	3	There was a land use plan, RPJMK (*Rencana Pembangunan Jangka Menengah Kampung* – Village Midterm Development Plan). Here different land types are determined what to use for, made by Customary Community (Village) and the District Government, assisted by TNC. There are boundaries among land use types, such as settlement, agriculture area, protection forest, and production forest.	1	There was a government version of the land use plan, but not in a participatory way. Villagers don't know the clear border among land use types, such as protection forest, production forest, or plantation concession owned by the government, concession holder, or company.
Congruence	3	The rule of forest management was highly related to the local condition. Villagers organized by Kerima Puri developed it.	1	The rule of forest management has been developed by the central government and coordinated by the FMU. Therefore, some forest management rules were incompatible with local conditions in Long Duhung Village.	1	The central government and the FMU have developed the rule of forest management. Therefore, some forest management rules were incompatible with local conditions in Merapun Village.
Collective-choice arrangement	3	Village authority, *Kerima Puri*, and villagers fully participate in the development of Village Forest regulation.	2	The customary board of the Village and Village representative participate in the development of Sacred forest area regulation (Wungun Forest)	1	All entities affected by FMU cannot participate in the development and modification of forest regulation. All regulations come from the central government.
Monitoring	3	Forest monitoring was conducted in a participatory manner. There was a sub-division of forest security at *Kerima Puri*.	2	The FMU developed a forest monitoring system for all forest areas. However, villagers' involvement in community forest monitoring was found only for sacred forest areas (Wungun Forest).	1	The FMU developed a forest monitoring system. However, the involvement of villagers in community forest monitoring was lacking.
Graduated sanction	3	A graduated sanctions system has been developed and enforced by *Kerima Puri* and the Village authority.	3	National statutory laws developed the graduated sanction. It was also found that customary groups enacted a sanction system to protect sacred forest areas.	1	National statutory laws developed the graduated sanction. FMU and District Forestry Service should enforce it. In practice, a lack of sanctions enforcement was found.
Conflict resolution mechanism	2	The conflict resolution mechanism is not well-documented yet. Conflict resolution normally uses the existing village rules and customary mechanisms.	2	Conflict resolution mechanism was available on multistakeholder forums and partnership schemes. Segah Sub-District Multistakeholder Forum was developed to deal with conflict between villages and logging companies. A partnership scheme is being promoted to solve the double claim problem in *Wungun* forest area between Long Duhung Village and a logging company.	1	Village authority was one normative option for conflict resolution using existing government rules, but it was ineffective.
Minimal recognition of a right to organize	3	*Kerima Puri is a local forest institution from local initiatives and develops its rules without restrictions. Kerima Puri got much support from the local government and NGOs. All entities, including central and local governments, recognized Kerima Puri.*	2	Local entities have recognized the customary board of Long Duhung Village. Recognition by the central and local governments was still under the approval process.	2	There was a clear recognition by the central and local governments since the government established the FMU. But the FMU does not represent a local institution initiative, including Merapun villagers.
Nested enterprises	–	This attribute is not suitable for VF. The VF is not a part of larger enterprise systems.	–	This attribute is not suitable.	–	This attribute is not suitable.
Total score	***20***	***High***	***15***	***Moderate***	***8***	***Low***

Remarks: 1 = no demonstrable progress; 2 = progressing well, but further development is required.
3 = significant progress.

social characteristics. Forest monitoring and sanction system were fully developed and referred to central government regulations. The lack of a conflict resolution mechanism was considered a serious problem until 2011 since Social Forestry has not yet become a mainstream program in the country. Therefore, an institutional transformation from DFO to the Village Forest contributes to improving the performance of institutional robustness under the supervision of FMU. A comparison of the formal national rules on forest rights between FMUs and Village Forests is presented in Table 6.

However, evidence from the selected sites shows that not all formal rules are respected in practice (see Ref. [12]). First, a part of the production forest under the FMU of Berau Barat (*Wungun* forest area of 1958.82 ha) was claimed by Long Duhung village as a customary protected forest. Second, most of the villagers (75% of respondents) in Long Duhung and 41% in Merapun villages claimed to have rights to manage the surrounding forests. Unlike the people of Merabu village, they had not been granted a formal license to conduct day-to-day activities within the forests. Third, some villagers (8.7% of respondents in Merabu, 33.3% in Long Duhung, and 3.9% in Merapun) claimed to have rights to alter forests for other land uses. Many competing claims over forest land have occurred throughout Indonesia (as reported by Refs. [63–68]). People fighting for tenure rights have generally brought claims against the state, private organizations, and social groups [64]. There have also been conflicts between logging and oil palm plantations [69], particularly in Sumatra and Kalimantan. In Merabu village, there are no differences between formal national rights and the rules applied in managing the village forest. These findings suggest that when national and local rules clash and rights are not effectively enforced, local rules have more influence on how people respond to threats to the forest, which could result in higher deforestation. Comparing the findings on institutional robustness with historical deforestation rates suggests that the weaker the institutional robustness, the higher the deforestation and vice versa. Thus, institutional robustness is negatively related to deforestation and positively related to forest sustainability.

Regarding income, most of the key stakeholders in Long Duhung and Merapun Villages depend on other land use and non-land-use income (non-forest income). Only two stakeholders (a logging company and the Long Duhung village community) depend on forest income. Because the logging company is interested in timber, and the villagers' interest lies in non-timber forest products (NTFPs), the relationship between them was found to be competitive. It is mostly related to conflicting withdrawal rights in particular territories (e.g., the *Wungun* forest area in Long Duhung village). The two parties claim different bases for legitimation: the logging company obtained formal rights from the government, whereas the community claimed local rights under customary rules. Table 7 summarizes these economic preferences.

Most of the key stakeholders in the Merabu Village also depend on non-land-use income. Two actors (*Kerima Puri* and the local

Table 6
National formal rules on forest rights under the FMU and Village Forest.

Attribute	FMU (Representing forest rights for Long Duhung and Merapun Villages)	Village Forest (Representing forest rights for Merabu Village)
A. Forest ownership and forest function		
Forest ownership	State	State
Forest function	Conservation, protection, and production forests.	Protection and production forests.
B. Bundle of right-on forest		
Access rights	A community can access the forest. The community should get compensation for losing access because of forest area determination.	Access rights are included within management/withdrawal rights.
Withdrawal rights	- The community should get tangible and intangible benefits. A community should get compensation for losing their access and benefits from the forest because of forest area determination. - Local people can collect non-timber forest products (from protection and production forests) and timber (from production forests for non-commercial use only). - FMU should utilize timber and non-timber forest products as well as environmental services. - A private company can utilize forest products by permit mechanism.	- Protection forest: non-timber forest products and environmental services. - Production forest: timber, non-timber forest products, and environmental services.
Management rights	- The central government transfers some forest management authorities to the local government. - Forest areas can be managed by FMU, private, cooperative, individual, government, and local government firms through concession permit mechanisms. - Scope of forest management: inventory (biophysics and socio-economics), forest arrangement and forest planning, rehabilitation, community empowerment, investment development, and program coordination and integration.	- The village should establish a Village Forest institution to conduct forest management activities within the Village Forest area. - Village Forest Management Rights include forest arrangement, planning, utilization, rehabilitation, and protection.
Alteration rights	Not stated	The rights holder is prohibited from: - Developing oil palm plantations. - Changing the forest's status and function can be used for other purposes.
Exclusion rights	FMU is responsible for protecting the forest area. The concession permit holder is responsible for protecting their concession area.	The right holder is responsible for protecting their Village Forest area and its function from destruction and environmental pollution.
Alienation rights	FMU does not have alienation rights. Another party can take a concession permit with the government's approval.	Another party cannot take over Village Forest Management Rights.

Table 7
Income (or inflow) composition of the key stakeholders in Merabu, Long Duhung, and Merapun Villages.

Village	Key stakeholder	Forest income	Other land-based income	Non-land-based income	Land use preferences
Merabu	District Forestry Service			✓	Forest
	FMU Authority			✓	Forest
	NGO			✓	Forest
	Village authority			✓	Forest
	Kerima Puri	✓			Forest
	Local community	✓	✓	✓	Forest
Long Duhung	District Forestry Service			✓	Forest
	FMU Authority			✓	Forest
	Logging company	✓			Forest
	NGO			✓	Forest
	Donor			✓	Forest
	Village authority			✓	Forest
	Village community-	✓	✓	✓	Forest
Merapun	District Forestry Service			✓	Forest
	FMU Authority			✓	Forest
	Palm oil company			✓	Oil Palm
	Village authority			✓	Oil Palm
	Village community		✓	✓	Oil palm

community) earn income from the forest. However, their respective utilizations of the forest are cooperative: *Kerima Puri* manages the forest for ecotourism and earns income from environmental services, while the villagers utilize forest resources to meet their subsistence needs (non-timber products, such as wild meat, fruits, honey, and medicinal plants). Also, unlike the Merapun stakeholders, all the key stakeholders in the Merabu Village tend to prefer forest land use. Table 8 summarizes these economic preferences.

The local community living around forest areas under the Berau Barat FMU reported contrasting income structures. Villagers in Long Duhung depended heavily on the forest, which they regarded as a protected area where they collected non-wood products for their subsistence. By contrast, the villagers in Merapun were almost unconnected from the forest. Findings on the economic preferences reveal that higher stakeholder reliance on earning money from other land use is associated with greater deforestation. Conversely, the higher the income from non-wood forest products and forest services, the better the condition of the forest. People who depend greatly on the forest are more inclined to protect it.

4.3. Deforestation: reciprocal consequences among influencing factors

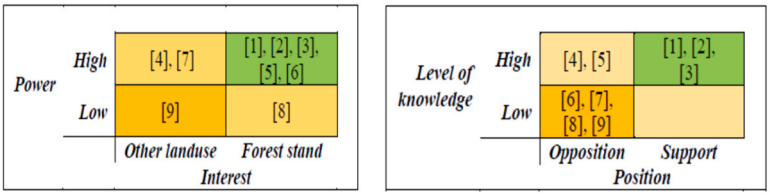
A stakeholder analysis was conducted to understand how influencing factors related to property rights are linked to deforestation. The first analysis concerns the behavior of actors in Long Duhung and Merapun Villages under the Berau Barat FMU. Its most important actors were the District Forestry Service, FMU authorities, a logging company, a palm oil company, and NGOs (such as TNC, Forclime, Pena Buluh, and Yakobi). The key actors had high relative power (Fig. 3a). In this context, power is defined as the combined measure of the number of resources and the capacity to mobilize them [62]. Key actors' awareness of formal rights was measured by their knowledge of forest ownership and management rights and the existence and role of the Berau Barat FMU and by whether they supported or opposed the forest rights policy. We found that several important actors did not support the forest rights policy and lacked sufficient knowledge. In particular, the palm oil company, the Merapun village authorities, and the communities of Long Duhung and Merapun showed low awareness of formal rights under the Berau Barat FMU (see Fig. 3b).

The interests of the key actors fall within three categories: business (the logging company and palm oil company); household income (the village authorities and communities of both Long Duhung and Merapun); and forest conservation (District Forestry Service, NGOs, donors, and the FMU authorities). These respective interests influence the actors' actions toward the forest. In this

Table 8
The structure of income in 3 selected sites (on average, annual income per household).

Income source	Long Duhung Village		Merapun Village		Merabu Village	
	Average	%	Average	%	Average	%
Agriculture	516,958	1.09	2,002,155	3.78	1,858,089	5,04
Livestock	101,042	0.21	188,095	0.36	61,333	0,17
Fishery	1,370,483	2.89	369,786	0.70	171,067	0,46
Business	800,000	1.69	4,851,429	9.17	3,907,556	10,60
Wage	22,685,083	47.83	44,731,571	84.52	10,652,680	28,90
Remittance	986,667	2.08	250,000	0.47	2,795,556	7,58
Wood	–	–	14,071	0.03	–	–
Forest Service	–	–	–	–	13,650,000	37,03
NTFPs	20,965,133	44.21	519,767	0.98	3,762,204	10,21
Total	47,425,367	100	52,926,875	100	36,858,484	100

Source: primary data from household survey (2015).



Notes: (1)_District Forestry Service; (2) FMU authority; (3) Logging company; (4) Palm oil plantation company; (5) NGO; (6) Village authority of Long Duhung; (7) Village authority of Merapun; (8) Community of Long Duhung; (9) Community of Merapun.

Fig. 3. Relative power and interest (a), and level of knowledge and position (b) of related key actors on forest rights in Long Duhung and Merapun Villages under the Berau Barat FMU.

regard, we identified four stakeholder actions: (1) forest protection (District Forestry Service, FMU of Berau Barat NGOs, donors, Long Duhung village authorities, Long Duhung village community); (2) forest conversion to other land uses (palm oil company, Merapun village community), (3) selective cutting (logging firm); and (4) do nothing (Merapun village authorities).

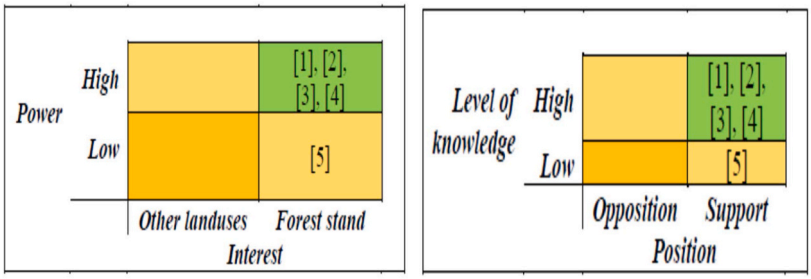
Stakeholders' actions in the forest area under the Berau Barat FMU produced financial and institutional outcomes. The logging company, oil palm plantation, Merapun village community, and Long Duhung village community-generated financial income. Meanwhile, the District Forestry Service, FMU of Berau Barat, NGOs, donors, Merapun village authorities, and Long Duhung village authorities gained institutional performance.

The second analysis of the actors' behavior focused on the Merabu Village. The most important actors were the District Forestry Service, NGO (TNC), village authorities, and Kerima Puri. They reported a high awareness of formal rights within the village forest, high power, and support for the forest rights policy of the Merabu Village Forest (see Fig. 4a and b).

Key actors of the Merabu Village Forest acted in two ways: (1) protection (the District Forestry Service, NGOs, village authorities, and *Kerima Puri*) or (2) do nothing (local community). Their respective actions were driven by different interests: business (village authorities and *Kerima Puri*), household income (local community), and environmental services (District Forestry Service and NGOs). Another factor influencing their actions was the pay-off; the village authorities, *Kerima Puri*, and the local community generated a financial profit, while the District Forestry Service and NGOs gained institutional performance.

A stakeholder analysis of the two forest management schemes reveals that the relationship between FMU and village actors with outside organizations is based upon shared interests. The alliance between a palm oil company and Merapun villagers interested in land conversion for household income resulted in the conversion of forest to other land uses. Village and palm oil company actors had low awareness of formal forest rights, and one (the palm oil company) had high power. Another alliance between TNC (an NGO) and the Long Duhung village community tended to protect the forest; their pay-offs differed but shared a common interest. They showed different levels of awareness of formal forest rights and different levels of relative power. The same alliance pattern resulting in zero deforestation was found between TNC and the Long Duhung community. These three cases imply that shared interests determine alliances and that the relative power of the community's alliance has an important influence on how people act toward the forest.

Though awareness of formal rights and regulations shapes different alliances' actions, forest property rights determined by formal rules are insufficient to protect forest areas from conversion. Actors' behavior toward the forest is predominantly based on their interests. When both formal rights and the key actors' interests prioritize protecting the forest, better forest performance can result. In contrast, forest conversion is more likely when their interest lies in other land uses. Though forest property rights alone were not indicative of forest conservation, institutional arrangements were associated with greater forest conversion. The District Forestry Service and FMU actors are most interested in enhancing institutional performance. Although the District Forestry Service and FMU (as government representatives) have high relative power and a strong interest in the forest, their pay-off is institutional performance (administrative approach). Since these organizational priorities do not reflect the economic preferences of some actors, they were not



Remark:
1. District Forestry Service; 2. NGO; 3. Village authority; 4. Kerima Puri; 5. Local community

Fig. 4. Relative power and interest (a), and level of knowledge and position (b) of key stakeholders of Merabu Village Forest.

strong alliance options for the communities. It demonstrates a weakness in the institutional arrangement concerning collective action. The case of Merabu village offered insight into how the high relative power of the government aided in meeting community interests; transferring forest management rights to the village increased the performance of its institutional settings. Ultimately, a strong institutional setting provides support for controlling deforestation.

Under the Berau Barat FMU, Long Duhung Village and Merapun Village represent different outcomes. Long Duhung village had a high level of forest income resulting in good forest performance, although the local rules clashed with national rules, and the village's institutional setting was weak. While Merapun village also had a weak institutional setting and local rules that clashed with formal rights, its forest income was very low, resulting in extensive deforestation around the village. In these two cases, households report similar interests and pay-offs, but their economic preferences differed largely due to the interests of alliance partners. It reveals that economic preferences are more important than formal rules or institutional robustness in determining forest performance. These cases also confirm that the community's alliances are important in determining the community's actions.

5. Discussion

This study indicates that the devolution of forest management associated with institutional robustness, economic preferences, and forest property rights will influence forest cover change. This study reveals three patterns of combinations between institutional robustness and economic preferences. Combination 1 (high institutional robustness–high economic preference for forest use) results in relatively little deforestation, as Merabu Village Forest shows. Combination 2 (weak institutional robustness–low economic preference for forest use) results in increased deforestation, as shown by Merapun village under the Berau Barat FMU. Combination 3 (weak institutional robustness–high economic preference for forest use) results in relatively high forest cover performance, as Long Duhung village shows.

Two main findings have important practical implications. The first highlight is a complex interaction between factors influencing the relationship between forest property rights and forest cover change. One implication is the importance of local rules for forest rights, which significantly impact forest performance more than national (formal) rules. Thus, perceived tenure security is not necessarily related to legal status but is influenced by various factors, such as the strength of traditional claims [70]. Forest performance at the three research sites was also unrelated to the level of institutional robustness. Zero deforestation can occur under low institutional robustness, as demonstrated by combinations 1 and 3. Another important factor is economic preferences. Their interests largely determine the people's response toward forests. Therefore, to promote sustainable forest management, economic preferences and the interest of alliance partners must favor forest conservation.

Deforestation is usually low when people economically depend on the forest (higher non-timber forest income). This finding supports the argument that variation in property rights institutions is explained by economic factors [14,51,71,72]. Also, local people appear very responsive to economic opportunities: they do not hesitate to change their livelihood system if this could increase their income [73]. Lessons from other sites demonstrate that forest conservation regulations should respond more to communities' needs [17,44,53]. The current design of property rights fails to consider the broader economic context in which reserves must generate a viable revenue stream [74]. [75] similarly contended that the missing link between conservation and livelihood security is supply-demand interventions. Therefore, this study implies the need for economics-based policymaking to reduce deforestation in Indonesia.

The second main finding of practical significance is that the local forest organization is vital in determining actors' behavior toward the forest. The Merabu Village Forest demonstrates the benefits of transferring forest management rights to the villagers. The program has been effective in encouraging the local implementation of formal rights and in increasing the effectiveness of the institutional setting. Centralized management seems to be a poor choice for forest performance in Indonesia. Local users and their representative institutions should possess property rights that transform them into claimants and proprietors to achieve effective decentralization [37]. By contrast, the wide range of FMU areas generates a complicated reciprocal consequence among related actors and influencing factors, making it difficult for property rights to contribute to sustaining forests effectively. However, the GoI is contemplating scaling down FMUs to cover smaller areas. It will localize stakeholder interests and economic preferences and improve the institutional robustness of the forest governance system. Co-management is also recommended to ensure that FMUs effectively strengthen institutional robustness concerning forest dwellers. The effectiveness of local forest organizations is related to their capacity to enforce rights. When forest right holder experiences difficulties monitoring and enforcing their rights, the forests become de facto open-access resources [76,77]. In this situation, land rights are sought through deforestation: the forest is converted to claim land rights, even with de jure rights. In this regard, deforestation could be considered a risk management strategy [52]. Property rights insecurity reduces the present value of forests and fosters forest conversion into agricultural and pasture lands.

Looking at the case of Merabu Village Forest compared to forest management in Long Duhung Village and Merapun Village as a counterfactual, it shows that the different outcomes in forest governance at the village level and avoided deforestation have more to do with the different socio-economic and governance contexts of each village rather than the extent to which forest management rights have been devolved. It is in line with the studies of [55,78,79], and [54], which were conducted in Various Village-Forests in Kalimantan and Sumatra. In terms of socio-economics factors [55], found that the performance of Village Forests in avoiding deforestation is fundamentally affected by anthropogenic circumstances over time and space. Socio-economic contexts influence local institutions [78]. Accounting for these in program design and implementation may help address existing social inequalities that influence achieving joint social and ecological objectives and the importance of institutional setting. In line with [79], organizations outside communities and governance networks play essential roles in achieving multiple social and ecological objectives.

Deforestation is typically high because anthropogenic pressure is intense [54]. For communities within the boundaries of

Permanent Production Forest Areas where cash crop plantations are the dominant livelihood sector, land availability for plantations is reduced by Community Forest, increasing pressure on intensive agricultural production. Because smallholders and company plantations exist in this zone, the success of forest governance will require close cooperation with both sectors.

Finally, the study confirms that devolution in natural resources, particularly property rights, is foundational for understanding resource use [77]. Sustainable forest resource management requires identifying property rights allocations [39]. Clear property rights in forests incentivize the efficient use of resources, and strengthening these rights is a long-term development challenge [76,80]. Tenure security is important for assuring rights, establishing responsibilities, preventing a resource rush, and protecting existing livelihoods and rights [46]. When the two influencing factors are not well-managed, they will become sources (the holes) of forest resource loss. This concept supports the development of a science-policy interface, especially in the integration component of the Research-Integration-Utilization (RIU) model [81]. The RIU model has been used to analyze science-policy interactions in many cases [82–86]. It is in line with the growing need of policymakers for science-based policy advice to guide their decisions on natural resources, particularly in the forestry sector [83,86].

Integration is a very important step because it can selectively link science and policy, which are otherwise separate, independent, and follow different forms of reasoning, to generate science-based solutions [87–90]. No automatic connection between the two spheres of science and policy leads to the linear application of science in policymaking. Integration requires orienting research toward political and practical problems to describe and solve them [87,90]. The concept follows the criteria: orientation toward forest sustainability –or minimum deforestation-as a public goal [91,92], relevance for practical problems with forest property rights [93,94], and target group-oriented intermediation [95, 96]. However, actor orientation has some weaknesses (in terms of alliances). Specific attention should be paid to involving external allies who can exert political pressure on practitioners to constructively cooperate with researchers and allies who use scientific findings in their everyday reality.

6. Conclusions

This study confirms that devolution in forest management associated with property rights arrangement is very important to conserve forests and provides an alternative approach to analyzing deforestation from a forest rights perspective. This study reveals that combining influencing factors in a single analysis helps explain the relationship between property rights and deforestation. The study's framework also helps to explain if and how forest property rights can effectively control deforestation. This study confirms that a complex interaction mediates property rights' link to deforestation between the passage of robustness of the institutional settings and economic preferences. The interaction of these influencing factors determines how property rights are implemented and how actors respond, with impacts on forest cover. The existence of rules that determine property rights can promote forest conservation when people's interests are served by forest land use, even if there exist overlapping claims or conflicts between informal and formal rules. Economic preferences play an important role in shaping whether property rights control deforestation. This research suggests addressing deforestation through a devolution program and an economic approach toward rural livelihoods.

Author contribution statement

Yanto Rochmayanto: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Dodik Ridho Nurrochmat: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Bramasto Nugroho: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Dudung Darusman: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data. Thorkil Casse: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

Arif Satria: Contributed reagents, materials, analysis tools or data.

James Thomas Erbaugh: Analyzed and interpreted the data; Wrote the paper.

Donny Wicaksono: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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