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REGULAR RESEARCH ARTICLE

Assessing Indigenous Forest Management in Mount Merapi National Park Based on Ostrom's Design Principles

Catharina Depari [1,*]

AFFILIATIONS

[1] Universitas Atma Jaya Yogyakarta, Yogyakarta, Indonesia
*Corresponding author: catharina.depari@uajy.ac.id

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ABSTRACT

Despite their abundant potential to support the current understanding of environmental changes and improve natural resource management, Indigenous Peoples remain excluded from policymaking. Such marginalization partly stems from the formal government-driven adoption of colonial-style controls over natural resources, which historically had marginalized local populations politically and economically. Using the case of the Pelemsari sub-village, this article attempts to analyze the robustness of Common-Pool Resource institutions in Mount Merapi National Park according to Ostrom's design principles. The methods used for this purpose are participant observation, document reviews, and semi-structured interviews. The research findings indicate social capital as the main factor that contributes to the local institution's robustness. Nevertheless, the principles corresponding to authority suggest challenges of engaging communities in reforestation and conservation programs. The shortcomings in these principles contributed to the people's slow recovery and ongoing degradation of forest diversity in Mount Merapi after the eruption in 2010.

KEYWORDS

Colonial forest management; Indigenous forest management; Ostrom's design principles; National park; Merapi.

1. INTRODUCTION

Maintaining ecosystem balance is deeply rooted in the traditions of indigenous populations (Berkes et al., 2000; Finn et al., 2017; Suminar, 2023). Over generations, local institutions accumulate knowledge of how to manage natural resources and predict disasters based on observations and social-ecological memory (Ford et al., 2020). Local knowledge is an asset that helps improve resource management and provides unique insights into issues of disaster and ecosystem change (Berkes & Folke, 2002). Local communities serve as a key source of that understanding. However, rights over natural resources remain excluded from policymaking, which according to scholars, is attributed to the colonial legacy maintained by governments (Peluso, 1992; Wong et al., 2020).

Relative to other natural resources, forests are considered highly vulnerable to conflict of interest for their common pool resources (Agrawal, 2007), which are difficult to be divided, controlled, and managed (Bruce & Mearns, 2001). Numerous cases of forest conflicts have been largely studied on this account (Dhiaulhaq et al., 2017; Fleischman et al., 2014; Lukas & Peluso, 2020; Maring, 2022; Nindyatmoko et al., 2022). Among them is Java, which provides an important example of complex land tenure conflicts where strict colonial policies had once controlled its forests (Peluso & Vandergeest, 2001). Villagers within and adjacent to forest boundaries in Java have experienced many physical burdens from cultivating trees and caring for them, as well as cutting down trees and hauling them during the colonial period (Kosuke et al., 2023; Peluso, 1992). As of today, communities are still considered as threats to the environment (Enters & Anderson, 2000). Despite new policies that allow for partial

tenure and use of the forest, the government still formulates regulations (Kosuke et al., 2023) that restrict communities from exercising their customary rights. This legacy of marginalization makes efforts in motivating community participation in conservation programs challenging.

In Indonesia, nearly 48.8 million people live in forests and make use of their natural resources. According to the Central Statistics Agency (*Badan Pusat Statistik or BPS),* of 120.50 million hectares of its forests recorded from 2017 to 2020, about 2.10% is situated in Java comprising 735,000 hectares of protected forests, 423,521 hectares of limited production forests, and 1.39 million hectares of production forests (BPS, 2016). Of those protected forests, about 6,410 Ha cover the Mt. Merapi region. The volcanic ash provides for a fertile arable environment, improving the soil and enabling three harvests per year. This is highly productive when compared to elsewhere in Indonesia. This condition has resulted in people living on less productive lands to move further up into the volcano's flanks (Troll et al., 2015: 138). Nevertheless, the sustainability of their rights over forests is continuously challenged by state policies, given the resource's ecological roles for much larger interests, namely water consumption and tourism-based revenue. With the loss of autonomy, poverty continues to overshadow livelihoods which to some extent, intensifies distrust of government (Murtazashvili et al., 2019). As a result, the government—owing to its lack of financial capacity—failed to optimize reforestation after the eruption in 2010. Of 450 Ha of damaged land, only about 90 hectares had been completely reforested by 2017. To expedite reforestation, the government divided reforestation programs into phases promoting exotic species *Acacia decurrens* to take over damaged lands (Hapsari, 2017; Suryawan et al., 2015). This practice, however, could jeopardize biodiversity and water supply of the forest (FAO, 2022) and result in undesirable environmental changes. Long-tailed *macaques*, for instance, started to invade land plots in the forest, making this species a serious threat to dairy farmers (BTNGM, 2010; Utomo, 2022).

Elinor Ostrom's work outlines design principles for governing commons, which serves as a point of departure for this article. Relying on empirical analyses of varied common pool resource institutions (CPR) in different settings, the breakthrough shows that when certain principles are met, people can sustainably manage their natural resources and avoid overexploitation of a resource that can lead to ecological degradation (Wilson et al., 2013). The principles had been largely applied in CPR studies for varying purposes: improving the applicability of the principles at the local level (Cumming et al., 2020; Weeden & Chow, 2012), developing principles to address risks from emerging technologies (Stern, 2011), evaluating local institutional robustness in managing fisheries (Klain et al., 2014) and forests (Lopez & Moran, 2016; Perfect-Mrema, 2022), as well as analyzing institutional gaps in different CPRs (Rahman et al., 2017). Despite critiques of oversight on social relations variables, external factors, and complexity (Cox et al., 2010), the principles are compatible across numerous cases and CPR settings worldwide.

The objective of this study is to analyze the robustness of the Pelemsari sub-village's institutions in governing forest resources in Mt. Merapi relative to Ostrom's design principles. This community faces ecological crises in the context of prevailing restrictions from national parks and the impacts of eruptions. After the 2010 event, they collectively relocated from their homes within 5 km of the summit to an area 3 km further to the South and maintained traditional ties with their homes and the forest. Using a qualitative research approach, this study employs methods of participant observations, document reviews, and semi-structured interviews. Both the principles and critiques provide invaluable guides for this study to analyze the relative

success/failure of the institution in dealing with uncertainty after the 2010 event. It is expected that the findings could provide insights into commons scholarship on forest use in a volcanic and culturally-distinct region.

2. LITERATURE REVIEW

2.1 CPR design principles

Failures of centralized conservation programs in the past, coupled with global demand for governance reform has forced governments to reposition resource management initiatives towards increased rights and authority in local hands (Agrawal, 2003; Saunders, 2014). Drawing from ideas of decentralized governance, formal agencies have been motivated to adopt Ostrom's design principles into their policies and projects (Agrawal, 2003; Saunders, 2014). This set of principles is considered pragmatic because it helps simplify complex information and provides efficiency of replication (Saunders, 2014).

Ostrom's principles were initially formulated based on her examination of fourteen cases from around the world. Representing the characteristics of local institutions in managing uncertainties, the principles comprise clearly defined boundaries, congruence between appropriation, provision rules, and local conditions, collective-choice arrangements, monitoring, graduated sanctions, conflict-resolution mechanisms, minimum recognitions of rights by external authorities, and nested enterprises (Ostrom, 1990).

2.2 Critiques of design principles

The universalism of Ostrom's theory makes it applicable to almost all decision-making arenas (Agrawal, 2003; Saunders, 2014). However, this formulation is not without criticism. *First,* the theory ignores the pluralistic aspects of the community. Community is simply viewed as a small spatial unit and homogenous social structure that shares common interests and norms, rather than as what comprises multiple interests and actors, local-level processes, and institutional arrangements (Agrawal et al., 1999; Saunders, 2014).

Second, it ignores the external social-political-institutional and physical factors that shape context (Agrawal, 2003; Cleaver & De Koning, 2015; Cox et al., 2010), the complexity, uncertainty, and dynamics of multiple factors (Cleaver & De Koning, 2015; Saunders, 2014), and relationships among institutional variables (Agrawal, 2003) that include markets, states, and communities (Cox et al., 2010).

Third, it fails to define the commons in terms of their complex dynamics**.** Ostrom (1990) asserts that "commons are resources embedded in a specific form of social relation" and "largely self-given rules are best suited to form appropriate institutions" (Ostrom, 1990). The postulate, however, does not specify the number of rules that must be self-given, or the users targeted by the rules, aspects of a community, and relationships between rules-making, resources, people, and other factors (Euler, 2016). Rather than a resource, a common is a form of social organization through which resources are (re)produced and by which reciprocity is fostered (Fournier, 2019).

Fourth, it ignores the complex factors influencing collective decisions and actions. Users are not purely placed-based, rational resource users with fixed identities and a common purpose. Their rational choices and decisions are shaped by different factors which include their interdependency rather than the economy (Saunders, 2014), social systems, power dynamics, routinized practices (Cleaver & De Koning, 2015), collective interests, and the goods and services the CPR provides them (Saunders, 2014).

2.3 Reformulated design principles

In 2010, Cox et al. (2010) analyzed 91 cases and found that the principles are empirically well-supported. They divided principles 1, 2, and 4 into two sub-components (Table 1) for their analysis (Cox et al., 2010). Among these, principles 2 and 5 are worthy of attention. According to Baggio et al. (2016), the congruence between rules and local conditions, the proportionality between investment and extraction, and combining congruence with graduated sanctions would lead to a higher chance of an institution's success (Baggio et al., 2016).

Table 1. Cox et al.'s (2010) reformulated design principles serve as the study's theoretical framework.

Design principle	Description
Principle 1 A: User Boundaries	Clear boundaries between legitimate users and nonusers must be clearly defined.
Principle 1 B: Resource Boundaries	Clear boundaries are present that define a resource system and separate it from the larger biophysical environment.
Principle 2 A: Congruence with local conditions	Appropriation and provision rules are congruent with local social and environmental conditions.
Principle 2 B: Appropriation and provision	The benefits obtained by users from CPR as determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules.
Principle 3: Collective choice arrangements	Most individuals affected by the operational rules can participate in modifying the operational rules.
Principle 4 A: Monitoring users	Monitors who are accountable to the users monitor the appropriation and provision levels of the users.
Principle 4 B: Monitoring the resource	Monitors who are accountable to the users monitor the condition of the resource.
Principle 5: Graduated sanctions	Appropriators who violate operational rules are likely to be assessed and graduated sanctioned (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or by both.
Principle 6: Conflict-resolution mechanism	Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.
Principle 7: Minimal recognition of rights to organize	The rights of appropriators to devise their own institutions are not challenged by external government authorities.
Principle 8: Nested enterprises	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

2.3.1 Principle 1 A: User boundaries

According to Cox et al. (2010), the clear boundaries principle is separated into user boundaries and resource boundaries. Critiques of this principle are that boundaries are too rigid while "fuzzier social and geographic boundaries are needed to facilitate more flexible concession between respondents" (Cox et al., 2010). Access rules are often politically malleable, making spatial boundaries fluid (Turner, 1999). In particular, CPRs such as fisheries in the Pacific Islands grant community access based on social relationships, rules, and kinship that are influenced by external pressures, causing spatial boundaries to be constantly redefined (Ruddle & Nishinomiya-shi, 1996). Boundaries can be fluid. However, they still have some degree of access restrictions. The local institution of the Upper Berau Adat Area in Kayan Mentarang National Park

supports this argument. The villagers formed customary laws to regulate access to gaharu and restrict outsiders from collecting them. Depending on the extent to which the collector was a part of the community (e.g., long-term resident, non-resident), village leaders served as boundary keepers to decide level of access granted (Wollenberg, 2003).

2.3.2 Principle 1 B: Resource boundaries

Resource boundaries refer to the boundaries around which the resource system is managed and used (Cox et al., 2010). Resource boundaries define the specific use(s) of land and users who have rights to access it. Without clear boundaries, the eligible users can be ripped off by outsiders, lose high returns for their efforts, and have their resources destroyed by others. Clear boundaries, however, do not guarantee that the eligible users' risks to conflicts would decrease as the resource management system is also affected by factors such as the number of resource units they harvested in or extracted from the resource. The rules limiting appropriations and/or mandating provisions are thus needed for making the institution effective (Ostrom, 1990).

An example of the implications of this principle on CPR institutions can be found in Danau Sentarum National Park. Unclear resource boundaries of the park had created long-standing conflicts between Dayak Iban and Malay communities which relied on forest and fish resources. The ambiguity is present because of the historic use of natural features like hills, rivers, and trees, to mark the boundaries of those resources (Yasmi et al., 2007)

2.3.3 Principle 2 A: Congruence with local conditions

Cox et al. (2010) separated two conditions in this principle into the congruence between appropriation and provision rules with local conditions and that between appropriation and provision rules (Cox et al., 2010; Ostrom, 1990). To sustain resource use, appropriation rules and provision rules should be congruent with the local social-ecological conditions. Otherwise, the management would be at risk for violations, causing the governance to lose its legitimacy (Al Mamun & Brook, 2015).

For example, the village authority of Duru-Haitemba Forest Reserve in Tanzania managed an inventory of the forest to assess the stock of the resource. Thereafter, rules were developed to control exploitation by applying one fundamental principle, that is the volumes being harvested annually must not exceed the mean annual increment of the forest (Kajembe et al., 2003).

2.3.4 Principle 2 B: Congruence between appropriation and provision rules

This principle means that the benefits gained by users from a CPR is determined by appropriation rules, which should be proportional to the input required in the form of labor and material resources or money as determined by provision rules (Cox et al., 2010; Ostrom, 1990).

For an indigenous community such as Amarasi, rules are driven by their belief system. Living near Herman Yohanes Park in Kupang, they believe that if they destroy the forest, the spirit will punish them in the form of natural disasters. The cost the people pay by not cutting down trees is believed to give them a benefit in the form of life safety. This belief also caused them to value the park as a sacred forest (Van Ast et al., 2014).

2.3.5 Principle 3: Collective-choice arrangements

This principle stresses that individuals affected by operational rules can participate in modifying the rules so as to better fit their goals (Cox et al., 2010; Ostrom, 1990). Despite users devising good rules for themselves, this would not guarantee compliance

to persist. Users can fail to commit, bypass rules, or propose new institutional forms to facilitate their interests, particularly when temptations arise (Ostrom, 1990). These temptations include internal and external factors influencing one's decisions to comply or not (Ramcilovic-Suominen & Epstein, 2012). Fear of entanglement in law enforcement, fines, and imprisonment are among those that affect one's compliance, thus, are often employed in the context of protected forests. Government can affect compliance through means such as technology, assistance programs, and circulated dissemination, and can be negotiated through local leaders (Resosudarmo et al., 2023).

Participation is a critical indicator for this principle in promoting an effective institution (Haryanto et al., 2022; Van Ast et al., 2014). It empowers people to mobilize their capacities, be it social actors managing projects, making decisions, and controlling activities (Wells et al., 1992). Participation, however, should be activated throughout the process. The authority of commercial forestry in Oaxaca, Mexico, for example, actively involved residents in decision-making, which expands from access to general management to the opportunity to approve forestry plans. These conditions enhance the legitimacy of the foresters' decisions and in turn, the forest quality (Antinori & Rausser, 2003).

2.3.6 Principle 4 A: Monitoring users

Cox et al. (2010) divide this principle into monitoring users and monitoring the resource. Monitoring users refers to monitors who are accountable to the users and oversees the appropriation and provision levels of the users. This principle apprises users who do not comply and informs strategic behaviors of those who comply toward effective rule enforcement (Cox et al., 2010). For example, the Lamza community in Africa established the *hiza'ti* system (woodland enclosure) to restrict outsiders from cutting trees and grazing. The system is led by a village assembly which is responsible to devise laws and solve conflicts. The assembly appoints one guard who decides the payment and receives fines levied. The guard then selects a father of herders to watch over herders' activities and enforce sanctions (Robson et al., 2014).

The monitor can be the users themselves. As long as they are a small-sized group with frequent communication, cultural homogeneity, and adherence to shared norms; reciprocity, effective, easy, and low-cost monitoring is likely to occur (Ostrom et al., 2002). Once users are engaged in rules-making processes (Pandey, 2010; Ostrom & Nagendra, 2006) and given the right to harvest, they are likely to engage in local monitoring and sanctioning (Coleman & Steed, 2009).

2.3.7 Principle 4 B: Monitoring the Resource

Monitoring the resource refers to oversight over who are accountable to the users to supervise the resource's condition. Effective, easy, and low-cost monitoring can be achieved if the resource is stationary in nature, small in size, and clear in its boundaries (Ostrom et al., 2002). A large resource's territory such as forests, therefore, can exceed the institution's capacity to govern given the high cost needed to define boundaries, monitor uses, and develop knowledge (Dey & Chattopadhyay, 2017; Ostrom, 2009).

Monitoring may not perform well if users do not directly benefit from improved resources. Monitoring thus becomes accountable to those who most rely on the resource (Cox et al., 2010). For example, communities in four villages bordering Prey Lang forest in Cambodia actively monitored their forest from illegal loggers despite them lacking power, funding, and land-tenure rights. Their reliance on forest resources and fear of threats of losing resources motivated their collective monitoring (Turreira-García et al., 2018)

2.3.8 Principle 5: Graduated Sanctions

This system is created to discourage violations of collective rules and assure quasi-voluntary compliance, that is, compliance motivated by a willingness to cooperate only when the collective objectives are achieved and other users also comply with the rules (Ostrom, 1990). A threat to the institution is when users violate the rules repeatedly (Ostrom, 2000), thereby, graduated sanctions are needed. Graduated sanctions advance incrementally based on the severity or the repetitions of violations. They help maintain community cohesion, maintain proportionality between the severity of violations and sanctions (Cox et al., 2010), and warn users that if they do not comply, they must pay higher sanctions, and at worst, be forced to leave the community (Ostrom, 2000). However, in some cases where strong social capital is present, graduated sanctions may not be needed (Cox et al., 2010).

Villagers of the Upper Berau Adat area, for instance, imposed graduated sanctions to limit outsiders to collect *gaharu* in their territory thus affecting only those outside their members. Non-villagers must obtain the village head's permission and pay fees but those who entered with no permission were to be sent home, seized, and charged a fine of IDR 50,000 per collection trip to the village leader (Wollenberg, 2003).

2.3.9 Principle 6: Conflict-resolution mechanism

This principle aims to reduce conflicts over a resource and resolve disputes. The continuity of the mechanism relies on whether the cost is relatively low (Cox et al., 2010). When developing the mechanism, Ostrom (1990) warns that some concerns must be addressed such as what constitutes a conflict and how fairness is applied to different levels of violation.

In some cases, conflict-resolution mechanisms can be informal and local leaders become the conflict resolvers (Ostrom, 1990). For example, Dolakha's community in Nepal always put forward compromises and places the elders as conflict mediators. A conflict is only considered severe only when it harms social ties. Their mechanism is less antagonistic due to its accommodative nature and concern for social ties as a critical factor in managing problems (Upreti, 2001).

2.3.10 Principle 7: Minimum Rights Recognitions by External Authorities

One of the key factors affecting CPR institutions is the local capacity to exercise rights in devising and creating their institutions without being challenged by external entities (Ostrom, 1990). External agencies' imposed rules and lacked understanding of local conditions would, in turn, disadvantage the agency (Cox et al., 2010). There are two approaches typically employed to solve them: economic rationalism stressing that people respond primarily to economic stimuli (Stern, 2008), and human-centered stressing local participation (Wells et al., 1992).

For example, the managers of protected areas in La Amistad Biosphere Reserve, Costa Rica, banned shifting cultivation agriculture and hunting in areas where Bribri and Cabecar communities traditionally depended on. Those rules, interestingly, were inconsistent with the policies outlined in the formal plan that otherwise permits the traditions to exist. On top of that, the lack of participation of local communities in policy-making reduced the community's trust in the government and the legitimacy of the formal management (Sylvester et al., 2016).

2.3.11 Principle 8: Nested Enterprises

This principle recognizes all the governance activities as those operating in multiple layers of nested systems involved in resource management (Ostrom, 1990). Nesting smaller CPR systems within a large system is critical because social systems have cross-scale relationships when organizing a complex CPR and need mechanisms to facilitate

cross-scale cooperation. Therefore, this principle must be framed in connection with a horizontal linkage (intracommunity linkage) and a vertical linkage (multiple jurisdictional levels) (Cox et al., 2010).

For example, the protected areas of the East Usambara Mountains in Tanzania faced environmental degradation due to industrial logging that promoted the expansion of exotic *Maesopsis*. A restoration project was carried out by involving regional authorities, ministries, an international conservation union, and the residents. The programs were centered on the community which include promoting income-earning substitutes, funding road repair and maintenance, hiring villagers to plant boundary trees, establishing village tree nurseries, and promoting small-scale cooperative enterprises. Many claimed that the project had a promising success for its intensive cross-scale collaborations (Wells et al., 1992).

3. RESEARCH METHODS

3.1 Research context

Yogyakarta is a center of Javanese culture that exists under the influence of the ancient Javanese kingdom. Retaining the feudalism system within Indonesia's modern democracy, its palace is built with respect to the positions of the Indian Ocean and Mt. Merapi, which is believed to house the spirits of ancestors. Politically, the Sultan serves as a governor (De Jong & Twikromo, 2017) and holds absolute power of controlling land in the region (Onghokham, 1983). Having this dualistic power, the Sultan is often censured for supporting unpopular policies among which are postdisaster relocations and the national park stipulation.

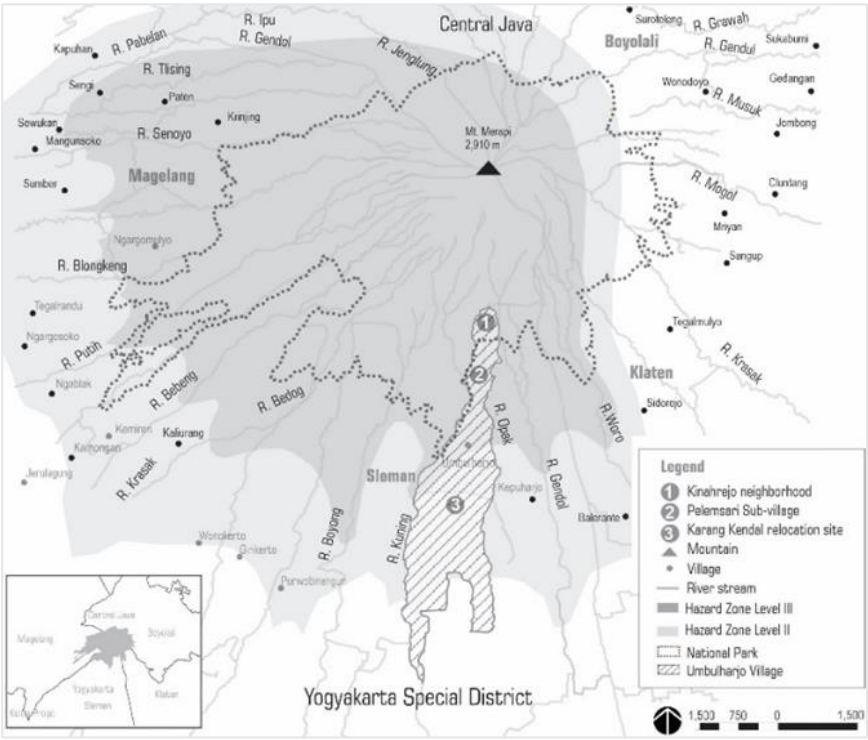

Figure 1. The map shows the location of the Pelemsari sub-village in Hazard Zone III before and after the eruption in 2010.

Merapi is located about 30 km north of metropolitan Yogyakarta and is the most active volcano in Indonesia (Hidayat et al., 2003; Mei et al., 2016). Since 1800, the volcano claimed over 130,000 casualties (Thouret et al., 2000) yet today is home to about 1.6 million people (Surono et al., 2012). Among the eruptions in the 20th century, the event in 2010 had the most significant impact on local livelihoods. It damaged about 435,000 ha of Merapi's land, claimed about 367 lives (Bakkour et al., 2015), killed about 1,961 cattle (Muhammad, 2010), and forced nearly 15,366 people to evacuate (BNPB, 2011). In 2011, the government issued a renewed hazard map regulating the types of development permitted in three high-risk zones (BNPB, 2011). Among these, Hazard Zone III is the highest risk of eruption impact and covers thirty sub-villages. The government then annexed this zone as a protected forest, which consequently forced inhabitants to relocate (BNPB, 2011). Of the 3,612 households targeted, around 1,059 refused to relocate (Suryandari et al., 2013).

Pelemsari community, being subjected to relocation by authorities (BNPB, 2011; Ghafur, 2012) face threats of losing access to the forest they depended on. They are well-reputed for their elders who were continually appointed by the Sultan to lead the rite called *Labuhan Merapi*. One of these individual's was the volcano's spiritual guardian, Maridjan, who defied the Sultan's evacuation orders during the eruptions of 1994, 2006, and 2010. The last event claimed his life, including 36 other residents, and forced the survivors to relocate to an area about three kilometers from their original location. In 2011, they autonomously organized a relocation after learning that the governor responded slowly to their demand for issuing certificates of former homes in the high-risk zone. To fund the relocation, they collectively managed the village treasury, donations, and income earned from collective *ojeg* (i.e., motor-taxi) which transported sightseers to/from the late Maridjan's home. Over generations, this community practiced *ngarit-mugut* (cutting-collecting grass) in the forest. Maintaining proximity to their original location would therefore help them gain sufficient control over their homes and land plots in the forest.

3.2 Data collecting methods

As Table 2 shows, the research data were gathered through semi-structured interviews, participant observations, and document reviews. The data were collected in two phases: *first,* from October to November 2021, and *second*, from January to March 2022, that is during eruptions and COVID-19. The local authorities' large-scale community restrictions (Farisa, 2021) and public entry to the 5 km zone (Pribadi, 2022) inevitably limited researcher's mobility. However, these contexts enabled the researcher to gain insights into the respondents' day-to-day interactions with the environment.

Table 2. Data, Methods, and Source

Information	Methods	Data Source
• The social, political, and environmental experiences after the 2010 event • Community forest farming and management system	Semi-structured interviews Participant observations	Respondents
• Mt. Merapi's hazard map • Mt. Merapi National Park's territory and zones	Document review	• The Ministry of Public Works; • The Ministry of Environment and Forestry's Mount Merapi National Park Agency
• The Umbulharjo Village's map • The Pelemsari sub-village's map	Document review	• The Umbulharjo Village; • The Ministry of Public Works' Community-based

Information	Methods	Data Source
• Karang Kendal's map		Reconstruction of People and Settlement;
• The Pelemsari's community profile	Official document	• The Pelemsari Sub-village
• Dairy farming management	Official document	• The Pelemsari Sub-village; • Sarono Makmur Dairy Cooperation

3.2.1 Semi-structured interviews

For in-depth interviews, the sample size generally relies on whether an additional interview will produce greater information (Watkins, 2017). In this study, data saturation was reached after interviewing the seventh respondent. Respondents were selected based on criteria (purposive sampling) and recommendations from other respondents (snowball sampling). To be eligible for interviews, they must have lived in the original location for at least five years before the eruption in 2010, directly experienced the event, and engaged in farming before the event. The sub-village head who was knowledgeable of community members was involved in the selection. Interviews with forestry experts from the national park agency and the University of Indonesia were conducted to provide a greater understanding of forest management in the region. The researcher conducted interviews with local respondents in two to three sessions; each of which was performed in their natural settings (e.g., grass plots) and lasted 90-120 minutes apiece. Employing a semi-structured interview, the researcher balanced pre-determined questions with spontaneous questions (Brinkmann & Kvale, 2015; Salmons, 2015). Interviews began with a general question about their daily routines, followed by their farming practices.

3.2.2 Participant observations

This method aimed to understand respondent interactions with their community and environment in their natural settings (e.g., cowsheds, land plots). The researcher adopted a marginal participation position type in which she let herself be completely seen by the respondents (Zeisel, 2006). It required 1-3 on-field surveys to observe respondents in land plots, depending on their quantity and locations. The observation aspects include respondent activities, the people whom they interacted with, the type of relationship, the environmental and social-cultural context, and the descriptions of the settings during the observations.

3.2.3 Document reviews

The researcher reviewed materials on forest management in Mt. Merapi from peer-reviewed journal articles, books, official websites, and archives of the dairy cooperation, village and regional authorities, ministries, and Mt. Merapi National Park Agency (Table 2).

3.3 Methods of analysis

The researcher integrated all the information gathered from various methods for coding analysis. The steps of the analysis are, *first,* identifying thematic statements pertaining to Pelemsari's CPR institution in each transcript by paying attention to social-cultural characteristics (e.g., *kenduren, dairy group meetings*). *Second,* the identified codes that shared common traits were then grouped under one category labeled based on the principles (e.g., conflict-resolution mechanism). *Third,* the researcher open-coded for enablers and barriers to enhance the local institution. *Fourth,* the researcher verified the findings through discussions with peers. In Figure 2, the principles are the research

parameters that define the types of information needed for analysis. The results inform the current CPR body of literature.

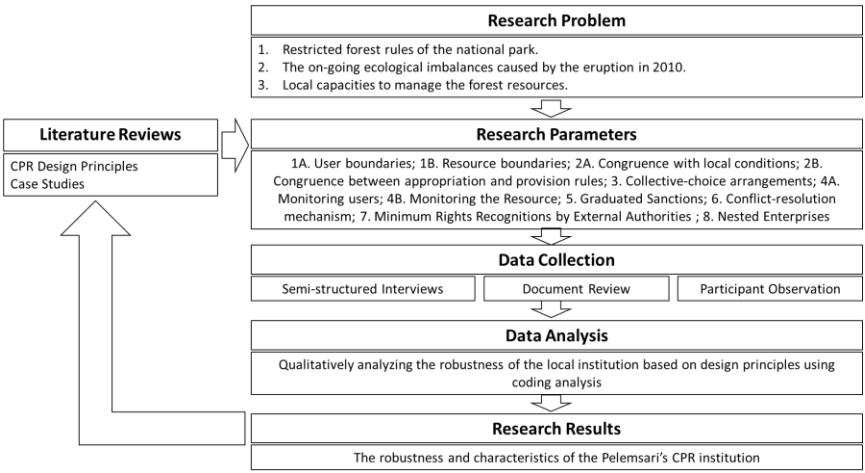

Figure 2. Research Framework

4. RESULTS AND DISCUSSION

4.1 Colonial forest management

In 1832, the Dutch implemented *cultuurstelsel* in Java to force villagers to work and subsidize the colonial administration's teak and agricultural products (Depdikbud, 1997). The system urged villagers including a hermit named Kyai Wonodriyo to refuge in Merapi's forest and clear the land for dwellings. Since his settlement was regularly passed through by the court's *Labuhan Merapi*, Wonodriyo was charged by the Sultan with the tasks of handling the rite which then made him a royal servant (Triyoga, 1991).

In 1910, the Dutch issued the Law for Protection of Wild Mammals and Birds, which gave way to the annexation of moorlands on the southern flank into protected forests. Protecting the adjacent regions from floods and erosion triggered by land clearance in the forest was often used by the colonial administration to legitimize their actions (Atmojo et al., 2018). At the local level, the law restricted villagers from cultivating and grazing cattle in the forest. As a result, they changed their swidden agriculture to a fallow-system (Kuswijayanti et al., 2007; Triyoga, 1991), domesticated their cattle, and sought fodder in the forest. They built cattle sheds nearby houses and regularly transported manure dried off in an open area to their home yards for fertilizing crops (Triyoga, 1991). The law thus changed villagers' farming traditions and disrupted their direct connections with the forest. In 1931, the Dutch expanded protected forest territory to about 6,472.1 hectares of forest lands in two jurisdictions: Yogyakarta and Central Java. In Yogyakarta, the forestry service were restricted to hydrology, botany, and aesthetics in accordance with the concession between the Dutch and Sultan's forest (Atmojo et al., 2018).

4.2 Post-colonial forest management

During the presidencies of Soekarno and Soeharto, forests were constant battlegrounds between the state, militant Islamist groups, and communist partisans. During Soeharto's regime, the State Forestry Corporation (i.e., *Perusahaan Umum Kehutanan Negara* or *Perhutani*) centralized forest management and excluded villagers from decision-making. As a response, villagers' resistance was conducted through timber

extraction and burning, devastating forests. The agency attempted to reduce this impact by making concessions with them in the form of limited rights of forest use under social forestry programs. However, they were never successful. After the fall of Soeharto in 1998, illegal logging and land encroachment increased, forcing SFC to use lethal weapons. This consequently augmented villagers' antagonistic feelings toward the agency (Lukas & Peluso, 2020).

The Department of Agriculture issued decree No. 347/KPTS/ UM/8/1975 in 1975 to stipulate the protected forest as the Nature Reserve of *Plawangan Turgo* and the forest land as the Nature Tourism Park of *Plawangan Turgo*. The forest was managed by the Provincial Agency of Forestry and Plantation in 1984 and 1989 before the authorization was transferred to *Perhutani*. Farmers under this enterprise were recruited to rehabilitate the forest (Atmojo et al., 2018). In 1980, the government brought dairy cows to forest villages in Java. Dairy farming soon attracted villagers to buy cows, particularly after knowing that the sector's infrastructure and market were already available. They continued building cowsheds in the settlement areas and feeding cows with grass planted in the forest's understory (Lukas & Peluso, 2020). *Perhutani* foresters favored farmers by introducing *Brachiaria Mutica* (i.e., kalanjana) as the alternative to, among others, *Imperata cylindrica* (i.e., alang-alang) and *Brachiaria Distachya* (i.e., blabakan) for fodder. In Resort Cangkringan, *Perhutani* also introduced *Acacia decurrens* through a mixed-cropping system (i.e., *tumpang sari*), a system that was introduced by van Vreeden in 1873 (Depdikbud, 1997). Supervised by a forest officer called *Mantri*, the system was adopted under a new concession that in the first two-three years, villagers were permitted to cultivate mixed crops and collect grass under the pine stands in exchange for mandatory pine-sap tapping for the state (Atmojo et al., 2018: 48; Lukas & Peluso, 2020). Since the 1980s, the number of livestock increased much more of the understory planted with grass than those under *tumpang sari*. Such changes in land use motivated a renegotiation between the government and villagers to incorporate products in the understory (Lukas & Peluso, 2020).

On May 4, 2004, the Ministry of Forestry passed Law No. 134/Menhut-II/2004 to legitimize the forest land conversion into a national park. The decree was motivated by the government's concerns about the forest's degraded ecosystem and unmanageable sand mining. However, the policy was poorly disseminated. From 2001 through 2003, the government only conducted a three-time coordination with stakeholders and a one-time socialization with residents in three districts (Hidayat, 2009). The socialization, however, invited only two local-level authorities, which reflects the act of elite capture (Saunders, 2014). Upon hearing about this idea, people who allied in the *Forum Rembug Merapi Merbabu* censured the government that the policy would only give way to capitalism and isolate them from continuing their farming traditions. About 26 NGOs and grassroot organizations further challenged the government. Friend of the Earth Indonesia (i.e., *Wahana Lingkungan Hidup Indonesia*) even demanded the law be repealed by the State Administrative Court. However, the Court decision favored the state (Hidayat, 2009; Kuswijayanti et al., 2007). To enforce the decree, the government then established a national park agency in Cangkringan District in 2006. The agency is run by a head of the national park, assisted by a *mantri* and on-site officers comprising forest police, ecosystem controllers, and forest consultants.

For years onward, the people of Mount Merapi continued exercising their rights to collect grass (i.e., *muguit*) and fuelwood (i.e., *ngrencek*). There are 30 villages adjacent to the park (±6,410 Ha), seven of which lie within the Sleman Regency territory. About 107,488 residents of these villages rely on the forest for grass, fuelwood, freshwater, tourism, and cultural activities (Atmojo et al., 2018).

Table 3. Zoning Details of Mount Merapi National Park (Atmojo et al., 2018).

Zone	Size (Ha)	Areas	Services
Core Zone	1,041.2	Around the summit and the mountain hill, *Gunung Bibi*	Preserve the ecosystem and the authenticity of the volcano's biodiversity
Wilderness Zone	2,980.19	Forest Pathuk, Kumpulrejo, Gunung Pasir, Block 45, Block Koci, Gemer, and Bokong Semar	Preserve the core zone and the use zone
Utilization Zone	461.73	Plawangan Turgo, Kalikuning, Kaliadem, Gandok, Hutan Bambu Tritis, Jalur Pendakian Selo and Deles, Deles Indah, *Goa Jepang* (Japanese Cave), Gumuk, Jurang Jero	Nature-based tourism
Traditional Zone	1,504.62	Areas that are intensively worked on by villagers such as collecting grass for fodder	
Spiritual, Cultural, and Historical Zone	11.57	Alas Bedengan and Petilasan, the cemetery of Syekh Jumadil Kubro, and the harbor of *Labuhan Merapi* rite, the Srimanganti (Kendit Hill).	Facilitate the local's socio-cultural activities in Mount Merapi
Rehabilitation Zone	418.42	Alas Gandok, Resort Srumbung, and Resort Kemalang	Restore habitats
Special Zone of Mitigation and Reconstruction	189.88	Putih River, Gendol River, and Woro River, including spots of agency installed devices of the Investigation and Development of Geological Disasters Technology which is authorized for issuing hazard zone maps.	

4.3 Current forest management

Figure 3. Long-tailed *macaques* are seen going down the southern flank of Mt. Merapi after environmental changes.

The environmental changes in Merapi's forest after the 2010 eruption call for serious attention from the government. The event damaged the forest that reached about 1,128 Ha of land, particularly in Resort Cangkringan and Resort Pakem-Turi (BNPB, 2011). The National Park Agency estimated that it required 40 to 50-year reforestation efforts to restore the forest (Zakaria, 2010). Some studies even cautioned that almost all those damaged areas had become monoculture thickets due to *Acacia decurrens'* invasion (Afrianto et al., 2017; Nigussie et al., 2021; Sulitijorini & Setyawati, 2017; Suryawan et al., 2015). Growing rapidly in severely damaged lands (Gunawan et al., 2015; Sulfiantono, 2012) and having a preference to open, vacant land and intensive sun rays, this species outcompeted native trees (e.g., *Schima Walichii*). As a result, forest diversity was degraded to a level that threatened wildlife sustainability (Sulistiyono & Rochwulaningsih, 2013). This is evidenced by the intrusion of long-tailed *macaques* into settlements and farmers' lands after the event (BTNGM, 2010; Utomo, 2022).

The ecological problem presses the government to promote local participation in reforestation programs while trying to win people's trust after a history of marginalization could be extremely difficult. In 2011, the agency developed two models of community partnerships. The first model is aimed to optimize the use of natural resources outside the national park by providing infrastructure and assistance to locals under the *Desa Binaan* (i.e., mentored villages) scheme. The second model is aimed to legitimize the community's *ngarit-mugut* traditions within the national park which is manifested through the incorporated traditional zone in the national park zonation (Fig. 4). The zone was produced based on the agency's surveys since 2011. The agency expected that these models can facilitate concession renewal and increase people's willingness to participate in reforestation through silviculture that is based on local knowledge (Atmojo et al., 2018).

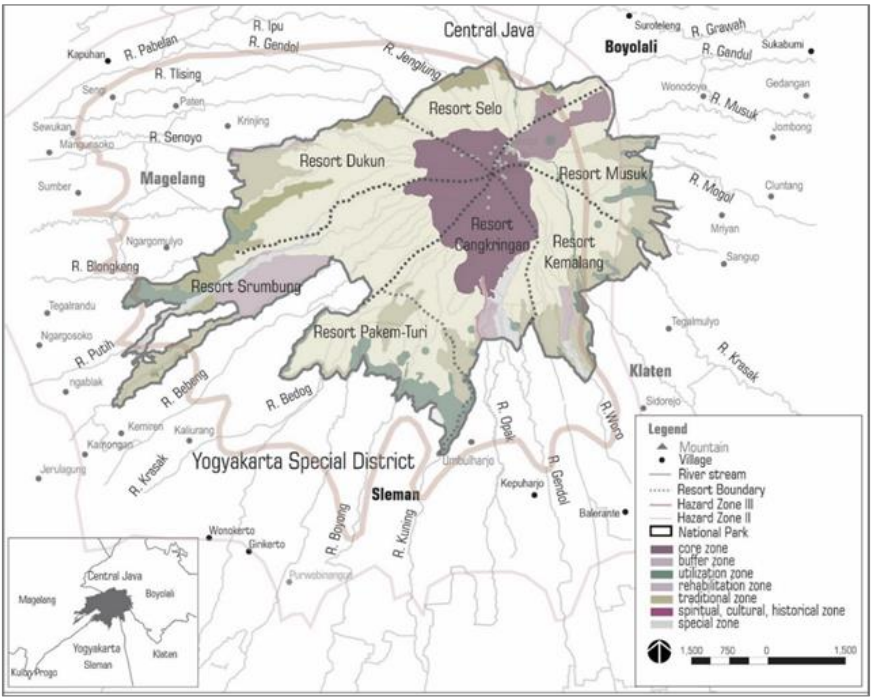

Figure 4. People's *ngarit mugut* traditions in the forest are labeled as traditional zone (gold). The image was redrawn based on the national park agency's map in 2022.

4.4 Common pool design principles in Mount Merapi National Park

This section discusses the robustness of the Pelemsari community's institutions based on reformulated design principles by Cox et al. (2010). Interview excerpts and other materials are used to support the analysis.

4.4.1 Principle 1 A: User Boundaries

Farmers rely on their home yards in the upland and land plots in the forest for fodder and dry wood. Here, they are bound to a concession with the authority that they must manage the state's trees in exchange for the right to collect grass and dry wood (Atmojo et al., 2018). People typically used the term *kontrak* (i.e., contract) or *sanggeman* to refer to a land plot allotted to them for a two-year labor of managing the state's trees in the forest.

> *The forest was once a production forest. It was planted with state's trees by farmers who then could plant the understory with mixed crops. That is why the land is called 'kontrak', which lasted for two years* (Magio, 2022).

According to research respondents, the plot's size was determined based on the farmer's own estimate of his capacity in managing the state's trees. A farmer could ask for any land size as long as he promised that he was able to manage all the state's trees within that area. This reasonably makes the size of land plots allotted to each farmer vary greatly. Magio (pseudonym) recalled his ancestors' experience to explain how the land plot was determined in the 1970s.

> *The forest land was parceled out but the size allotted to each farmer may not be the same. Someone could get a ¼ Ha, ½ Ha, or 1 Ha. The land could be planted with corn or other crops but he must promise that he could manage the land* (Magio, 2022).

The features used to indicate land plots' boundaries were determined based on the negotiations between neighboring farmers. Those boundaries or *kikis* in local terms, usually take the forms of natural features like bamboo, *Albizia Chinensis* (*sengon*), trenches, or river valleys. Utilizing natural features as boundaries may create ambiguities, which are typically promoted by the lack of appropriate means, well-defined natural features, and clear concepts of a land plot (Bluemling et al., 2021). Since the boundaries are known only by the farmers themselves and their neighbors, it would be challenging therefore for the park agency to be able to complete the land plot inventory without their participation.

Figure 5. *Albizia Chinensis* and bamboo signify the land's boundaries in the forest. Images courtesy of the author, 2022.

The fluidity of boundaries is present when a user other than the right's holder can access and use a land plot. This rule, however, is applicable only when the user is the holder's descendant, spouse, or family who resides in the same sub-village or a resident of the same sub-village. These rules are not applicable if the user, regardless of his relationship with the holder, resides in another sub-village. When the right's holder, for some reason, is no longer able to manage their land plot, the right can be transferred to an eligible user. However, if the holder or a descendant reclaims the land, the new user must be willing to return that right. This phenomenon is termed by Schlager and Ostrom (1992) as the right of alienation, which is a choice right that permits the holder to transfer part or all of the choice rights to another party (Schlager & Ostrom, 1992). A farmer also has the right of exclusion, a choice right authorizing its holder to devise operational-level rights of access. For example, the right holder may let his neighbors collect grass on his land after considering their request for his kindness or *nembung* in the local term.

4.4.2 Principle 1 B: Resource Boundaries

Some villagers fail to identify the boundaries of particular zones in the National Park, regardless of the signage already installed by the agency. Such a condition is attributed to the government's socialization of the park agency which was only limited to the sub-village level authorities. Fajar (pseudonym) admitted that she can only identify the park's boundaries whenever she encounters a forest police.

> *Once I notice forest police, I immediately will know that I am just about to enter the protected forest territory* (Fajar, 2022).

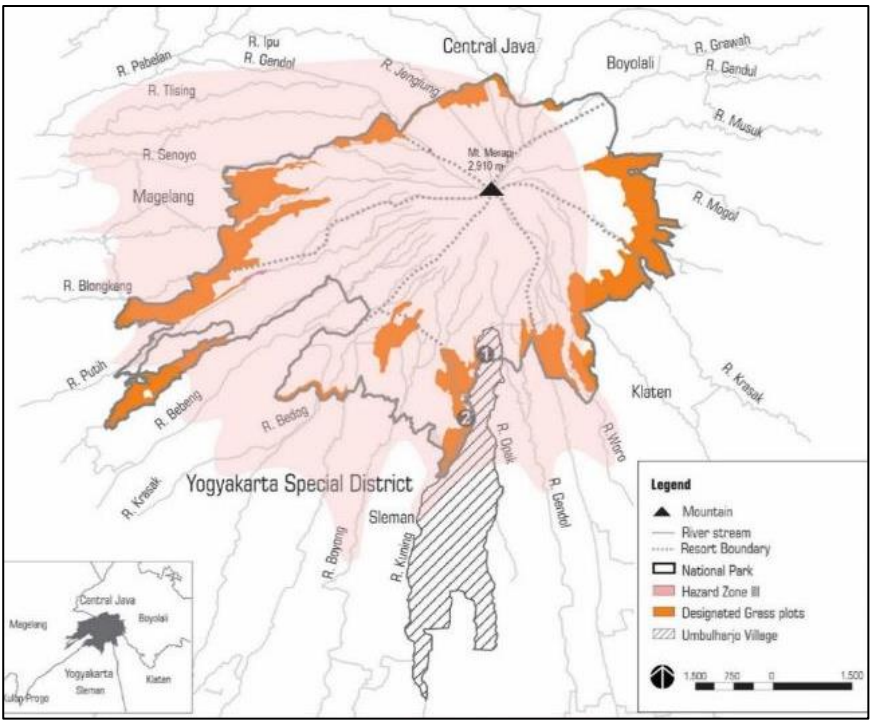

Figure 6. The distribution of grass plots in the national park zone (orange). The map is adapted from the National Park Agency, 2022.

The national park's traditional zone represents a territory within which farmers are bound to a concession with the national park agency about the use of the forest understory (Table 4). The zone was designated based on the agency's surveys, however, it has not yet represented the existing land plots allotted to Merapi's farmers in the past (Fig. 6). Based on interviews, a farmer may have two or more land plots; many of which are even located about two kilometers from the summit, beyond the designated zone. Up to the time this study was carried out, the agency still conducted surveys to complete their inventory by engaging local farmers. It can be expected that a revised zoning and new concession will occur sometime in the future.

Table 4. Applied rules to use resources within the National Park.

Categories	Description	Involved Actors
Allowed uses and activities	Planting trees designated by the state. Collecting grass under the tree stands. Collecting dry wood on the ground.	State-Farmer
Permitted uses and activities	Collecting grass and dry woods in other farmer's land plots with permits from the right owner.	Farmer-Farmer
Limited uses and activities	Planting trees not designated by the state. Cultivating the understory with crops other than those designated by the state. Cutting trees. Cutting dry branches off the trees.	State-Farmer

4.4.3 Principle 2 A: Congruence with local conditions

During the dry season (April-August) when young grass is rare, farmers would go further up into the forest in groups. They locate sources together and share the grass among them. If the source happens to be owned by a particular farmer, they get an access grant in the first place. During the rainy season (September-March), farmers would refrain from cutting grass around the slopes to reduce risks of erosion.

Figure 7. The agency's truck transported farmers' fodder during the eruption in 2021 (left) and *ngarit-mugut* in the forest (right). Images courtesy of the author, 2022.

People's farming activities in the forest can be disrupted by government restrictions such as during eruptions. However, economic interests often force them to ignore the rules by collecting grass in the forest. Thus, when eruptions occurred in 2020-2022, the agency decided to help transport farmers' grass from some designated stations to their communal cowshed in Karang Kendal. Farmers must register through the sub-village head at least one day beforehand and manage the quantity of grass to be transported given the limited space of the agency's truck. This voluntary assistance is believed to have effectively reduced farmers' risks of eruptions during difficult times while also restoring people's trust in the agency.

4.4.4 Principle 2 B: Congruence between appropriation and provision rules

Living in a relocation compound after the 2010 eruption forces farmers to find ways to remove manure from their communal cowsheds. They collectively rent a truck to transport manure from the cowshed to their former home yards weekly. By so doing, they can also fertilize grass and trees therein. However, it is possible for anyone, either from within or outside the sub-village, to collect the manure. This would be therefore the responsibility of that person to pay the cost associated with the transport.

Figure 8. *Labuhan Merapi* rite was held to appease the deities and led by the volcano's spiritual guardian in March 2022. Images courtesy of the author, 2022.

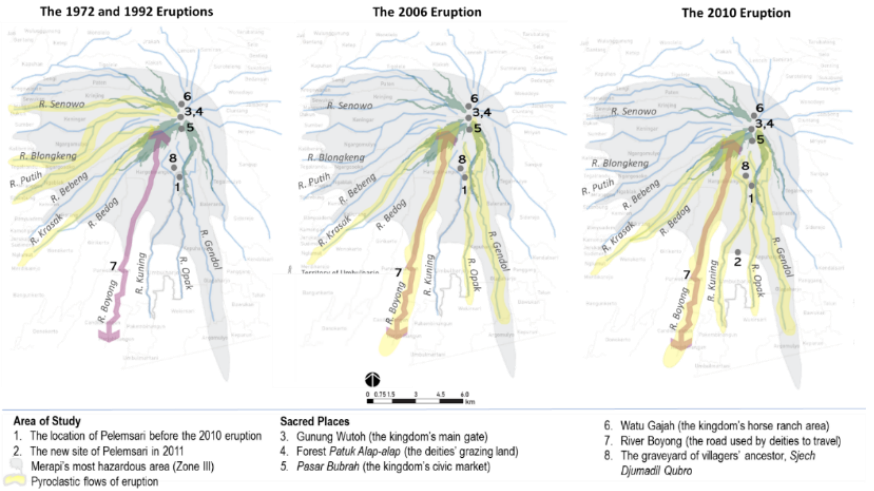

Figure 9. Sacred places lie within the designated hazard zone. The image was developed based on literature reviews.

Besides manure management, myth-imbued norms also support this principle. Holding a belief in the importance of maintaining harmony with the spirits, they are obliged to appease them via rites and obey local norms (Fig. 8). For example, they must refrain themselves from collecting grass in places that are believed to be homes of the spirits. These places refer to high-risk areas within the five-kilometer zone of the summit (Fig. 9). Violations against the norms are believed to raise the spirits' anger expressed through a disaster (Triyoga, 1991).

4.4.5 Principle 3: Collective-choice arrangements

To find solutions to collective problems at the sub-village level, all the community members are engaged to participate in meetings, either at the sub-village head's or the neighbor head's home. All collective problems associated with local groups' interests are discussed in internal meetings. These local groups include, but are not limited to, dairy farming groups, family welfare movements, youth organizations, and jeep associations.

Figure 10. Social gathering or *kenduren* in the sub-village.

The community also regularly conducts social events as a mechanism to foster social cohesion. *Kenduren*, for example, is a Javanese communal feast tradition that binds the community together by reciprocity (Geertz, 1960) and is usually held to celebrate the birth of cattle, appease deities (Triyoga, 1991), or welcome the Islamic fasting month. *Kenduren* can be used as a means to exchange and disseminate information concerning the community's welfare (e.g., eruptions, undesirable policies). For example, the sub-village head disseminates disaster messages he receives directly from the government through the event. Local leaders and meetings can, therefore, be critical means for higher authorities to enforce collective compliance to disaster warnings.

> *In the kenduren, last night, the sub-village head advised people to be aware of eruptions. He said that Merapi could no longer be predicted, and is different from previous incidents* (Subur, 2022).

4.4.6 Principle 4 A: Monitoring users

Despite the community's acceptance of the National Park, it does not necessarily mean that all members comply with their rules; particularly, since local participation has been completely ignored from the policy-making. A respondent admitted that he sometimes surreptitiously cut branches from a living tree, which clearly violated the forest rules. Villagers, who also do not comply with such rules, also often choose to keep silent by

not reporting violations by fellow villagers to authorities.

> *People mainly take grass and can take dry wood as long as they are small [in quantity]. But, in the past, there was someone who took a large portion one silently. I also sometimes take large amounts of dry wood as I need them for my farm. But I do not do it every day* (Magio, 2022).

Furthermore, since no farmers are allowed to collect grass in another farmer's plot in the forest without a permit, monitoring users is a critical role. However, community does not perceive monitoring as necessary because of their trust in fellow villagers.

> *I let it (the land plot) be left unmonitored. I just believe that nobody would encroach on my land plot in the forest* (Puji, 2022).

The mechanism used by the community for enforcing rules and monitoring is preserving their norms imbued with beliefs about deities living in high-risk areas (Triyoga, 1991). Fear of deities refrains people from harming their environment which, in turn, decreases their risks of disasters and the overuse of forest products. For example, a norm that people must not cut down bamboo because it is a place where spirits reside. This myth-imbued norm helps preserve bamboo for its invaluable role as a traditional Early Warning System. Rohman (pseudonym) supported this by describing how bamboo that emitted explosion sound during the 2006 eruption helped some people navigate to safety.

> *When Mt. Merapi erupted in 2006, the lahars reached this river stream. There was a bamboo forest at my home. Some people nearby who evacuated heard the sound "Duar! Duar!" from the bamboo. They ran immediately avoiding the source* (Rohman, 2022).

4.4.7 Principle 4 B: Monitoring the Resource

Resort Cangkringan within which Pelemsari lies covers an area of 985.95 hectares (Atmojo et al., 2018). After the 2010 eruption, almost all parts of this resort along with Resort Pakem Turi (1,128 hectares) were devastated (Atmojo et al., 2018). It forced the government to escalate reforestation efforts. To monitor the resort, the government relies on a few on-site officers. It is, thereby, unreasonable to expect these officials alone to effectively monitor the resort and enforce forest rules.

Since people heavily rely on the forest, a high degree of forest monitoring at the local level is very likely. They have first-hand and low-cost access to information about their situation (Cox et al., 2010). A research respondent, for example, observed degraded forest diversity after the eruption and link it with changing behaviors of long-tailed *macaque*.

> *Many monkeys go down and they are mainly from Plawangan Turgo. They eat fruits from trees in the forest but today, the choices are limited. So, they go down and eat young grass* (Magio, 2022).

The agency then engaged the local community in forest monitoring groups such as the Community and Forest Police Partnership Group and the Fire Awareness Community Group. Self-development and training assistance is provided to the groups which to date comprise 15-21 members (BTNGM, 2022). This low group size warrants the necessity for the agency to enhance more participation from the community.

At the local level, the findings from daily observations are typically shared mouth-to-mouth and through community meetings. However, to the best of the author's knowledge, no collective solutions were yet put in place to address this issue at this

level.

4.4.8 Principle 5: Graduated Sanctions

The community has diverse socio-economic-cultural groups and runs regular meetings and gathering events that indicate their strong social capital. This capital has led them to become a role model for a successful community-led relocation after the 2010 eruption (Siara, 2018).

Figure 11. The communal cowshed in Karang Kendal. Images courtesy of the author, 2021.

Living in a relocation site requires the community to adjust to new norms. For example, when sharing a communal cowshed in Karang Kendal, farmers must ensure the cleanliness of their cows and compartments. Particular farmers, however, are unaware that other farmers become annoyed. Having strong social capital, people do not perceive that graduated sanctions are needed (Cox et al., 2010). No formal sanctions are thus applied to them. However, informal sanctions like being shunned and gossipped could be more damaging. Feelings of shame and embarrassment expressing discomfort with the self can rise as a result of violations (Halmesvaara et al., 2020; Klass, 1990).

4.4.9 Principle 6: Conflict-resolution mechanism

To reduce conflicts, the sub-village head uses persuasive mechanisms by advising the perpetrator in person and motivating the community to maintain social cohesion through community meetings and *kenduren*. Besides the sub-village head, elders and the volcano's spiritual guardian are also equally important in addressing collective problems. When confronting powerholders, the community avoids confrontation by putting forward the living in harmony principle and a win-win solution.

After the national park decree was enacted in 2004, several meetings were conducted. The first meetings were held at the sub-village head's house to unify the community's voices through debates and discussions. A final meeting was held at Maridjan's house and invited the park agency. Maridjan proposed that that only when the government let the villagers maintain their right to collect grass in the forest, would he accept the national park policy.

> *We held some meetings at the sub-village head's house and finally, one meeting with the park agency at Maridjan's house. He told them," I would let the National Park exist but if you do not let my people cut grass in their land plots, I would not recognize them."* (Magio, 2022).

The meeting forced the agency to accept the people's customary rights over the forest. Such an achievement is inseparable from Maridjan's reputation as the volcano's spiritual guardian. A research respondent explained that the negotiation was successful although the National Park decree remains in effect.

> *Soon after the meeting, the agency let us collect grass in the forest. But they also once said that we could only collect grass in an area within 100 meters of the national park territory. But, how could it adequately fulfill the need of so many farmers?* (Magio, 2022).

4.4.10 Principle 7: Minimum Rights Recognitions by External Authorities

As of today, the community still performs *ngarit-mugut* in the forest. However, the National Park decree has already exacerbated distrust towards the government. Puji (pseudonym) expressed this by associating the eruption in 2010 with the state.

> *The agency can have its own interests but if Merapi's spiritual guardians do not agree, fire and lahars will happen. The eruptions in 2010 seem to warn the agency about their disagreement and defense for the people* (Puji, 2022).

The protected forest rules that limit locals from exercising their customary rights (e.g., cutting trees, cultivating forest) represent the continuation of colonial forest controls (Kosuke et al., 2023; Peluso, 1992). Being monitored by the forest police also raise like-a-thief feelings among the locals. It is worth mentioning that timber theft had long been labeled a crime of forest villagers by the state (Peluso, 1992).

> *Whenever I have to collect grass further into the forest, I have to play hide and seek with the forest police. I feel like a theft (laughing)* (Fajar, 2022).

People have experienced many physical tasks under different forestry regimes. As Kosuke et al. (2023) put it, if local people are hostile, sound management is impossible (Kosuke et al., 2023). This undeniably implies a challenge for the next principle to be met.

4.4.11 Principle 8: Nested Enterprises

The 2010 eruption significantly changed Merapi's forest composition in Resort Cangkringan through the domination of *Acacia decurrens*. To restore the forest, the Ministry of Environment and Forestry worked with different actors by engaging the provincial, regional, district, and village-level authorities, including communities living in thirty villages near the park in their reforestation programs. The approach employed is a genetic-based restoration, which is aimed to bring back the ecological and economic values of the forest by prioritizing the cultivation of endemics that have been well-adapted to the forest environment (BIOTIFOR, 2019). Positing the community as a partner, the agency develops forest inventory, promotes nurseries, and provides community assistance.

At the community level, Merapi villages comprisesmany grassroots environmental groups that are knowledgeable of the forest environment, like the Kaliurang Village Environment Awareness Community and the Women's Agriculture of Merapi Asri Group. A research respondent informed of the types of trees preferred by the long-tailed

macaques.

> *Those surviving the eruption in Plawangan Turgo also go down the slope because not many fruit trees are available after the eruption. They now eat young grass. There had been a great variety of trees before the event like melojo and gondang* (Magio, 2022).

Magio's excerpt about forest trees such as *Quercus pyrenaica* (melojo) and *Ficus variegata* (gondang) indicates local knowledge that is valuable for reforestation. Despite this local potential, it is yet unknown to what extent the community has been engaged in the programs, including the factors influencing their decisions to participate. These warrant the need for future research to address these concerns toward an improved forest institution and sustainable forest ecology.

Table 5. The findings of the assessment on the robustness of Pelemsari's forest institution using the reformulated design principles.

Design principle	Findings
Principle 1 A: User Boundaries	• The neighboring farmers determined the types of natural features for land plots' boundaries. • The boundaries are known only by the neighboring farmers • Farmers are cooperative in assisting the agency to recognize the land plots' boundaries for the forest inventory. • Social norms based on residential status, kinship, kindness, and reciprocity regulate local rights to access and use a land plot.
Principle 1 B: Resource Boundaries	• Local's failure to recognize the national park and its zones' boundaries. • The socialization of the national park territory and zonation was limited to sub-village level authorities. • The designated traditional zone does not yet represent the actual land plots' distribution and boundaries
Principle 2 A: Congruence with local conditions	• Collecting grass in groups during hard times. • Refraining self from cutting grass on slopes to reduce disaster risks in the forest during raining season.
Principle 2 B: Appropriation and provision	• Collectively managing manure • Refraining self from cutting grass and logging trees
Principle 3: Collective choice arrangements	• Sub-village level meetings are used to address community-related conflicts. • Internal meetings are used to address local groups' problems. • Social gathering events can be used to exchange and disseminate information.
Principle 4 A: Monitoring users	• Monitoring users is absent in the community because of: • trust in their community • belief of myths
Principle 4 B: Monitoring the resource	• People's heavy reliance on the forest motivates their high-quality monitoring. • People monitor the ecological imbalance after the eruption • The government engaged the local community but the group size is still limited compared to the resort's size.
Principle 5: Graduated sanctions	• People use persuasive mechanisms rather than imposing sanctions. • Local leaders use a personal approach to advise transgressors. • Violating rules leads to informal sanctions and feelings of shame, guilt, and humiliation.

Design principle	Findings
Principle 6: Conflict-resolution mechanism	• People focus on reaching a consensus, using persuasive mechanisms to solve social conflicts, and negotiating for a win-win solution to avoid confrontation. • All community members are engaged in community meetings. • Local leaders motivate people to maintain social cohesion through meetings and social gathering events. • Local leaders represent people's voices when dealing with oppressive power.
Principle 7: Minimal recognition of rights to organize	• People's distrust of the government remains. • People's feeling of being a thief in the customary lands. • Negative experiences of the government.
Principle 8: Nested enterprises	• National level: the government launches genetic-based restoration programs that engage the local community. • Local level: local knowledge of forest diversity and environmental groups.

5. CONCLUSION

All the critiques of design principles warn of the need to recognize the diverse aspects of the community, external variables of context, and their complex relationships in creating a sustainable CPR institution (Agrawal, 2003; Agrawal et al., 1999; Cleaver & De Koning, 2015; Cox et al., 2010; Euler, 2016; Fournier, 2019; Saunders, 2014). In light of those insights, this study analyzes Pelemsari's relative success/failure in managing its resources by employing Ostrom's design principles.

The study demonstrated how Pelemsari's social capital, enforced by community meetings, social-cultural events, norms, and leadership, has contributed to their institution's robustness in dealing with uncertainties. *First,* despite the ambiguity of land plots' boundaries resulting from the use of natural features, conflicts can be avoided due to the local rules of use that are influenced by social ties (residential status, kinship, kindness). Such rules make the boundaries fluid, thus, reducing potential conflicts. *Second,* the local disaster knowledge evidences the congruence of rules with local conditions, and myth-imbued norms about sacred/haunted places evidence the congruence between appropriation rules and provision rules. *Third*, meetings and social events engage all community members with local leaders who serve as conflict mediators when dealing with collective problems. *Fourth,* user monitoring is absent for their trust in the community and beliefs in myths while resource monitoring exists due to people's reliance on the forest and fear of losing access. *Fifth,* graduated sanctions are absent in the presence of their strong social capital, leading to their preference to use persuasive mechanisms and consensus to solve conflicts. Shame may be a key factor for violation of collective rules. *Sixth,* win-win solutions are used in negotiation with antagonists and local leaders serve as the mediators of their collective interests. *Seventh,* the current forest rules that reflect colonial forest controls might have exacerbated people's distrust, making community participation in reforestation efforts challenging. *Eighth,* although reforestation programs have engaged multiple stakeholders and the community, local distrust likely hinders the success of collaborative reforestation, thus, making this principle relatively unsatisfactory.

This study, however, has some limitations. Its low number of research respondents puts the study at risk of generalizability for the entirety of the site. To address this concern, increasing the sample size and employing cross-sectional and longitudinal research approaches are recommended. The complex materials embedded in the interview transcripts may cause this study to unexpectedly overlook important

conditions; factors that shape local institutions. McGinnis and Ostrom's social-ecological systems framework that identifies CPR variables and their relationships (McGinnis & Ostrom, 2014) can be a critical point of departure for future commons research.

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