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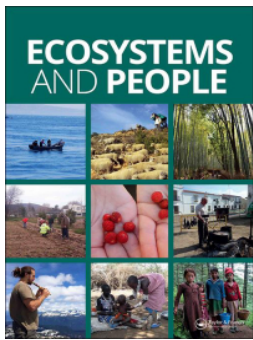
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RESEARCH



Challenges for the development of environmentally sustainable cage culture farming in Lake Maninjau, Indonesia: an institutional perspective

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ABSTRACT

The environmental condition of Lake Maninjau, a complex tropical system in Indonesia, has been suffering from the proliferation of tilapia cage culture practices. The area around the lake is inhabited by the Minangese ethnic group, which has strong customary laws and clan system. Applying the Institutional Analysis and Development (IAD) framework and based on face-to-face semi-structured interviews, this paper aims to understand the challenges for the development of environmentally sustainable cage culture farming. Our institutional analysis reveals that the main challenges are low levels of trust between communities and officials, and conflicting formal and informal institutions which have prevented the emergence of strong rules-in-use. This is a particularly interesting theoretical contribution to the literature on the management of common pool resources (CPR), as our case study is an example of private property farming in a common pool resource (the lake), a dynamic which remains understudied in the CPR literature. We provide suggestions for local stakeholders as well as regional and national government related to the importance of seeking local legitimacy of the working rules to govern cage culture. The lessons learned from this case study might be useful for the governance of aquaculture in other lakes in Indonesia and countries of the Global South.

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I. Introduction

Common Pool Resources (CPR) are an intriguing yet challenging type of goods to manage sustainably (Ostrom et al. 1994). Characterised by difficulty in excluding users and a high degree of subtractability, CPR often face pressures from human exploitation and are subjected to complex multi-user conflicts of interest (Steins and Edwards 1999). In his influential essay, *The Tragedy of the Commons*, Hardin (1968) claims that the devastation of CPR is to be expected because many users are sharing scarce resources and it is in the individual user's interest to overexploit the resources (e.g. grazing land, forests, fisheries). As a consequence, there has been a widely held belief amongst policymakers that resource users cannot be trusted with governing CPRs, leading many to argue for centralised (state-led) or private governance systems (Janssen 2015; Ostrom 2015).

However, there is extensive evidence that communities of resource users *can* successfully govern CPR, under certain conditions (see Basurto et al. 2013; Long et al. 2017 for examples of self-governed fisheries). This community self-governance of CPR has been usefully analysed through applications of the Institutional Analysis and Development (IAD) framework, which supports researchers investigating the factors influencing the ability of communities to create rules and norms—i.e.

institutions—for governing their resource, and the outcomes of these institutions (Janssen 2015; Ostrom 2015). The IAD framework views the CPR's biophysical conditions, community attributes, and institutions as affecting actors' actions towards their resource and the outcomes of these actions (Hardy and Koontz 2009; Zhang and Zhao 2019).

We apply the IAD framework to understand the challenges for the development of sustainable management of tilapia (*Oreochromis niloticus* Linnaeus 1758) cage culture farming (TCCF) in Lake Maninjau, Indonesia. We are not aware of applications of the IAD framework to analyse community self-governance of aquaculture. Applications in the fishery sector focus on capture fisheries (Imperial and Yandle 2005; Ostrom 2015; Li et al. 2016). Moreover, literature on open aquaculture management rarely pays attention to the institutional setting despite aquaculture being commonly operated within CPR (Van-Houtte 2001; Nadarajah and Flaaten 2017). An exception is Siddiki et al. (2009), who used IAD institutional grammar (which is an approach to operationalise the concept of institutions) to identify and categorize acts related to aquaculture in Colorado, USA, but we are not aware of similar research in the context of the tropical Global South.

Analysing TCCF, which is practised by using pens or cages in common pool water bodies such as lakes, through the IAD framework is particularly interesting as it presents a case of private property farming in a CPR. With the expansion of TCCF aquaculture systems in common pool water bodies, any unsustainable practices by one farm will generate impacts (externalities) for other farms. Negative externalities include declining water quality, which reduces the productivity of other farms. We observe this occurring in our case study, Lake Maninjau, where TCCF was introduced in 1992. Water quality deterioration is also affecting the lake's tourism industry, indicated by declining tourist numbers and low hotel occupancy rates (Everina et al. 2017). TCCF has been significantly expanded in the lake and now exceeds the lake's carrying capacity (calculated with Phosphorus and Nitrogen budget balance by Hartoto and Ridwansyah (2001)). This situation has resulted in environmental degradation indicated by eutrophication, mass fish kill (MFK) events, and a reduction of TCCF productivity (Henny and Nomosatryo 2012; Sulastri et al. 2012). Most lake users are claiming that these adverse effects are due to hydrological alteration caused by hydropower activities. They demanded the closure of the operation of the hydropower plant and a significant riot occurred in 1999 (Sulastri et al. 2012). The conflicts were followed by protests demanding higher Corporate Social Responsibility funds from the hydropower company. Protests are still continuing at the time of writing. The misperception of the causes of lake deterioration and MFK events is still common despite scientific evidence pointing to irresponsible TCCF practice as the likely leading cause of water quality degradation (i.e. Henny 2009; Junaidi Syandri and Azrita 2014). More importantly, Fakhrudin et al. (2002) proved that hydropower activities did not lead to declining water outflow and MFK events.

This case study is particularly fascinating because many of the factors associated with sustainable CPR management found in the commons literature are present (such as dependence on a resource, the presence of a homogenous community, and widely recognised depletion of resources affecting livelihoods), yet it appears durable institutions have not been established, raising a pertinent and intriguing question about what we can learn from such a case for the management of this and other cases of cage culture farming, and more generally, aquaculture in lake systems. We contribute to the commons literature through our analysis of why it has proven difficult to devise a local institution to sustainably govern cage culture farming in a lake system. Through our analysis, we demonstrate that low levels of trust between communities and officials, and conflicting formal and informal institutions led to the absence of rules-in-use to manage TCCF practices, ultimately reducing the sustainability of the cage farming and the lake itself.

2. Materials and methods

2.1. The IAD framework and applications to fisheries

We turn first to outlining the three main components of the IAD framework which will frame our analysis. The first component, *external conditions*, comprises (i) biophysical characteristics, (ii) community attributes, and (iii) rules-in-use which, taken together, are understood as the factors affecting actors' behaviour across levels (as will be explained below). Much research has studied how the size, complexity, state, and productivity of the resource affects behaviour of CPR users (Ostrom 2009). The community attributes of interest may include the level of understanding of the CPR, the degree of homogeneity, resource distribution, and political and socio economic parameters (Imperial and Yandle 2005). Together, attributes of community determine the cultural setting (Ostrom et al. 1994), which is an important factor for the governance of natural resources (Berkes 1996; Zander et al. 2014; Singleton 2017; Chunhabunyatip et al. 2018). Daily practices in community (culture) may influence people's views and behaviour in governing the resources (Hanna and Jentoft 1996). In terms of social relationships, culture may help CPR institutions to emerge and be durable, by increasing trust, reducing uncertainty, and endorsing cooperation (Sick 2008). Rules-in-use are defined as the working rules followed by resource users (Cinti et al. 2010) which may not necessarily align with formal rules found in policies and legislation. They govern individual actions, and shape social interactions within the community (Cinti et al. 2010; Mehring et al. 2011). The biophysical characteristics, community attributes and rules-in-use interrelate to influence behaviour and outcomes, for example, Ostrom et al. (1994) argue that rules governing a resource must be compatible with its biophysical setting for sustainable management to emerge.

The external conditions influence the second framework component, the *action situation*, which is where actors interact in a particular context (Ostrom et al. 1994; Zhang and Zhao 2019). In our case, we are interested in the behaviour of actors involved in lake governance across three nested levels: constitutional choice, collective choice, and operational choice (Ostrom et al. 1994; McGinnis 2011). Constitutional choice level activities are associated with the process of legitimation and constitution of all institutions involved in the lower operational choice and collective choice levels and therefore the activities at this level are of the widest scope (McGinnis 2011). The collective choice level includes the policies and norms which have emerged as a result of the actions at the constitutional choice level. At the lower operational choice level, we can analyse the behaviour of the resource users as they interact with the CPR of interest.

The third main component consists of the *pattern of interactions* across the three levels outlined above, which lead to resources and livelihoods outcomes, and the *criteria to evaluate the interactions and the outcomes* (Ostrom 1999). Ostrom (2011) explained that interactions are correlated with the degree of communication between the participants and are influenced by past experiences of interactions. As a result, greater opportunities to communicate tend to increase the chance that participants achieve a better joint outcome, therefore, the way that participants interact with each other across levels can be used to predict outcomes.

Before introducing the case study and approach to data collection, we briefly review IAD case studies related to (capture) fisheries, with the aim of identifying insights for our research on TCCF, and in order to better position our case study within the CPR governance literature related to fisheries. Li et al. (2016) use the IAD framework to analyse rules to govern coastal and marine ecosystem services. They found that municipal and provincial governments should focus on regulatory support to coordinate competition among resource users and facilitate social incentives, instead of continuing with the traditional command and control system. These insights apply to TCCF, which may be conceived as an ecosystem service competing with the provision of other ecosystem services. Extending the work of Li et al. (2016), TCCF requires coordination among participants across different levels, which may become a task for government. Imperial and Yandle (2005) employed the IAD framework to expose the pitfalls of institutional design and performance in capture fishery management regimes (bureaucracy, market-

based, community based, co-management). They found that the framework was particularly useful for examining the biophysical conditions and community attributes specific to each setting, thus avoiding generalisations about each regime. Further, Ostrom (2015) identified that the absence of an institutional mechanism to design local rules and a system of conflict resolution, led to the failure of a self-governed capture fishery in the Bay of Izmir and Bodrum, Turkey. The lack of operational rules aligning with inadequate law enforcement, heterogeneity of the participants' interests, and the demand for quick economic returns were identified to create a system exhibiting high transaction costs. This indicates that the IAD framework can also be used to investigate why institutions are absent.

2.2. Study site

Lake Maninjau is a large volcanic lake in West Sumatra, Indonesia (Figure 1). Its total surface area is 97 km², and its catchment area is approximately 133 km² with a total water volume of about 10 billion m³ (Apip et al. 2003). The lake was declared a national priority area in 2009. This means that *de jure*, lake restoration is the jurisdiction of the national government, including funding, coordination, and program implementation.

2.3. Data collection and analysis

Data for this study are interviews across the three levels of the IAD framework, complemented by an analysis of legal and policy documents.

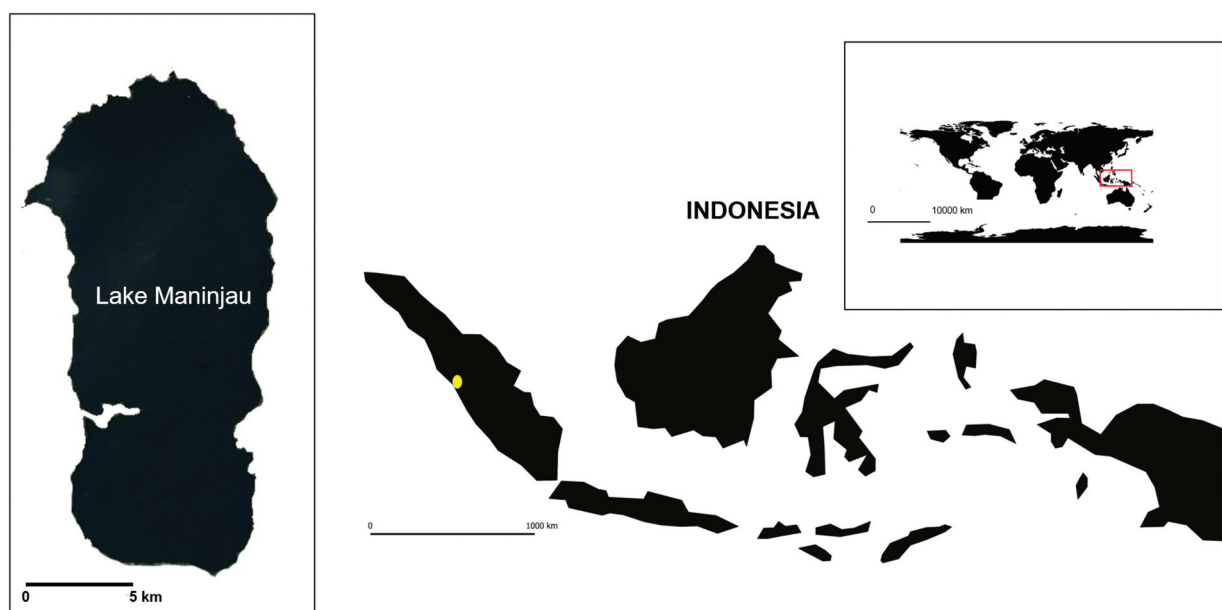


Figure 1. Study site (Figure is created with QGIS Software 3.2.1 based on maps provided by <http://www.naturalearthdata.com/>, retrieved on 2 March 2021).

2.3.1. Respondent sample strategy

At the operational choice level, 25 TCCF farmers, eleven fishers (three of them own TCCF), and seven hotel owners (the only remaining operated hotels and homestays in the area) were selected.

At the collective choice level, five of eight *wali nagaries* (Chiefs of the villages) were selected, four feed distributors, six staff of local government (sub-Regency and Regency level), who were chosen from the agencies which actively participate in the Save Maninjau Program, including technical staff and the directors, and the Vice Head of Agam Regency. Some respected customary and religious leaders are included amongst the hotel owners and *wali nagari* respondents. At the constitutional choice level, two representatives from the Ministry of Public Works (MoPW) and Ministry of Environment and Forestry (MoEF) were interviewed. We interviewed four female respondents: one in the sub-Regency government, one feed distributor, and two in the national level government.

Following Guest et al. (2006)'s purposive sampling method guidance, we interviewed a total of 25 farmer respondents involved in TCCF. Informed by our local assistant, we selected respondents based on the level of education and bridging social capital, indicated by the degree of connection to decision-makers. These criteria were chosen as studies have shown that education and social capital are related to the degree of acceptance of improved natural management practices and involvement in collective action (Marenya and Barrett 2007; Auer et al. 2020). Two groups (TCCF-A and TCCF-B) emerged due to congruence between our criteria:

- (1) TCCF-A: lower levels of education (secondary elementary or high school graduates) and limited involvement in local public meetings (10 men).
- (2) TCCF-B: higher levels of education (College graduates) with connections to local decision-makers and who actively participate in public meetings (15 men).

Whilst relatively more farmers in the study area fall into the TCCF-A group, many were not willing to be interviewed, therefore we were not able to interview a representative sample from each group.

Non-TCCF farmer respondents were selected by using a purposeful sampling method to capture rich insights on the relevant institutions and lake sustainability (Emmel 2014; Palinkas et al. 2015). This was done through collaboration with our local assistant and a snowballing strategy until we reached data saturation. A snowball sampling technique is a non-probability sampling method, in which samples are based on initial respondents referring researchers to further respondents. It is often used when difficulties

accessing interviewees exist, such as in our case (Naderifar et al. 2017; Frey 2018).

2.3.2. Interview approach

Following guidance by Nusbaum et al. (2017), data were collected using face-to-face semi-structured interviews. This allowed for synchronous communication, allowing the lead author conducting the interviews to provide direction to respondents' answers to specific questions, while still offering flexibility for respondents to speak without being steered towards particular response options (Opdenakker 2006; McIntosh and Morse 2015).

Following a semi-structured interview format, we asked TCCF farmers to identify rules-in-use, their views on who should be responsible for lake management, the problems related to lake management and their opinions of the actors across the three levels. We also asked about their knowledge of, and participation in, efforts to manage the lake and their routine activities in each farming cycle. Additional topics for the fishers and hotel owners covered the impacts of lake management on their businesses.

Specific questions to local government agencies covered their specific roles in the *Save Maninjau* Programme, formal regulations, agreed actions, their views on the challenges and complaints related to the TCCF management, and the communication patterns between local government and TCCF farmers. The latter topic became a central point of the interview as farmers had raised this as a pertinent issue. We asked respondents from the national government about the master plan for Lake Maninjau, challenges with its implementation, and any further issues emerging from interviews with local people and local government.

2.3.3. Field work

The interviews were conducted between February and April 2019. Before conducting the interviews, we received ethical clearance from the Ethical committee of the School of GeoSciences, University of Edinburgh. Each interview lasted 1–2 hours. We interviewed the farmers first, followed by hotel owners, fishers, feed distributors, sub-Regency and Regency government and finally members of the national government, to allow for insights from lower levels to inform the interview design for higher level respondents.

Interviews with TCCF farmers and hotel owners were conducted in the respondents' houses in four *nagaries*/villages connected to the lake (*Nagari* Maninjau, Bayur, Tanjung Sani, and Sungai Batang). We selected those *nagaries* because most of the hotels and the cages are located there. Bahasa Indonesia, which is the national language, was used to conduct the interviews. A local guide assisted with the direct translation of any Minangese vocabulary used during the interview.

2.3.4. Data analysis

The interviews were transcribed and analysed to interpret patterns in interviewees responses following Creswell (2009) and Raheem (2014). We also reviewed documentation of the laws related to Lake Maninjau, presentations of highly positioned governmental staff, and policies related to Lake Maninjau management, as shared by respondents. A document analysis was conducted of Law Numbers 12/2011 6/2014, 12/2011, and 32/2009, local policies such as Provincial Government Regulation No. 2/2007 and Agam Regency Regulation No. 12/2007.

3. Results

To ease the presentation of our results, we present our findings using the components of the IAD framework, in Figure 2.

3.1. External conditions

The external conditions comprise the biophysical environment, community attributes, and rules-in-use. Geologically, Lake Maninjau was formed by tectovolcanic activities (Apip, Fakhrudin, Sulastrri, Subehi, & Ridwansyah, 2003) and is as a result naturally rich in sulphur, which is deposited in the sediment (Henny 2009). It has a natural sulphur purification process which is locally called *tubo belerang* (Henny 2009;

Badjoeri 2013). This process occurs when there is mixing of lower-and upper-layer water and is commonly referred to as upwelling. The sulphur cycle and its interaction with organic material govern the balance of the lake ecosystem; preserving it will mitigate the consequences of upwelling such as mass fish kill (MFK) events.

All interviewed respondents at the operational choice level mentioned that—in the past—*tubo belerang* only took place about once every 5 to 10 years, and only after strong earthquakes. However, since its first official recording in 1995, the frequency of *tubo belerang* has been increasing. *Tubo belerang*, and subsequent MFK events are now reported to occur after storms in the rainy season. The death of thousands of tons of fish was recorded in each year of 2002, 2008–2011, 2015–2018 (Fakhrudin et al. 2012; Hamdani et al. 2014; Endah and Nadjib 2015; Murdaningsih 2018). Furthermore, the eutrophication level characterised by algae bloom and declining water transparency is also alarming (Sulastrri et al. 2012, 2015; Henny and Nomosatryo 2016). Anecdotal evidence provided by TCCF farmers suggests that in the past the lake was clear; the bottom could be seen with the naked eye, TCCF productivity was high, and people loved to swim.

The lake has reportedly lost its attraction to tourists. There are also concerns about more frequent *tubo belerang* and MFK events, especially in the rainy season. Further, *tubo belerang* also affects

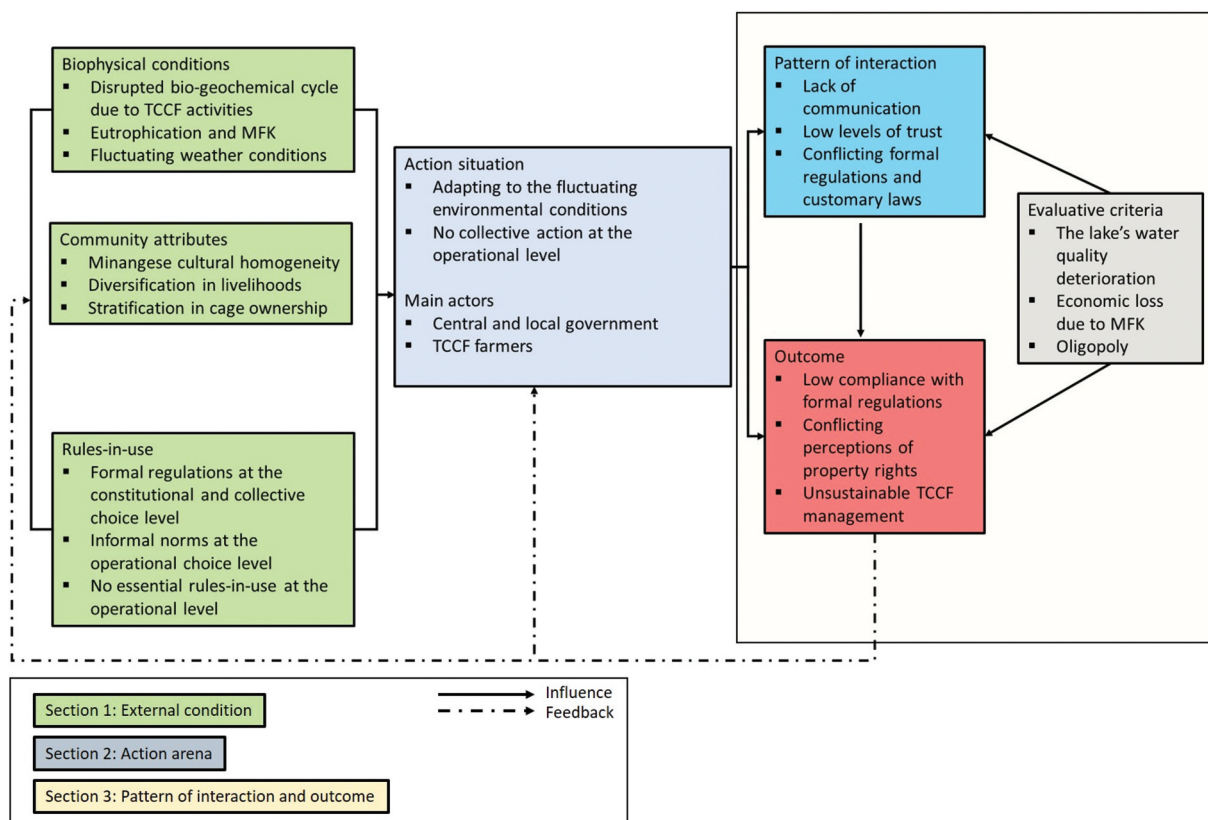


Figure 2. The principal findings organised with the IAD Framework adapted from Ostrom (2005, p. 15) and Ostrom (2011, p. 10).

capture fisheries. It affects native wild fish and molluscs by causing them to either faint or die. A Bayesian Belief Network model (Yuniarti et al. 2021) predicts that MFK is related to temporary forgone production of a native wild fish, *Gobiopterus* sp., due to the deterioration of the lake's water quality. This makes the fishers stop capturing *Gobiopterus* sp. for several months, shifting to other species instead. Despite the perceptions of negative impacts of *tubo belerang*, TCCF farmers also stated that shortly after *tubo belerang*, water quality is much better, raising productivity for fish farming. TCCF farmers mentioned that fish production is doubled or even tripled in the farming cycle after *tubo belerang*, presumably because the water becomes cleaner, richer in oxygen, and more suitable for green algae growth. Thus, there appears to be both positive and negative impacts of *tubo belerang* on the lake ecosystem.

The local communities occupy nine villages located in close proximity to the lake, eight of which have direct access to the lake. Almost all villagers belong to the Minangese ethnic group, which is strongly bound by their customary laws and clan system (Stark 2013; Franzia et al. 2015; Armiami et al. 2018). Minangese people are culturally homogeneous, which is also reflected in their livelihood practices. Most people engage in TCCF activities including producing seeds, transporting, harvesting, post-harvest businesses, feed distribution, farming, and the TCCF daily activities (e.g. feeding and securing the area). Agam Fisheries Agency (2017) reported that there were 1,636 registered TCCF owners in 2017; in 2016, there were 146 cage operators, 1,383 seed producers, and 26 feed distributors.

Besides engaging in TCCF activities, the villagers are also involved in plantations and agriculture, fishing, trading, tourism, and other service activities that offer alternative livelihoods (Agam Regency Statistical Bureau 2018). The fishers mostly capture *R. maninjau*, *Gobiopterus* sp., and wild tilapia (*Oreochromis niloticus*). Occasionally, they catch other native fish such as *Osteochilus hasselti*.

Villagers can be categorised based on their formal educational background, their position in the cultural hierarchy (clan leader, elders, and members), and financial capital. Based on the involvement in the cage farming daily operational activities, the individuals are categorised as owners, funders, operators. The *owners* are individuals who legally own the cages and finance their construction, but do not always operate them. The *farmers* are the people who own, fund, and operate their cages. The *funders* financially support the daily operational cost in one farming cycle for a number of cages, but only rarely legally own cages. *Operators* are paid a monthly salary to conduct the daily operation of the cages.

Customary law only allows local Minangese living in the lake area to own the cages. However, the *de facto* owners can be the kin of the locals who live outside the lake area. More importantly, both *de facto* funders and owners can be outsiders, 'borrowing' names from the locals. Meanwhile, anyone with a different ethnic background living in the lake area can be an operator. Furthermore, many individuals who fund cage operations, but neither own nor undertake farming activities, live outside the area. Unfortunately, it was not possible to interview this type of funder.

Another important community attribute is customary decision making at the village level. Most TCCF farmers mentioned that all decisions should be made via a collective decision-making group, the *Badan Musyawarah* (BAMUS). Once agreed by this collective group, the decision becomes *nagari* policy and is viewed as legitimate by local people. In Minangese culture, only decisions made through collective decision-making (referred to as *musyawarah*) are viewed as legitimate (Arifin and Gani 2011).

BAMUS consists of *ninik mamak* (customary elderly group), *alim ulama* (religious leaders), *cadiak pandai* (intellectuals), *rang mudo* (the youth), *bundo kundang* (a respected woman group) and *Lembaga Pemberdayaan Masyarakat Nagari/LPMD* (local empowerment group) (Putra 2013). Inclusion of these groups in BAMUS puts this institution at the core of *nagari* leadership (Asrinaldi and Rusta 2016). Members of the community can collectively voice their opinions in BAMUS (Oktafia 2012; Putra 2013). Further, all members of the community can be included in the collective decision-making through the *musyawarah* process because people's opinions are collected in the pre-*musyawarah* stage. This arguably makes this system more deliberative than most systems based on representation (Asrinaldi and Rusta 2016).

However, BAMUS's authority has been reduced by a lack of acknowledgement of *nagari* policies within the formal regulation structure (Putra 2013; Asrinaldi and Rusta 2016). In the past, a *nagari* policy was acknowledged as a formal regulation, however its status is no longer formally acknowledged even though it is still culturally legitimate. Only, *wali nagari* policy-created by *wali nagari*- is seen as legitimate in formal laws (Putra 2013).

Table 1 illustrates the rules-in-use applied in constitutional choice, collective choice, and operational choice levels. The rules-in-use relate to the governance of Lake Maninjau in general and focus on TCCF as the primary target. The interviews revealed that respondents from the MoPW, MoEF sub-Regency, and Regency government mostly use and refer to formal regulations as their rules-in-use.

Table 1. Rules-in-use.

Subject	Constitutional choice	Collective choice	Operational situations
Indonesian lake in general	1945 constitution statute 33: land, water, and natural resources are owned by the country National government Regulation PP Number 38/2011 (about lake banks: 100 m from highest water level should be cleared from any buildings and is used for green belts) Note of Agreement of 9 Ministers (2009) about 15 national priority lakes Grand design of restoration of lakes' ecosystem (2012) (drafted and proposed by MoEF) Grand design of Lake Maninjau management (drafted and proposed by MoPW) Law Number 32/2009 about Environmental Protection and Management	N/A	N/A
Lake Maninjau	N/A	Save Maninjau movement act including alternative livelihood provision Agam Regency Regulation Number 5/2014 about Lake Maninjau conservation (highlight: TCCF should be limited up to 1,500 units or 6,000 slots) strengthened by Bupati Agam official letter Number 533.2/611/DKP-AG/IV/2016 (limitation of additional TCCF construction) Provincial Government Regulation about Zonation of Lake Maninjau's Strategic Area (legalized on 1 April 2019, not yet implemented)	Scope rules: the area within a throwing stone range belongs to the owner of the house (customary law)
Spatial planning	National government Regulation Number 15/2010 about spatial planning, strengthened by The minister of MoPW regulation Number 4/2015: zoning is the responsibility of MoPW The minister of MoPW regulation Number 28/2015 about assessment of watershed lines of rivers and lakes		N/A
Local governance	Law Number 12/2011 (<i>wali nagari</i> regulation is acknowledged as a formal regulation) Law no 6/2014 about village Law no 12/2011 about the systematic of policies	Provincial Government Regulation Number 2/2007 about <i>Nagari</i> (BAMUS works together with the <i>wali nagaries</i> to decide <i>Nagari</i> policies) being revised by Provincial Government Regulation Number 7/2018 about <i>Nagari</i> (enlarging KAN authority, and not mention about BAMUS) Agam Regency Regulation Number 12/2007 about <i>Nagari</i> Governance Sustainable TCCF practice regulation (being discussed by Regency Government, Fisheries agency and Agam Planning Agency) including iron material cages, floating feed, low stocking density, one feeding time per day, dead fish body clean up from the lake, extra time between farming seasons	Information rules: BAMUS decision is respected
Cage farming	Ministry of Marine and Fisheries Regulation Number 02/MEN/2004 about legal permit for aquaculture		Entry and exit rules: only local/native people who can own TCCF (based on customary law), but in reality, outsiders can have TCCF by 'borrowing' names of the locals. As a result, no limitation of number of owned cages, so people with strong financial capacities may have as much TCCF as they want. Position rules: no organised structure related to TCCF. Authority rules: not applicable Aggregation rules: not applicable (permit license is proposed, but have not been conducted yet) Pay off rules: not applicable, no sanctioning, no monitoring
Others	Water quantity protection becomes the main responsibility of MoPW Water quality protection becomes the main responsibility of MoEF	N/A	N/A

Currently, the ‘grand design’ of Lake Maninjau is being drafted by the MoPW (constitutional choice level). Meanwhile, the MoEF is developing a restoration master plan for all priority lakes in Indonesia. The plan covers lake management and protection, spatial planning, and local governance. However, until recently, national government regulations have not specifically addressed the management of Lake Maninjau.

At the collective choice level, the regulations are more specific to the TCCF and Lake Maninjau management area. They consist of Provincial Regulations, Agam Regency Regulations, and the Head of Agam Regency/Bupati Regulations (Table 1). Some of the formal rules at these levels are still in development (i.e. sustainable TCCF practice). Others are currently being legalised; thus, their implementation is still an on-going process (i.e. Regency Regulation No. 5/2014 and Bupati Agam official letter No. 533.2/611/DKP-AG/IV/2016). None of the regulations being drafted or legalised refer to self-governance. Thus, TCCF self-governance at both collective and constitutional choice levels is not recognised.

At the operational level, we found that there is a lack of institutions specifically guiding farmers’ actions around TCCF management (Table 1). We can imply from the interviews that farmers’ behaviour and choices are mostly directed by their claim to the customary right that the lake is their property. The farmers inherited *hak ulayat* and *tanah ulayat* (customary rights and property rights) as they were born in the lake area as Minangese. Although, these rights are to act as stewards of the lake, they are commonly understood by villagers as granting them the privilege to manage land and common property in their area. Many farmer respondents quoted their common saying that ‘the area within our throwing stone is ours’. Moreover, according to the customary law, property ownership is inherited and authorised by the elders of the clan (*mamak*). The members of the clan (*kamanakan*) inherit the right to use and manage the lake (Putri 2018). As an implication, the farmers believe that only the elders can withdraw their rights to nature.

Regarding TCCF, this customary right is translated into entry, exit and scope rules, which only allow the native Minangese living in the lake area to own cages in the lake (Table 1). We could not identify other institutions to regulate TCCF, including pay-off rules (i.e. sanctioning). This situation is nevertheless contrasted with the customary land tenure system where sanctioning of violators is observed (see Syahyuti 2006). Sanctions in the land tenure system are decided by the *musyawarah* and include fines or social sanctioning such as exclusion. More importantly, entry and exit rules are sometimes undermined through arrangements such as renting and cost sharing (Table 1). This eventually results in the

transformation of the CPR into an open access regime, as will be discussed below.

3.2. Action situation

The characteristics of the action situation across levels of governance are described in Table 2. We did not find evidence of collective action among the farmers at the operational level. We observed that individual participants’ actions at this level are mainly responses to biophysical conditions and profit earning motives.

The main participants in the action situation are:

- (1) Operational choice level: TCCF farmers (TCCF-A and TCCF-B), tourism entrepreneurs
- (2) Collective choice level: feed distributor, BAMUS, and Regency government agencies
- (3) Constitutional choice level: national government agencies

Further, we identified several different strategies TCCF farmers employ to adapt to water quality deterioration, changes in seasonal weather conditions and climatic fluctuations (*El Niño* and *La Niña*). The first strategy is that all farmers (TCCF-A and B) shifted from carp into tilapia farming. Tilapia has high tolerance to low levels of dissolved oxygen in the water (as a sign of water quality deterioration). The interviews revealed that there is actually higher demand for carp which also attracts a higher market price than tilapia. However, it requires good water quality, therefore data from Agam Fisheries Agency (2017) reveal that all farmers have shifted from carp to tilapia farming since 2009.

The second strategy is that TCCF-B (higher education and more access to the decision makers) farmers adopt feeding strategies that are arguably more sustainable to align with the water quality condition. Some individuals in the TCCF-B group have changed their feeding management (i.e. reduced feeding time, using floating feed instead of submerged feed). We found that all TCCF-B only feed the fish once per day. Such changes were not observed among TCCF-A farmers, who feed the fish between one and three times per day. Five TCCF-A respondents stated that they feed the fish three times a day because the fish look hungry. They also insisted that the fish would not be able to eat naturally occurring food such as abundant phytoplankton.

The third strategy is to change farming strategies to deal with weather conditions across seasons. Four TCCF-B respondents mentioned that most farmers alter their farming activities due to both water quality and weather conditions. For example, the farmers harvest larger and thus more profitable fish, increase stocking density and extend the farming period (3–4 months per cycle) if the water quality is good in the dry season.

Table 2. Action situation.

Action situation		
Level	Actions	Participants
Operational Choice	Owning, funding, and technical worker of tilapia farming	TCCF-A and B, mostly from TCCF-B
	Owning and technical worker but not funding	TCCF-A and B, mostly from TCCF-A
	Generating income from the profit	TCCF-A and B, mostly from TCCF-B
	Profit sharing	TCCF-A and B, mostly from TCCF-A
	Understanding the formal regulations related to TCCF	TCCF-A and B, mostly from TCCF-B
	Maximizing production after MFD as the water is really productive after the event to balance their financial loss during MFD	TCCF-A and B
	Maximizing stocking density in dry season (March-August) and lowering it in rainy season to avoid loss from MFD	TCCF-A and B
	No zoning, using customary law: the area within a throwing stone range belongs to the owner of the house, no green belts rules	TCCF-A and B
	Less engagement in alternative livelihood	TCCF-A
	Low awareness of sustainable TCCF practices such as still using submerge feed instead of floating feed, high stocking density after MFD, and throwing dead fish to the lake	TCCF-A
	Predicting weather. So, if there is a sign that it will be stormy, they harvest their fish as fast as possible to avoid further loss	TCCF-A and B TCCF-A and B
	Adjusting farming strategies to adapt with weather conditions	
	Changing fish species over time. It was carp at the beginning and then tilapia because it has higher tolerance to limited dissolved oxygen	TCCF-A and B
	Renting TCCF to investors	TCCF-A and B, mostly from TCCF-A
	Owning relatively few numbers of cages (4 to few more numbers)	TCCF-A
	Owning relatively high numbers of cages (up to x)	TCCF-B and feed distributor
	Understanding the impacts of unsustainable TCCF practices to the lake ecosystem	TCCF-B
	Reducing the frequency of feeding and the amount of feed	TCCF-B
	Using access to governmental agencies	TCCF-B
	Endorsing BAMUS function to communicate with people	TCCF-B
Generating income, providing livelihood, raising voice for zoning Changing target species	Tourism entrepreneurs & fishers TCCF-A & B, fishers	
Collective Choice	Controlling feed price, owning massive numbers of TCCF via co-partnerships, providing capital credits for TCCF, some are taxpayers	Feed distributors
	Making and disseminating regulations (including zoning), providing fund for alternative livelihoods	Local government (Provincial, Regency, Sub-Regency, and Village level)
	Formulating village decision with the <i>wali nagari</i> , a place for local people to voice their opinions	Local authority (BAMUS)
Constitutional Choice	Formulating regulations, providing fund for alternative livelihoods, planning the grand design of lake management, giving political and financial back up for restoring the lake, providing technical assistance, providing research resources	National government (MoEF, MoPW, Research Centre for Limnology-Indonesian Institute of Sciences)

TCCF-A: lower levels of education (secondary elementary or high school graduates) and limited involvement in local public meetings (10 farmers).

TCCF-B: higher levels of education (College graduates) with connections with local decision-makers and active participation in public meetings (15 farmers).

In the rainy season, they do the opposite (reduce stocking density and shorten farming period).

Similar changes in farming strategy have been reported as a response to temporary climatic shifts following *El Niño* and *La Niña* conditions. *El Niño*, or more precisely the El Niño-Southern Oscillation (ENSO), and *La Niña* are periods of extreme weather across South East Asia and Africa triggered by sudden shifts in the surface temperature of the South-Eastern Pacific Ocean. *El Niño* and *La Niña* both resulted in severe negative effects on aquaculture production (New et al. 2001; Gomez-Uchida et al. 2018; Bertrand et al. 2020). Specific to Lake Maninjau, a report from MoPW (2013) described that rain and strong wind, typical for *La Niña* conditions, triggers mixing and MFK events in the lake. As a strategy

to cope with the risk of MFK events and to mitigate the resultant severe financial loss, farmers reportedly reduce their production efforts and shorten farming cycles in response to adverse weather signals. They extend farming cycles and increase efforts under favourable conditions. Data on productivity per cage in the lake illustrate this (Figure 3). During a previous *El Niño* condition in 2015, the productivity per cage increased. During the subsequent *La Niña* condition (July 2016 to around March 2017) productivity per cage reduced (Figure 3).

We observed that TCCF-A and TCCF-B groups also differ in the norms of interaction with feed distributors and other funders, i.e. with the participants at the collective choice level. TCCF-B farmers commonly self-fund the operational cost (Table 2). In this

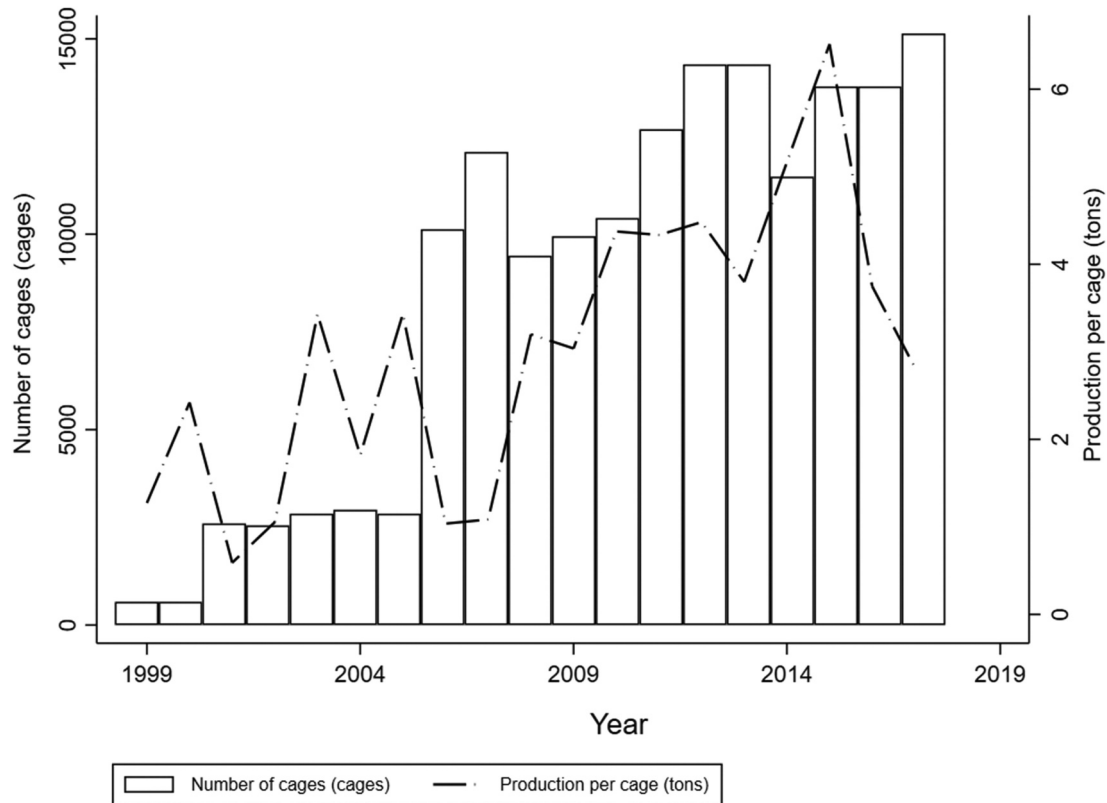


Figure 3. Production of tilapia per cage & number of active cages (Source: Author's creation based on the data from Agam Statistical Agency/(Agam Regency Statistical Bureau, 2000–2018)).

arrangement, TCCF-B farmers usually have fewer cages and run the business with their distant family, with whom they share the profit or loss.

TCCF-A farmers practice three kinds of norms of interaction (Table 2):

- (1) The owners pay the feed cost via an instalment system to the feed distributors and self-fund the stocking cost. If they make a profit, the feed cost will be deducted from their share, but if they make a loss, the feed cost will become a debt to be paid. This is the most widely practiced arrangement in the study area.
- (2) The funders pay all the operational cost, and the owners will receive 30% of any profit without a salary or renting fee.
- (3) The owners informally lease their cages to other parties such as the feed distributors and outsiders from other cities (i.e. Jakarta and Pekanbaru), and act as the operators who receive salaries but do not share the profit or loss.

Considering that the first norm of interaction is the most common practice among TCCF-A farmers, feed distributors are among the most powerful participants at both the operational and collective level. It is important to note that most feed distributors are categorised as a common type of funder as they develop farming networks by financially funding the operational cost of

the cages owned by many people with various agreements. Thus, they practically become the regulators for the action of participants at the operational level. This claim is supported by one of the *wali nagaries* and all TCCF respondents mentioned that the feed distributors informally control the price of the feed, who farms, and when to start farming and harvesting. This creates an oligopoly practice at the operational level. Further evidence of this practice is that one of the feed distributors is funding the operation of thousands of cages.

The oligopoly practice has become a serious concern for the cage farmers as it causes feed prices to rise. One TCCF-B farmer, who is a respected person in the area, mentioned that there had been an effort to create a farmer group to overcome the oligopoly practice and to improve coordination among the farmers. The group created a *koperasi*, an Indonesian collective economic system akin to a cooperative, to fairly distribute and regulate feed among the farmers. However, the lack of trust among the members and the group organiser caused the group to disband. Therefore, the farmers (TCCF-B, TCCF-A type 2 and 3) who do not belong to the feed distributor group currently act individually.

The above results explain why collective action is not observed among the farmers at the operational level. The individual participants' actions at this level are mainly responses to biophysical conditions and profit earning motives such as harvesting the fish

before a storm happens, maximizing stocking density in the dry season (March-August) and lowering it in the rainy season (Table 2).

In addition, we observed that fishers adapt to the changing environment in several ways at the operational level. In the past, a greater number of fishers had targeted the endemic fish species *Rasbora maninjau*, which has relatively high economic value. The interviewed fishers reported a shift in recent years towards catching wild tilapia (originating from cage culture escapees). One reason for this shift may be that wild tilapia can be marketed faster since it does not require any post-harvest treatment (e.g. smoking). However, there may equally be a shift in fish populations, an aspect requiring further research. More importantly, however, the interviewed fishers are pleased with the presence of cages as they provide additional habitat for another native fish, *Gobiopterus* sp.; thus, they fish more intensively in the cage area compared to its natural habitat. Fishers made a similar claim for *Rasbora maninjau*, although results of a species distribution model (Yuniarti et al. 2020 in review) only support a habitat effect for *Gobiopterus* sp. Considering these circumstances and the fact that most fishers also engage in cage farming activities, we are not aware of any indications of open conflicts between the fishers and the farmers.

At the collective choice and constitutional choice levels, government actions are guided by formal regulations based on the respective administrations' remit. At the national level, the MoPW is responsible for water security and focusses its work on maintaining the water quantity in the lake by conducting actions to combat sedimentation. Meanwhile, the MoEF is responsible for conserving the environment and focusses its attention on establishing a conservation zone in the lake and on funding projects for providing alternative livelihoods. At the same time, the Regency government is focusing on imposing a cage number limitation as a solution to the emerging environmental problems. We did not see any evidence at the national and Regency government levels of actions aimed at addressing oligopoly practices and managing the established open access regime.

3.3. Constraints of interaction across institutional levels

Our data reveal significant constraints to interactions across levels due to a lack of trust among the participants and contradictions between formal and informal institutions. These two constraints together represent the main obstacles for the development of rules-in-use at the operational choice level.

The lack of trust between actors at the collective choice and operational choice levels can be attributed to, and also compounds, limited and inconsistent communication. All TCCF-A respondents stated that the Regency government staff, except the Fisheries agency,

do not want to discuss lake governance with them. All TCCF-B respondents have a slightly better opinion of the Regency government, viewing the number of meetings as sufficient. More importantly, all TCCF farmers perceive the Regency government communication as limited and inconsistent. For example, after programmes are initiated, there is limited follow up support to enable their continuation. The perception of poor communication and of the government's inconsistency in response contributed to the development of distrust among the TCCF farmers and between the farmers and the Regency government.

Distrust between TCCF farmers and the Regency government is seen in our data as all TCCF-A respondents and ten TCCF-B respondents voiced doubts about the local government's commitment to cleaning the lake. TCCF-A farmers also stated that the government staff did not treat them with respect. However, interestingly the majority of TCCF respondents in both groups expressed trust in the Fisheries agency as the only local government agency which would discuss issues with them, try to understand their position, and attempt to help. The Fisheries agency appears to be the only agency that frequently sends its outreach staff to the field. This highlights the importance of frequent and consistent communication in creating a better perception of governmental officers amongst farmers, thereby building trust.

The feeling of distrust is mutual; most respondents from the Regency government mentioned that they do not trust local people, because they keep changing their commitments related to their compliance to better farming practices. One respondent stated that 'local people are stubborn, can't be trusted, and do not want to change'. This sentiment was supported by two highly respected hotel owner respondents, although they stated that they were also willing to mediate between the Regency government and local people. In fact, one of these respondents, who also holds an important position in the society, has already mediated between some fishers and Agam Environmental Agency to protect a proposed no-catch zone.

Further, interaction between the national and the Regency government seems limited. Although respondents from the national government claimed that they actively involve local government in decisions about the lake, five local government respondents stated that they are not given sufficient space to participate even though they claim to have better knowledge of the lake situation, indicating a lack of trust of local government by the national government agencies.

We also found evidence of formal regulations conflicting with customary laws, which usually become the foundation of rules-in-use. This can be seen with

the issuance of The Law Number 2/2011, which deemed the *Nagari* Regulations as not legally recognised (Putra 2013). Since 2011, the only legally recognised rules at the *Nagari* level are The Head of *Nagari*'s Regulations whereas before this date *Nagari* rules issued by BAMUS had more power than The Head of *Nagari* Regulations (as seen in the Provincial Regulation No.2/2007 about Basic Rules of *Nagari* Governance and Agam Regency Regulation No 12/2007). Formal regulations have weakened BAMUS' authority as the local institution though it is still viewed as legitimate by the local people.

We also observe conflict between formal regulations and customary law in efforts to create lake zoning and limit the number of cages. The zoning regulation is the necessary prerequisite to legally support entry and exit rules (the rules to control which actors can enter the system freely, and the conditions they face if they are leaving), therefore uncertainty about the issuance of the regulation causes a delay in establishing these rules. The respondent from the MoPW explained that the delay in crafting the zoning regulation is a consequence of conflicting customary law with formal law. She further clarified that to create spatial planning, the formal regulations (National Government Regulation number 15/2010 on spatial planning and Regulations of the MoPW No. 28/2015 on watersheds) clearly defined boundaries of 50 meters between people's houses and the maximum water line. However, the customary law allows people to inhabit and use the lake banks. Without resolving this contradiction, the creation of zones is likely to be postponed.

Moreover, differences among the rules used at the constitutional choice and collective choice levels and the rules at the operational choice level contribute to difficulties in forming the essential rules-in-use, such as pay off rules. Inadequate support from formal regulations to back up the formation of exit and entry rules, and pay off rules, further undermines local people's ability to protect their resources from transforming into open-access property (see the absence of entry and exit rules in Table 1). Further, this situation fuels oligopoly practices as previously explained. The oligopoly system aligning with the absence of authority and aggregation rules fuels the impact of the undermined entry and exit rules. This creates an open access regime, which means everyone can enter the business as long as they have money, evidenced by the fact that many of the cages are funded by non-natives (Agam Fisheries Agency 2017).

4. Discussion

One underlying cause inhibiting the development of sustainable TCCF in Lake Maninjau is the absence of several essential rules-in-use at the operational level, which leads to the establishment of an open access

regime and oligopoly practices. The absence is triggered by several factors such as confusion over the lake property rights regime across levels, poor interaction among the participants due to distrust and inadequate communication, and conflict between formal regulations and informal institutions (i.e. customary laws). This conflict undermines the success of the enforcement of legal rules. It also weakens the role of the essential informal institutions (e.g. BAMUS).

De jure, the lake is a state property. However, local people (including the farmers) perceive the lake resources to be exclusively granted through their customary right. However, TCCF is understood by the farmers as their private property. Thus, *de facto* the local people claim that the lake is their property. The unclear property regime further creates conditions whereby the CPR is managed as an open-access regime. This is a typical case in low- and middle-income countries, where the confusion surrounding the property right regime creates misunderstanding, which further extends the *de facto* open-access system due to lack of monitoring resources (Ostrom and Hess 2010). The open-access regime can be avoided once the participants develop essential rules-in-use for the appropriation and provision of resources and create clear boundaries (ibid), which allows them to exclude 'outsiders' and sustain their resource (see Ostrom 1994).

In a self-governed resource, the participants can make essential rules ensuring the sustainability of the resource. However, conflicting formal regulations and informal regulations result in the undermining of people's compliance with the legislation (Table 1). Usually, in the case of conflict between formal and customary laws in Indonesia, rigid repression will be the case (see Setiawati 2018). Nevertheless, in the case of managing the resources of Lake Maninjau, formal regulations do not function due to limited law enforcement and monitoring. Pomeroy (1995) and Atmaja and Nugroho (2011) revealed inadequate monitoring and weak law enforcement in the fisheries sector in Indonesia. In such a case, it is imperative to build agreed operational rules that sustain the CPR resources (see Basurto et al. 2013; Long et al. 2017).

Despite its importance, our study reveals that self-governance has not been acknowledged in the formal regulations related to TCCF and the lake ecosystem. Arguably, the conflict between legal rules and informal institutions also diminishes the role of the essential informal institutions such as in the case of BAMUS. Thus, it is necessary to map all formal and informal institutions, to identify which institutions can be used to regulate essential rules-in-use, and to readjust and realign the institutions. As a consequence, substantial bureaucratic work cannot be avoided. In this circumstance, co-management between local

farmers and local government may be the appropriate governance mode (see Atmaja and Nugroho, 2011, who argue for the need for co-management in the fisheries sector in Indonesia).

The other factor that needs to be addressed to shape essential rules-in-use and to ensure that the rules are followed, is to improve trust and communication among the participants. In our case study, lack of trust between the farmers and local government intertwines with conflicting institutions, resulting in difficulties to form rules-in-use such as in the case of cage limitation. Some farmers do not believe that their actions negatively impact the lake's water quality, despite scientific evidence supporting this claim and awareness raising from the governmental agencies. Such TCCF farmers do not engage with the cage limitation idea. In this case, people's distrust of the actions of the governmental agencies causes distrust regarding the information provided by the agencies and *vice versa* (Henry and Dietz 2011). Further, distrust results in the failure to form the entry and exit rules, which govern the basic implementation of cage limitation policy. This case shows that the absence of trust, which is an informal institution, exacerbates issues of conflicting institutions and can inhibit the formation of other institutions for managing the CPR.

Trust is imperative in solving a conflict of interest (e.g. Balliet and Van Lange, 2013). From the interactions between actors, a person learns who is trustworthy and who is not. In this case, the Fisheries agency and BAMUS have established themselves as being trustworthy. Other governmental agencies should learn from these institutions to gain the people's trust. This is in line with research which claims that trust itself is the key to cooperation for governing CPR where cooperation and reciprocity are required (Grootaert and van Bastelaer 2001; Ostrom and Walker 2003; Lewicki and Bunker 1996; Janssen 2015; Murtazashvili et al. 2019).

Communication, which is limited and inconsistent between local government and TCCF farmers, is a crucial element to understand various stakeholders' interests, and this understanding is the key for successful policy implementation (Cash et al. 2003; Avishek et al. 2012; Coq et al. 2015; Ruckelshaus et al. 2015; Sala and Torchio 2019). Janssen (2015) and Ostrom and Walker (2003) identified that clear communication, cooperation, and sanctioning are essential for collective behaviours. Also, Ostrom (1999) and Ostrom (2011) concluded that if communication levels are low, there is no chance to gain trust, and it is highly likely that self-governance of CPR will fail.

Our study has identified the challenges of sustainable management of TCCF in Lake Maninjau using the IAD framework. We have also pointed out the importance of building sustainable self-governance in the area. Equally important, we also have identified challenges that should be overcome to achieve the goal of building sustainable self-governance, such as the clash between regulations

and informal institutions and poor communication between the participants. We contribute to the commons literature by providing a case study of TCCF, which is a private property operation in a common property lake. More importantly, we have provided empirical evidence on how distrust of actions leads to distrust of information (Henry and Dietz 2011) and the importance of trust in building long enduring self-governance in a polycentric governance system, corroborating the work of Ostrom (1999) and wider commons scholarship.

We do not claim to be able to generalise our insights on TCCF governance due to differences in cultural, biophysical environment, and other community attributes between Lake Maninjau and other lake systems in Indonesia. Nevertheless, this research can provide insights into relevant institutions and their interactions applicable to other lake systems in Indonesia. Moreover, we recognise that we could only speak to a few local women respondents. Therefore, further research on gender and interactions between oligopoly and CPRs will respond to calls for commons research to include greater attention for the political economy (Clement 2010).

5. Conclusion

Based on our institutional analysis, one of the main challenges for the development of sustainable management of tilapia cage culture farming in Lake Maninjau is the absence of essential rules-in-use, particularly at the operational level. Some factors that may affect this absence are the confusion of the lake property regime between all government levels and the local people, conflicting formal regulations and informal institutions, and low levels of interaction across institutional levels due to distrust and inadequate communication. The recommended actions are to create a common understanding of the property rights and to map and discuss realigning formal and informal institutions. These actions are imperative for establishing the essential rules-in-use. Meanwhile, improving trust and communication among the participants by strengthening trustworthy authorities such as BAMUS is advised to increase communities' compliance with the agreed rules in the future. Our theoretical contribution is the provision of empirical evidence that the lack of trust across institutional levels can impede the formation of essential and durable rules-in-use, especially at the operational level.

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