The changes of property-rights regimes and lake degradation: an institutional analysis of Lake Rawapening

E Irawan* and N Haryanti

1 Watershed Management Technology Center, Jl. A. Yani, Pabelan, P.O. Box 295, Surakarta, 57102, Indonesia

*Corresponding author:
Email : evirawan17@gmail.com

Abstract. The effects of various property-rights regimes on natural resource systems have long been debated among scholars and practitioners. A large number of studies have investigated the relationship between various property-rights regimes and environmental outcomes and show that public, state, and private property regimes are each capable of producing sustainable environmental outcomes. However, the evidence is very diverse. This study examined how the changes in property rights regimes at the local level have impacted on lake degradation using an institutional economics perspective, specifically the property rights approach, by taking Lake Rawapening as the case. Lake Rawapening is a multifunctional semi-natural lake currently degraded where almost 70% of its surface is covered by water hyacinth and experiencing rapid siltation. This research used a case study method. Data and information were collected from in-depth interviews with key informants, government officials and reviews of reports and documents related to Lake Rawapening. Results of the study reveal that the current property rights regime in the lake and its catchment areas associated with social changes was driving local resource users towards greater lake degradation. There were opportunities to build on existing village-level institutions to develop collaborative management systems to help protect the lake ecosystem.

1. Introduction
There is almost no doubt that most of the major lakes in Indonesia were in critical condition, suffering from water pollution, siltation and eutrophication [1–4]. This has had profound significant ecological and social economic impacts on resource users [5–7]. There is a multitude of factors has been advanced to explain lake degradation. Compare to biophysical aspects, socio-economics aspects are often overlooked despite it is widely recognized in the field of hydrology that human actions are likely to have myriad impacts on lake ecology ranging from hydrological dynamics, water quality to biogeochemical cycles [8]. Closer looks at empirical studies of the socio-economic aspects of lake management in Indonesia, it seems likely that the studies have been so far much dwell on economic valuation of environmental services provided by the lake [e.g. 9–12]. It is argued that revealing the economic value of lake environmental services can heighten public awareness and may inform
decisions related to its use, conservation, and restoration [13]. Human behavior towards the environment, however, is not only influenced by the economic value of environmental services reflecting their scarcity, but is also influenced by the institutional arrangements that shape and regulate the structure of human interactions [14]. Inasmuch as property rights regimes are concerned, previous studies of socio-economic aspects of lake management in Indonesia did not pay sufficient attention to the nature of prevailing structures of property rights structures on the lakes that were the subject of those studies.

All lakes, natural or artificial, are in general provide a wide range of economic, social and ecological benefits and so attract multiple users with different objectives, interest, degree of powers and resources. Furthermore, a lake simultaneously constitutes resource units and resource systems. The goods and services it provides have private, common-pool and public good features. This has rendered lake management recognized as a complex challenge, involving diverse interests and stakeholders and requiring appropriate institutions to facilitate negotiations, conflict management, and integrated approaches. Among key institutions of natural resource management, such as lake, property rights regime plays a particularly important role since it structures incentives for users pertaining to the use of lake resources. The design of property rights regimes that are aligned with the functions of the underlying ecosystem of the lake is fundamental to successful and sustainable lake management. The core question this paper attempts to address is how the changes of property rights regimes at local level have led to the degradation of the lake by using the perspectives of institutional economics, in particular property-rights approach. The analysis of property-rights regimes is of importance for the studies of natural resource management since they govern the interactions among members of society concerning the natural resources [14–16].

2. The Concepts of Property Rights
The linkage between property rights regimes and environmental sustainability has been controversial since Garrett Hardin’s seminal paper [13]. Although widely criticized for his inaccuracy in using the term of common-property resource, Hardin’s idea has triggered many empirical research projects on the effects of property-rights regimes on the sustainability of natural resources [14–17].

There are numerous definitions of property rights can be found in the literatures, including “a claim to a benefit (or income) stream that some higher body—usually the state—will agree to protect through the assignment of duty to others who may covet, or somehow interfere with, the benefit stream”[17], “enforceable authority to undertake particular actions related to specific domain” [18], or “an aggregate of rights which are guaranteed and protected by the government” [19]. In essence, a property right is social institution describing relationships between people with respect to resources. It is necessary to emphasis that the rights held by one party will only find its validity when the others recognize and respect them. It means that rights must be accompanied by commensurate duties to respect those rights [17].

Property regimes are “the sets of rules (laws, regulations, customs) that define property rights” [19]. In the realm of natural resource management, there are four ideal property regimes known as private property, common property, state property, and open access, all of which have different types of rights associated with them [17]. Private property regimes are where property rights are vested to an individual rights holder or a private entity. Common property regimes are private property for a group of co-owners[17]. In the case of state property regimes, the rights are in the hands of the state. Open access is a situation without property rights. These property regimes are rather broad categories encompassing a variety of forms and therefore it is difficult to draw a strict line of demarcation between them [15]. Mwangi and Meinzen-Dick [20] suggested to focus more on the structure of property rights held by resource users rather than classifying those rights into rigid categories.
Table 1. Bundles of rights associated with positions[21]

| Right                  | Owner | Proprietor | Claimant | Authorized User | Authorized Entrant |
|------------------------|-------|------------|----------|-----------------|--------------------|
| **Operational rights** |       |            |          |                 |                    |
| 1. Access              | X     | X          | X        | X               | X                  |
| 2. Withdrawal          | X     | X          | X        |                 |                    |
| **Control/Collective-choice rights** |       |            |          |                 |                    |
| 3. Management         | X     | X          | X        |                 |                    |
| 4. Exclusion           | X     |            | X        |                 |                    |
| 5. Alienate            | X     |            |          |                 |                    |

The main messages of empirical studies of property rights analysis of natural resource management are at least four folds. First, property-rights regimes matter for the sustainability of natural resources being concerned since they structure incentives so as to influence the motivation of those who exercise the rights or work with the resources [18–20]. Secure and recognized property rights create incentives to invest long-term in maintaining and protecting resources, and without enforced property rights, resources often become degraded as it was envisaged by Hardin [13]. A number of empirical studies conducted in some countries, both developed and developing, has confirmed that there is a link between property rights security and the sustainability of natural resources [28–33]. Second, each property-rights regime is capable of yielding sustainable or otherwise unsustainable environmental outcomes [21]. Third, each property-rights regime entails transaction costs which have implications on the efficiency of resources management [22]. Finally, societies are capable to craft property-rights regimes if the enabling necessary conditions for crafting suitable institutions are present [23].

Schlager and Ostrom [21] developed further a useful framework for comparing property rights regimes across the bundles of property rights (table 1). There are five property rights have been identified with respect to natural resources [21]: (a) access right (the right to enter a defined physical property and enjoy non-subtractive benefits), (b) withdrawal right (the right to obtain the products of resources), (c) management right (the right to devise operational-level rights of withdrawal), (d) exclusion right (the right to devise operational-level rights of access), and (e) alienation right (the right to sell or lease all or part of the above collective-choice rights). These rights are granted by higher authority systems such as international organizations (de jure rights), government (de jure rights), and can also come from customary leaders (de facto rights) which are usually not recognized by the government. Not all resource users are entitled to all these rights. Rather, different bundles of property rights are distributed between different holders. According to this framework, owners are those who have the greatest bundle of rights. Proprietors lack the right of transfer, claimants lack the rights to exclude or transfer, authorized users have only the right of access and withdrawal, and authorized entrants have only access rights.

3. Methods
This study applied a case study method. As the case was the property rights regime of Lake Rawapening. The research location was selected purposively by considering three factors. First, the lake is currently experiencing environmental degradation due to uncontrolled water hyacinth invasion, siltation and water pollution. Second, the lake has undergone several changes in the property rights regime. Third, secondary data and information with regards to the lake were widely available and accessible. The research project was conducted in 2017 as a part of the Governance of Lake Rawapening research project carried out in 2015-2017.

Primary data were gathered from focus group discussion (FGD) and in-depth interviews. The key informants included officials from various officials of government agencies at provincial and regency
level, villages’ officials and community leaders (table 2). Key informants were chosen purposively and snowball sampling method based on information gathered from documents and reports related to Lake Rawapening as well as information gathered during the interview process. Overall, we have interviewed 17 key informants from a number of government agencies, village officials, representations of fishers and farmers groups, and community leaders. In addition, we also conducted an FGD involving 27 participants representing main stakeholders of Lake Rawapening to obtain broader information (table 2). Secondary data were collected from reports and documents related to Lake Rawapening.

The analysis of the data was conducted using qualitative data analysis approach. Primary data were processed through coding, summarizing, and interpreting using property rights concept as explicated in Section 2. Secondary data and information were analyzed using content analysis method. The multiple sources of information allowed for triangulation of the qualitative data to validate the information gathered.

| Table 2. Participants of focus group discussion and informants of in-depth interviews |
|---------------------------------|-------------------|-------------------|
| Focus group discussion | In-depth interview |
| Participants | Number of participants | Informants | Number of informants |
| Rawapening Sub-Watershed: | | |
| - Watershed Management Office of Pemali-Jratun officials | 2 | - Watershed Management Office of Pemali-Jratun official | 1 |
| - River Basin Management Office of Pemali-Juana officials | 2 | - River Basin Management Office of Pemali-Juana official | 1 |
| Central Java Province: | | |
| - Provincial Agency of Development Planning official | 1 | - Provincial Agency of Development Planning official | 1 |
| - Provincial Environmental and Forestry Services official | 1 | - Provincial Environmental and Forestry Services official | 1 |
| - Provincial Public Works and Water Management Services | 1 | - Provincial Public Works and Water Management Services | 1 |
| - Provincial Marine and Fisheries official | 1 | - Provincial Marine and Fisheries official | 1 |
| - Provincial Agriculture official | 3 | - Provincial Agriculture official | 1 |
| - Land Administration Agency | 1 | - Land Administration Agency | 1 |
| Semarang Regency: | | |
| | 1 | | 1 |
Focus group discussion | In-depth interview

| Participants | Number of participants | Informants | Number of informants |
|--------------|------------------------|------------|----------------------|
| - Agency of Development Planning official | 1 | - Agency of Development Planning official | 1 |
| - Environmental Services officials | | - Environmental Services officials | |
| - Agriculture and Fisheries Services official | 3 | - Agriculture and Fisheries Services official | 1 |
| - Public Works Services official | 1 | - Public Works Services official | |
| - Land Administration Agency | | - Land Administration Agency | 1 |
| | | | |
| | 1 | 1 |
| | 1 |
| Villages: | Villages: |
| - Bejalen Village officials | 2 | - Bejalen Village officials | 1 |
| - Rowoboni Village official | | - Rowoboni Village official | |
| - Asian Village Officials | 2 | - Asian Village Officials | 1 |
| - Kebondowo Village Officials | | - Kebondowo Village Officials | |
| | 2 | - Fishers and farmers Group officials | 1 |
| | 2 | - Community leaders | |
| | | 1 |
| | | 2 |

4. Results and Discussion
4.1. An overview of Lake Rawapening

Lake Rawapening is semi-natural lake and can be considered as multipurpose lake. This is a lake formed in a natural depression of surrounded by the volcanoes Merbabu, Telomoyo and Ungaran. Originally, this depression was a low swamp with the only outlet, Tuntang River, being a narrow channel located at the northeast side of the lake [22]. This lake gets water supply from 9 inlets which are Galeh, Torong, Panjang, Legi, Parat, Sraten, Rengas, Kedung Ringin dan Ringis. Its location is situated in Central Java, about 45 km south of Semarang City. When full, at 463.4 m above sea level, the lake covers 2,667 ha but, in the dry season, may be as small as 1,650 - 620 ha at 460 m [6,23].

Lake Rawapening in its current form is the results of the construction of two weirs in its outlet in 1912 and 1937 which raised the elevation of its surface to 463 m and increasing of the height of weir gates in 1966 which raised the water elevation to 463.4 m [23]. These constructions were mainly intended to secure water supply for two hydropower plants, Jelok and Timo, which can generate 20 MW of electric power. In addition, some of the water were allocated for irrigating about 24,000 ha of rice fields [24]. The present lake level varies throughout the year between the elevation of 463.4 m and 460.93 m [7,25]. Releases from the lake are controlled mainly to suit power generation at the existing Jelok and Timo power stations located in the upper reaches of the Tuntang River.
The lake is functioned as multipurpose lake. Aside from being a provider of water for electricity and irrigation, Lake Rawapening is also a place for aquaculture, agriculture, a source of raw water reserves for public water utilities and a tourist destination. The entire area around the lake is reputedly prime rice fields. The farmers traditionally have farmed the land left dry by the receding water. This lake is at present facing the problem of eutrophication and sedimentation which threatens its sustainability. Nearly 70% of the surface of the lake was covered by water hyacinth due to eutrophication [25,26]. Its depth was reduced significantly because of sedimentation resulting from unwise land management in the catchment area of the lake.

4.2. The changes of property regime in Lake Rawapening

The linkage between the condition of a lake's ecosystem and the property regime that governs it requires knowledge of the historical trajectory of changes in the property regime applied to the lake and changes in the condition of the lake ecosystem that follows it. The following subsection we will discuss the changes of property rights regime in the Lake Rawapening and its impacts on lake ecology.

4.2.1 Pre-colonial era

Reconstructing past social situations and environmental conditions of Lake Rawapening is usually plagued with incompleteness and in some cases even far from complete because of limited availability of literatures that can be used as references. Nevertheless, from its toponymy, that is comprising two words rawa and pening, rawa means swamp or marsh and pening means clear or transparent, it can be easily recognized that this lake must be shallow and had clear water in the past. The existence of Dukuh Temple on the lakeshore which is estimated to have been built in 9th century provides corroborating evidence to arrive at the allegation that the lake had an important role in the lives of communities living around the lake at that time [27]. Folklore “Naga Baruklinting” (Baruklinting Dragon) which tells a story of the origin of the lake and various sanctions for those carried out activities potentially damaging the lake ecosystem also shows that the community at that time was able to regulate the use and preservation of the lake. The folklore continues to be passed down from generation to generation and some traditions, such as ritual offerings (sedekah rawa) to appease divinities of the lake, are still preserved until today, although it is now arranged with some modifications, specifically adapted to Islamic rituals. Another myth that has also been developed at that time and is still believed by some people is a rule for every party or festival held by the villagers to face the lake [28]. This norm is intended to pay respect to the environmental services that the lake has provided and also as a form of suggestion to treat the lake as if “the front yard of every member of communities’ home” which must always be preserved.

Lake Rawapening in the past has been the main source of livelihood for local communities around the lake, especially for capture fisheries and tidal agriculture. Fishery gears were still very simple and the catches were to meet subsistence needs of the households. In the dry season, when the lake water shrinks, the riparian areas were used for agricultural cultivation of food crops, especially rice. Since at that time there were not any artificial chemical fertilizers and pesticides, the agricultural practices of the farmers constituted of organic farming and therefore did not cause major environmental problems. Their agricultural products were mainly used to meet households’ subsistence needs. The simplicity of fisheries and agriculture practices at that time can be traced from the local terminology about fisheries and agriculture which are still used in the communication of local communities around the lake [7].

| Table 3. Bundles of rights distribution among main stakeholders in the pre-colonial era |

| Right          | Villages Authorities | Fishers and Farmers | Other Villagers | Outsiders |
|----------------|----------------------|---------------------|-----------------|-----------|
| Operational rights |                      |                     |                 |           |
| 1. Access      | X                    | X                   | X               | X         |
| 2. Withdrawal  | X                    | X                   |                 | X         |


Lake governance was centered on the regulations of exclusion of non-members of local communities and distribution of fishing spots and agricultural lands among members of the communities [28,29]. The distribution of rights is provided in table 3. Villages authorities, fishers and farmers held the most bundles of rights, while the outsiders held the least right. There were four main groups of actors involved in the governance of Rawapening Lake, namely autonomous village authorities, fishers and farmers, other villagers and outsiders who lived in the upland areas or other villages away from the lakes. Village authorities consisted of elected village officials and community leaders, usually elders and religious leaders, held the authority to determine those who could farm the lands in the shoreline areas of the lake during dry season and those who could do fishing in the lake. The authorities also had the rights to determine the fishing spots, especially particular spots shared with other contiguous villages potential to instigate conflict. Every conflict arose, moreover conflicts involving fishers from other villages, would have been resolved in cooperation with authorities from the villages concerned. However, the conflicts that had occurred were allegedly to be very small and if they had continued, the conflicts could have been resolved quickly because of the strong kinship system among the villagers and the abundance of natural resources at that time. In short, the governance of the lake was more or less characterized as a common-property regime.

4.2.2 Colonial era

After the defeat of Diponegoro, a prince of Yogyakarta Sultanate, in Java war which was lasted for five years started from 1825 to 1830, Java and most part of main islands in archipelago, what is now known as Indonesia, was practically under the control of Dutch colonial government. The Java War drained a large part of the Dutch colonial government budget. This had caused the colonial government to become entangled in debt burden [30–32]. The conquest of Java was a great opportunity for the Dutch colonial government to overcome budget deficit by exploiting natural resources and implementing the cultivation system (cultuurestelsel) which forced peasant farmers in Java to plant export crops on their farmlands [30]. For this end, the Dutch colonial built weirs, dams and irrigation networks to meet water resources required for growing export corps, especially sugarcane [33]. Glapan weir which dammed the downstream part of Tuntang River, the only outlet of Lake Rawapening, was constructed in 1852 [34,35]. Lake Rawapening was converted from a marsh to a lake in 1912-16 and enlarged in 1939 by damming upstream part of Tuntang River [7]. In addition to irrigation water, the construction of dams on Tuntang River was mainly motivated by Dutch colonial government interests in providing electricity of Dutch people living in Salatiga. This is a point of the beginning of the change of property regime of Lake Rawapening, from common property regime to state-property regime. At that time, 28 hamlets of 4 sub-districts was submerged and its inhabitants were moved to nearby villages [36]. The Dutch also introduced water hyacinth brought from Bogor botanical garden as ornamental aquatic plant on the lake [37]. Since then, the plants proliferated rapidly and spread over almost the surface of the lake.

Table 4. Bundles of rights distribution among main stakeholders in the colonial era

| Right         | Dutch Colonial Government (Irrigation and Hydropower authority) | Villages Authorities | Fishers and Farmers | Other Villagers | Outsiders |
|---------------|---------------------------------------------------------------|---------------------|---------------------|-----------------|-----------|
| **Operational rights** |                                                               |                     |                     |                 |           |
| 1. Access     | X                                                             | X                   | X                   | X               | X         |
| 2. Withdrawal | X                                                             | X                   | X                   | X               | X         |
Change in the property regime has implied for changes in the bundles of rights of stakeholders of Lake Rawapening (table 4). Village authorities lost all their rights in governing the lake, while the rights of farmers and fishermen only left usufructuary rights. The role of village authorities in governing Lake Rawapening was replaced by the Dutch colonial government. The Dutch authority over the lake was further strengthened by the enactment of the Algemeen Waterreglement (General water law) in 1936 [38,39].

Following the operation of the dam, the Dutch has established an extractive institution characterized with strict rules deteriorated village-level rules (i.e. norms and conventions) that had previously acted to control lake’s ecosystem. It became increasingly difficult to take necessary, and customary, collective actions to address lake degradation. In order to maintain the volume of lake water, the Dutch installed boundary poles to mark the border of water body of the lake which are known as red poles for the lowest inundation and black poles for the highest inundation. Farmers were permitted to farm on the lakeshore areas between red and black poles during the dry season as long as they complied with the Dutch’s rules. In addition, most of lands on lakeshore areas were purchased and local communities were prohibited to build settlers on those lands, except for seasonal agricultural production [23,40]. At that time, agricultural practices were very traditional and the application of synthetic chemical fertilizers had not yet existed. The colonial government did not hesitate to impose severe sanctions on local villagers if they committed for violating the regulations [29,38]. Local communities highly depended on the lake as their main livelihood, especially from fisheries and tidal farming [29].

The damming of River Tuntang and introduction of water hyacinth has induced environmental problems. Peat soils lying on the bed of the lake were forced off by bubbles of gas generated during inundation process of the lake [41]. Lumps of peats in various sizes from flakes to great rafts have had enough buoyancy to rise to the water surface [22,41]. These floating peats were locally called “floating islands” which lay sluggishly awash until wind action broke them up or the gases which lifted them escaped [22,41,42]. The presence of water hyacinth clumps on the lake has made environmental problems complicated. When the clumps came in contact with the “floating islands”, their roots were ramified through it and drew nourishment and in turn caused water hyacinth to proliferate and spread rapidly. The buoyancy of the water hyacinth has prevented the "floating islands" from sinking back to the bottom of the lake [22,41,42]. Likewise, endemic aquatic weeds of the lake have propagated rapidly when in contact with floating islands. Water hyacinth, aquatic weeds, and “floating islands” regularly clogged the entrance channel of hydropower. As a consequence, the channel had silted up, thereby reducing the capacity of the channel. Fish stock was reported decreasing due to extensive cover of water hyacinth [7]. However, the Dutch interest was on the continuity of electricity generated from Jelok power plant and irrigation water for sugar cane plantations in Demak and Grobogan. In securing their interests, the Dutch controlled the spread of the population of water hyacinth and floating islands manually by employing forced laborers supplied from villagers around the lake. Over a period of 4 years (1933-1937) the cover of water hyacinth and "floating islands" had been reduced to 93% (1,400 ha) from the surface area of the lake at that time [7]. These control efforts stopped when the Dutch lost the war against Japan which resulted in the transfer of power over Java. Japan did not make efforts to manage the lake during its occupation, which only lasted for 3.5 years. It seems likely that the coercive approaches exercised by the Dutch colonial administrator were able to protect the lake ecosystem from being degraded.
4.2.3 Independence era

Once the Dutch colonial transferred the governance to a newly independent state in 1950, the Republic of Indonesia, the prevailing property regime of the lake did not change much. The government has shown little interest in revitalizing local-level system of authority [38,39]. The lake remains the “property” of the national government and is utilized mainly for the benefits of Indonesian citizens as is stipulated in the 1945 State Constitution of Republic of Indonesia. Nevertheless, it is necessary to perceive that the independence era was consisted of at least three periods, namely Old-Order period, New-Order period and Reformation period. Each of which has its own style in governing the lake.

The Old-Order period started from the early days of independence to 1965. It was characterized by political turmoil, economic turbulences, and regional insurgences. Despite facing fiscal difficulties, the government in 1957 built hydroelectric power plant at Timo next to the Jelok power plant to increase electricity production capacity in order to meet the increasing demand for electricity. The Timo power plant has been operating since 1962 and can produce 12 MW of electric power in its full capacity. This indeed requires a steady water supply. The development of water hyacinth, water weeds and floating islands that were not controlled during the Japanese occupation became a major problem that must be addressed by the government to ensure the security of water supply for the two hydroelectric power plants. The government has used manual and mechanical methods to reduce the area of water hyacinth, aquatic weeds and floating islands cover on the surface of the lake. Efforts to control these floating islands constitute cutting and discharging them over the dam during the peak of the rainy season (February to July) [23]. Large scale mechanical control and reinforced by spraying herbicides involving 212 hectares was done in 1963 by a civic mission of the army. After six months the area infested increased to 400 hectares. Manual control included cutting, removal, and transport of water hyacinth to the dumping grounds. This method was quite expensive. Four hundred people working for seven to eight hours a day could remove only one hectare [43]. Farmers, fishers, and villagers were being involved in the control activities as wage laborers [23,40,43]. It was reported that the water supply for electricity had decreased and the previously stabilized planting schedule of red pole lands established since the Dutch colonial era had been disrupted [23].

The failure of the Indonesian communist party coup in 1965 had implications for the succession of national leadership which paved the way for the birth of a military-style governance system of New-Order period that lasted until 1998. In the early days of the New Order period, government attention to Lake Rawapening was still focused on efforts to secure water supplies for hydropower plants and irrigated rice fields in Semarang, Grobogan and Demak. For lake management purposes, the government established an ad hoc management unit controlled by a territorial military command called the Rawapening Project Command (Koproning) in 1966. Koproning was tasked to increase electricity generation and to protect the prime rice fields on the lakeshore. Farmer farmers were permitted to farm the lands on the lakeshore provided they paid a license at a price of 150 rupiahs (± 0.6 USD) and shared 40% of their harvest to Koproning. Koproning was also authorized to increase lake water surface at ± 40 cm causing inundation in some rice fields located next to the lake. The change in lake water elevation was aimed at maintaining optimal water discharge for the operation of Jelok and Timo power station so that the generation of electricity from both stations could be maximized. At that time these power stations were the backbone of the electrical energy source in Central Java. The control of water hyacinths was undertaken using herbicides and mechanical methods.

In 1972 the authority of Koproning in governing Lake Rawapening was transferred to Ministry of Public Works casu quo Provincial Department of Public Works (DPU). This transfer was partly driven by the completion of the Java electricity network which significantly reduced the role of the Jelok and Timo hydropower plants as the main suppliers of electricity in Java. The DPU then directed its efforts in expanding the reach of irrigation water flow in Grobogan and Demak by lowering lake water elevation. Paddy fields that were flooded during the management period of Koproning were reopened for agricultural activities. At this time the central government was also incessantly running a rice self-sufficiency program by introducing high yield rice varieties (HYV) and the use of synthetic fertilizers and pesticides to increase rice production. The program has induced a significant increase in rice
production. The program has significantly increased rice production and at the same time produced negative impacts on the lake in the form of water pollution and sedimentation. Fertilizers and pesticide wastes and soil particles that have been transported by rainwater runoff to the lake have added to the burden of water pollution and then triggered the propagation of water hyacinth at a level that is difficult to control. The introduction of floating cage aquaculture also contributed to the complexity of lake pollution control. During the New Order era, efforts to control water hyacinth and sedimentation were routinely undertaken even though it was still below optimal level.

The monetary crisis then turned into an economic crisis in the mid-1990s was the cause of the end of the New Order period and the beginning of the Reformation period. During this period Indonesia has made fundamental corrections in national governance system, especially in terms of decentralization of power to local governments, especially municipal governments, and a more democratic government system than before. In line with political changes at the national level, the structure of lake management authority has also undergone a fundamental change. Rawapening Lake was designated as part of the national strategic watershed, Jagungseluna watershed, and resulted in unclear authority of provincial and regency governments due to the fragmentation of lake management functions among them. Interdependence nature of lake’s ecosystem and its catchment areas was not taken into account in policies making either at national or local levels. This was reflected in the structure of entitlements for lake resources at local-level. The government was not the sole authority governing the management of the lake. Rather, there were several stakeholders who were involved in management of the lake although not legally recognized (table 5).

Table 5. Bundles of rights distribution among main stakeholders in the independence era

| Right                      | Indonesian Government (National, Province, Regency) | Irrigation, Water utility, and Hydropower Authority | Villages Authorities | Fishers and Farmers | Other Villagers | Outsiders |
|-----------------------------|----------------------------------------------------|---------------------------------------------------|----------------------|---------------------|----------------|-----------|
| Operational rights         | X                                                  | X                                                 | X                    | X                   | X              | X         |
| 1. Access                   | X                                                  | X                                                 | X                    |                     |                |           |
| 2. Withdrawal               | X                                                  | X                                                 | X                    |                     |                |           |
| Control/Collective-choice rights | X                                                  | X                                                 | X                    |                     |                |           |
| 3. Management              | X                                                  | X                                                 | X                    |                     |                |           |
| 4. Exclusion               | X                                                  | X                                                 | X                    |                     |                |           |
| 5. Alienate                | X                                                  | X                                                 | X                    |                     |                |           |

Lake governance under the state-property regime during the Reformation era was not followed by the managerial capability of government in managing the lake and its catchment area. A number of plans and programs, such as the National Movement to Save the Lakes (Germadan), have been initiated by government to reverse the trend of degradation. However, most of them have failed due to lack of coordination among state agencies and the low capability of government officers in lake management. This practically has rendered the lake, and in particular its shoreline areas, to be open access. It means everybody could squat a parcel of land on the shoreline area and construct buildings and houses without having to fear facing legal sanctions. It seems that the regulations that have been made for the management of Lake Rawapening did not get legitimacy from the local community. Agricultural lands were carelessly managed regardless of their impact on the lake. Likewise, the growth of residential and commercial areas which were built on prohibited locations according to the rules was not controlled carefully. The most visible consequences were the decline in fish populations, impairment of lake water quality, and the siltation lake depth. Currently most fishers could no longer rely on fishing business in the lake for their livelihood, but instead earned income from harvesting water hyacinth.
From interviews with primary stakeholders of the lake including government officers as well as local residents, we obtained some information pertaining to the failure of the state-property regime as governance system of Lake Rawapening. First, there was a tendency among government agencies to be unwilling to take responsibility for the conservation of Lake Rawapening. This was most likely related to the huge amount of costs needed for conservation efforts and the possibility of resistance from local communities to various measures carried-out by government agencies. As has been mentioned, the situation of the lake was characterized by open-access regime that incentivized local residents to race for occupying available spaces on riparian areas for settlements and many spots on water body of the lake for cage aquaculture on the basis of “first-come, first-serve” rules. Most of local residents assumed those lands as private property and therefore asked for compensation if the government agencies asked them to leave their occupied riparian areas to carry out restoration actions of the lake. According to experiences in other places in Indonesia, moving out people from their occupied lands was not an easy-to-do process and might involve physical conflicts that often causing casualties on both sides. Second, restoring as well as sustaining ecosystem of the lake is inherently multi-level governance. It means that each agency involved in management of lake’s ecosystem must establish coordination with other agencies across governmental levels. Working with other organizations requires a dedication of staff time, material resources, and – most importantly – building trust and gaining recognition as a reliable, even necessary, partner. For most of governmental agencies, especially provincial and municipal government agencies, the costs of coordination needed for lake’s ecosystem government were considerably large and not commensurate with the benefits they may gain from it. Moreover, lake rehabilitation or restoration programs involve uncertainty in term of the outcomes and there is a considerable time lag between actions and results. This has made lake rehabilitation or conservation programs less appealing for decision-makers and therefore was not yet the top priority of provincial and municipal agencies. As a result, the efforts of lake’s ecosystem governance relied on central government agencies that in some extent lack of knowledge of local social-ecological systems. Nevertheless, both government and local communities still saw opportunities to improve situation. One of the solution arose out during the discussion was collaborative management between government and local community in managing the lake. From the government perspective, co-management systems were attractive because it open avenues for local participation in lake governance and more equitable benefit sharing while maintain some level of state control.

5. Conclusion
This paper highlighted the changes of property regime of the Lake Rawapening from common property regime to state-property regime. The changes can be roughly divided into three eras, namely the pre-colonial era marked by a common-property regime, the colonial era which was the beginning of property regime from a common-property to a state-property regime, and the era of independence marked by a state-property regime. The change in the regime has had implications for lake conservation through changes in incentives which in turn affected the action or behavior of stakeholders towards the lake. Destruction of common-property system in the colonial era was still influential to this day. The study shows that the current property rights regime was driving local resource users toward greater degradation of the lake. The opportunity existed to build on existing village-level institutions to develop a collaborative management system to help protect the lake ecosystem.

6. References
[1] Sulastri 2006 Inland Water Resources and Limnology in Indonesia Tropics 15 285–95
[2] Giesen W 1994 Indonesia’s major freshwater lakes: A review of current knowledge, development processes and threats Int. Vereinigung fur Theor. und Angew. Limnol. Mitteilungen 24 115–28
[3] Nontji A 1994 The status of limnology in Indonesia Int. Vereinigung fur Theor. und Angew.
Limnol. Mitteilungen 24 95–113

[4] Kementerian Lingkungan Hidup 2011 Gerakan Penyelamatan Danau (Germadan) Danau Rawa Pening (Jakarta, Indonesia: Kementerian Lingkungan Hidup)

[5] Soeprobowati T R 2015 Integrated Lake Basin Management for Save Indonesian Lake Movement Procedia Environ. Sci. 23 368–74

[6] Sulastri, Henny C and Handoko U 2016 Environmental Condition and Trophic Status of Lake Rawa Pening in Central Java Oceanologi dan Limnol. di Indones. 1 23–38

[7] Goeltenboth F and Kristyanto A I A 1994 Fisheries in the Rawa Pening Reservoir, Java, Indonesia Int. Rev. der gesamten Hydrobiol. Hydrogr. 79 113–29

[8] Born S M and Rumery C 1989 Institutional aspects of lake management Environ. Manage. 13 1–13

[9] Subanti S, Irawan B B, Sasongko G and Hakim A R 2016 Economic Valuation on Change of Tourism Quality in Rawapening, Indonesia: An Application of Random Utility Method Journal of Physics: Conference Series 755 pp 1–6

[10] Hakim A R, Subanti S and Tambunan M 2011 Economic Valuation of Nature-Based Tourism Object in Rawapening, Indonesia: An Application of Travel Cost and Contingent Valuation Method J. Sustain. Dev. 4 91–101

[11] Subanti S, Hakim I M, Daerobi A, Nasir M S and Hakim A R 2017 Determinant of Willingness to Pay and Economic Value for Ecotourism Object Using Contingent Valuation Method: The Case of Rawapening, Semarang Regency. Central Java, Indonesia 28 250–2

[12] Ginting T, Ismail A and Simangunsong B 2017 Economic Value of Medicinal Plants in Danau Sentarum National Park, West Kalimantan J. Ekonomi dan Pembang. Indones. 18 22–34

[13] Reynaud A and Lanzanova D 2017 A Global Meta-Analysis of the Value of Ecosystem Services Provided by Lakes Ecol. Econ. 137 184–94

[14] Vatn A 2005 Institutions and the Environment (Chelthenham, UK: Edward Elgar Publishing)

[15] Vatn A 2001 Environmental resources, property regimes, and efficiency Environ. Plan. C Gov. Policy 19 665–80

[16] Ostrom E 2005 Understanding Institutional Diversity (Princeton, New Jersey: Princeton University Press)

[17] Bromley D W 1991 Environment and Economy: Property Rights and Public Policy (Cambridge, MA and Oxford, U.K: Blackwell Publishing Ltd)

[18] Schlager E and Ostrom E 1992 Property-Rights Regimes and Natural Resources : A Conceptual Analysis Land Econ. 68 249–62

[19] Buck S J 1998 The Global Commons: An Introduction (Washington D.C., USA: Island Press)

[20] Meinzen-Dick R S and Mwangi E 2009 Understanding Property Rights in Land and Natural Resource Management Institutional Economics Perspectives on African Agricultural Development ed J F Kirsten, A R Dorward, C Poulton and N Vink (International Food Policy Research Institute) pp 295–317

[21] Schlager E and Ostrom E 1992 Property-Rights Regimes and Natural Resources: A Conceptual Analysis Source L. Econ. 68 249–62

[22] Polak B 1951 Construction and origin of floating islands in the Rawa Pening (Central Java) vol 121 (Bogor, Indonesia)

[23] Jratunseluna and NEDECO 1974 A Proposal for Cleaning the Lake of the Floating Aquatic Weeds Including Recommendations for Maintenance and Scientific Research

[24] Badan Penelitian dan Pengembangan Provinsi Jawa Tengah and Fakultas Teknik Universitas Diponegoro 2004 Studi Optimalisasi Potensi di Kawasan Rawapening (Semarang, Indonesia)

[25] PT. Suwanda Karya Mandiri 2015 Studi Pengukuran, Sedimentasi dan Kualitas Air Waduk Rawa Pening (Semarang, Indonesia)

[26] Hidayati N, Soeprobowati T R and Helmi M 2018 The evaluation of water hyacinth (Eichhornia crassiper) control program in Rawapening Lake, Central Java Indonesia IOP
Sedyawati E, Latief F and Indonesia. Direktorat Pelestarian Cagar Budaya dan Permuseuman 2013 *Candi Indonesia* (Jakarta: Direktorat Jenderal Kebudayaan)

Sutarwi 2008 Proses Kebijakan Konservasi Sumber Daya Air Danau Rawa Pening di Jawa Tengah *Widyaprana* I 40–72

Christie J W 2007 water and rice in early Java and Bali *A World of Water: rain, rivers and seas in Southeast asian histories* ed P Boomgaard (Leiden, the Netherlands: Koninklijk Instituut voor taal-, land- en Volkenkunde) pp 235–58

Wie T K 2013 Colonial extraction in the Indonesian archipelago: A long historical view *Colonial Exploitation and Economic Development: The Belgian Congo and the Netherlands Indies Compared* pp 41–59

Carey P 2011 Revolutions Europe and the Destruction of Java’s Old Order, 1808-1830 *Hist. Int. J. Hist. Educ.* 12 296

Carey P 2008 *The Power of Prophecy: Prince Dipanagara and the end of an old order in Java, 1785-1855* (Leiden, the Netherlands: KITLV Press)

Kop J H, Ravesteijn W (Willem) and Kop K J 2015 *Irrigation revisited : an anthology of Indonesian-Dutch cooperation 1965-2014* (Delft: Eburon)

van der Eng P 1996 *Agricultural Growth in Indonesia* (London: Palgrave Macmillan UK)

Gany A H A, Mahdi S and Pasandaran E 2004 *Irrigation History of Indonesia* (Jakarta, Indonesia: Ministry of Settlement and Regional, the Indonesian National Committee of International Commission on Irrigation and Drainage)

Budijanto B 2009 *Values and Participation: Development in Rural Indonesia* (Oxford: Regnum)

Backer C A 1936 Verwideringscentra op Java van uitheemsche planten *Trop. Nat.* 25 51–60

Pasandaran E 2015 Assessing Development History of Law on Irrigation Water and Water Resources *Forum Penelit. Agro Ekon.* 33 33–46

Teeuwen B 2016 The role of the legal framework in implementing water resources development projects during the second part of the 20th century *Irrigation Revisited, an anthology of Indonesian-Dutch cooperation 1965-2014* ed J H Kop, W (Willem) Ravesteijn and K J Kop (Delft, The Netherlands: Eburon Academic Publishers) pp 17–36

Hieselaar W 2016 Jratunseluna Basin Development Project (JBDP) Central Java (1970–1976) *Irrigation Revisited, an anthology of Indonesian-Dutch cooperation 1965-2014* ed J H Kop, W (Willem) Ravesteijn and K J Kop (Delft, The Netherlands: Eburon Academic Publishers)

Little E C S 1969 The floating islands of Rawa Pening *Int. J. Pest Manag. Part A* 15 146–53

Hayashi I, Pancho J V, and Sastroutomo S S 1978 Preliminary report on the buried seeds of floating islands and bottom of Lake Rawa Pening, Central Java *Japanese J. Ecol.* 28 325–33

Soewardi B and Utomo I H 1975 *Kemungkinan Pemanfaatan Tumbuhan Pengganggu Air.* (Bogor, Indonesia: SEAMEO Biotrop)