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Adapting livelihoods to the impacts of tin mining in Indonesia: options and constraints

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ABSTRACT

This paper explores the socio-ecological changes perceived by the X-hamlet local community in Bangka Island before and after the spread of large-scale tin mining and how it adapted to those changes. Using evidence collected by household surveys, combined with key informant interviews and focus group discussions, this study shows that the spread of tin mining activity on large and small scales were perceived differently by subsistence groups within this hamlet as a key driver of coastal ecosystem and land tenure system changes, leading to income uncertainty. The household economic conditions, resource availability, relationships, and networking are important factors influencing household decisions on diversifying income sources. Nonetheless, the lack of capital (physical, financial, human), limited skill, and low education levels constrained to them in diversifying their income sources. Thus, landless households are facing a greater challenge in adapting, particularly fishers who are facing ongoing fish depletion yields due to suction dredger and small-scale coastal mining. The landless fishers are potentially marginalized by engaging in mining activity which is an economical, socially, and environmentally unsustainable alternative livelihood. Therefore, future policies need to address those key issues for securing local's lives and livelihoods.

1. Introduction

On Indonesia's Bangka Island (population of ~961,000 in 2010), the environmental and social impacts of tin mining have long been felt. Bangka Island has been widely referred to as "the tin island of Indonesia" by scholars, who have examined in depth these impacts over the years (Ross, 2014). How have the island's residents coped with the problems this production has introduced?

Indonesia is currently the world's second largest exporter of tin (Nurtjahya et al., 2017; Kuo, 2011), and its twin islands of Bangka and Belitung account for ninety percent of its production (Agus et al., 2017; Erman, 2008). Since the colonial period, on both Bangka Island and Belitung Island, tin mining has been carried out onshore and offshore by large- and small-scale operators (Ibrahim, 2016; Erman, 2008). Onshore, large-scale tin mining has, historically, been predominantly carried out by the state; offshore, however, large-scale mining activities, which feature suction dredgers, are carried out by both domestic companies (state-owned and private) and multinational companies. Rosyida and Sasaoka (2018) project that these activities will intensify in upcoming years due to a combination of relaxed taxation, which is will undoubtedly appeal more to investors, a worldwide technological boom which demands significant supplies of metals, including tin; and depleting tin deposits onshore. The subsequent decentralization of mining governance provided a equitable space for local Bangka communities to position themselves to derive benefits from local tin extraction, principally through small-scale activity carried out both inland and along the coastline. These activities fueled a local boom in tin production (Erman, 2010).

Indonesia, like many developing countries, has experienced a dramatic growth in mineral exploration in recent years (Bebbington et al., 2008). The mining which this activity has yielded has long been viewed as an essential economic activity (Gilpin, 1995; Hilson, 2002), consistently accounting for between eight and thirteen percent of national Gross Domestic Product (GDP) since the 1980s. Indonesia produces fifteen percent of the world's nickel, six percent of its copper (in 2009) and four percent of its coal (in 2010) (Elias and Noone, 2011; PWC, 2012). It also generates twenty-seven percent of the world's tin, the production of which, while lucrative, can cause significant harm to the

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natural environment (Arogunjo et al., 2009). In 2007, tin mining activities carried out onshore damaged approximately 340,000 ha of agricultural land and sixty-five percent of Bangka's forests (Ibrahim et al., 2018). The damage caused in the sea (which is often not visible) is not comparable to that on land (Rosyida and Sasaoka, 2018) but the exploitation of tin ore along coastlines causes abundant sedimentation, and as waves move dynamically, this has created cluster masses of mud, which have subsequently scattered, in turn, adversely impacting ocean life. A study conducted in Indonesia by Ambalika (2011) revealed that the spread of sediment originating from mine tailings and the extent of its impact on marine life are functions of weather and dredge type. Here, the distribution of total suspended solids reaches up to 5,000 square kilometers during the region's windy season. Moreover, sedimentation has caused coral bleaching, which can destroy reefs. Some 18 of Bangka Island's 31 coral reefs were severely damaged by offshore tin mining sediments during the period 2007–2011; the costs of restoring these reefs far exceeds the economic benefits that have been derived from the mining activities that destroyed them (Ambalika, 2011).

This paper builds on this analysis by focusing on the impacts of tin mining on community wellbeing in Indonesia. We explored adaptation strategies employed by a coastal resource-dependent community on Bangka Island, Indonesia. Using case studies from X-hamlet, we examined the socio-ecological changes perceived by the local community before and after the spread of large-scale tin mining, and we considered how the community adapted to changes based on these perceptions. Our aim is to build a case for policymakers in Indonesia to make coastal tin mining more of a focus of development efforts. The next section of the paper outlines the methods and materials used in this study. The empirical results and discussion are presented in Section 3, and in Section 4, we prescribe several recommendations which, if implemented, could enhance local communities' capacities to adapt to a changing environment.

2. Methods

The coastal hamlet is referred to here as ‘X-hamlet’, a locality in West Bangka, Indonesia, and in close proximity to mining activities. X-hamlet is geographically-remote; it is situated within Y-Village; and its dominant ethnic group is *Bangka Malay*. Economically, most of X-hamlet’s residents are dependent on traditional fisheries and shifting cultivation for their livelihoods. Part of its fishery productionis subsistence, while the remainder generates income. Here, fishing is conducted in groups, which facilitate individual dependencies and social interactions. According to a local elder ‘HK’ (72 years old), fishing not only generates income for the hamlet's dwellers but is also part of their identity. Agricultural activities were inherited from ancestors.

The findings presented here are drawn from intensive household surveys, in-depth key informant interviews, group interviews, and focus group discussions (FGDs). The household survey featured structured and semi-structured questions, each of which sought to elicit details about respondents' households, livelihood trajectories, and adaptation strategies employed to cope with the changes induced by large-scale tin mining activities. Eighty households were surveyed. In most cases, the head of the household was interviewed; if the head was unavailable, another adult in the household was consulted. Three respondents were excluded from the analysis, as they were not permanent residents of the area.

In-depth interviews with 22 key informants were also undertaken, which shed light on (a) the history of X-hamlet and the dynamics of local subsistence, (b) the history and development of mining activity in the area, (c) major events that have triggered significant socio-economic and biophysical changes, and (d) local adaptation strategies employed to cope with environmental changes. These key informants were selected following an initial survey in the village using a snowball sampling technique. Interviews were conducted with men and women to capture the perceptions of both genders on these issues. The interview targeted knowledgeable individuals such as village officers; hamlet chief; local elders; representatives from fishing, farming and mining groups; and religious leaders. Interviews were also conducted with women who mostly played a supportive role in the household, undertaking domestic duties.

The FGDs were arranged with a four groups from the hamlet’s inhabitants: eleven fishers, eight small scale miners, six farmers, and six housewives. The aims of these FGDs were to (a) triangulate information obtained from household surveys and interviews with key informants; (b) explore the various groups' views on the perceived changes; and (c) map out the fishing trends and changes, agricultural patterns, and seasonal calendars. All of the interviews and FGDs were recorded using a digital audio recorder, supported by notes taken during the interviews and discussions.

In addition, field observations were conducted to clarify answers from the household surveys, key informants, and group interviews. All of the data collected were analyzed qualitatively, and they are presented herein descriptively. We conducted an extensive literature review using internet-based journals, books, theses, and other documents, supported using information drawn from secondary documents provided by local residents, government officials, and representatives of private institutions.

This study was granted a research permit by Hokkaido University and the West Bangka District Government. Village-level governments granted our team verbal permission to conduct research. Before commencing our research activities, the first author of this paper visited the area, explained the research activities and their purpose, and received verbal permission from villagers. We then asked the villagers to help us identify individuals with relevant knowledge for our key informant interviews and FGDs. Before each FGD, key informant interview or household survey, details about the purpose of the activities, the selection process, the use of voice recordings, and the data collection were shared once again. All participants were asked for verbal consent before an interview and for permission for recording. Personal and demographic information was collected, and all data were kept anonymous to preserve the respondents' confidentiality.

3. Major findings

3.1. History of changes from the early formation of X-hamlet until 2016

To gain a better understanding of the history of X-hamlet, we collected data from key informant interviews and FGDs. We used the historical trajectory approach method to obtain significant information about past events that may potentially shape the hamlet's future. The responses to our research questions about changes that have occurred since the formation of X-hamlet until the suction-dredging,[1] post-conflict period are presented in this section. We identified important events underlying the changes, which we defined as changes to the environment, individuals' lives and their livelihoods, changes to ecosystems, and changes in resource utilization. The historical periods of change in X-hamlet can be divided into the five periods described below.

3.1.1. Early formation period of X-hamlet (1950–1980)

The key informant interviews and FGDs clarified that inhabitants of X-hamlet were descendants of sailors from Z-Village, a village neighboring X-hamlet and connected by the coastline. According to informants, in the 1950s, only seven migrant fishers were living in X-hamlet in temporary traditional houses made of coconut stems and

[1] In 2014 A border conflict arose as the result of village official maps consequently creates tension among related villages and affects the claims over right to access and ownership of the coastal areas. Post border conflict begin at 2016 when the conflict resolved after court decision announced that X-hamlet and Y-village owned the rights to use and control the disputed area.

leaves. These fishers normally stayed for three days in X-hamlet and returned to their original homes for two days; this cycle was then repeated.

In the 1960s, the number of migrant fishers increased. Some decided to permanently reside in X-hamlet to save time and avoid the logistical problems inherent in commuting in a traditional boat every three days. They began to build semi-permanent wooden houses. As a survival strategy during the low-catch season, the fishers began to engage in small-scale agricultural activities around the beach by planting vegetables, including chili cassava and onion. In the early 1970s, they opened the forest for traditional dry farming, as the beachfront land was less productive. They grew peppers as their main commodity and fruits and vegetables for consumption, including cassava, banana, rambutan, and durian. They expected to maintain soil fertility by crop rotation.

3.1.2. Hamlet's growth period (1980–2000)

In the early 1980s, the coastal settlement shifted to the deep forest and merged with a neighboring hamlet (which was part of the Y-Village) due to the coastal settlement's remote location and low population. This impacted the local land tenure system as more forest land opened. Agricultural land was considered the most important factor of agricultural production, and thus, to avoid land tenure conflicts, the community agreed on "*system tebas pakai*"; one of the local elders explained that this agreed-upon rule was that whoever clears the forest land has the right to use that land.

After a new shortcut road was opened connecting the village main road with X-hamlet in the 1990s, the number of households gradually increased and migrants arrived to pursue economic opportunities (often related to resource exploitation). The arrival of outsiders for work and marriage brought new values to the locals. At the same time, X-hamlet was formally registered with the district government. After long negotiations with the district government, in 1997 X-hamlet became a unitary administrative unit that had the authority to manage its territory.

3.1.3. The mining period (2001–2004)

Unlike other hamlets, tin mining in X-hamlet was "introduced" by migrants in early-2002. Numerous small-scale mines, commonly called "*unconventional mines*", emerged, which were supported by outside investors. These investors convinced residents to abandon their subsistence fishing and farming — which was time-consuming and required patience for crop harvesting — and join a tin mining operation with the promise of instant cash income.

On land, small-scale mining reached its peak in 2004 as did small-scale mining in coastal areas, undertaken by outsiders. At this time, the local populace was involved only in small-scale inland mining; coastal mining was considered dangerous and risky, and that it had significant capital requirements. During an in-depth interview with the hamlet chief, it was explained that small-scale mining activity started to decline following depletion of land. Furthermore, he mentioned that the technologies used for mining could not reach the depth of sites. This was followed by suction-dredger activity in X-hamlet in 2009 without formal consent from the local community and government, lasting approximately two years until the end of 2010.

3.1.4. Spread of suction-dredging and the border conflict period (2009–2015)

In March 2011, suction-dredging was permitted by local and district governments on Bangka Island. In 2014, suction-dredging stopped because of a border conflict arising from an ambiguity on official maps between Y-village and O-village. The conflict was over the sea boundary belonging to Z-village and part of X-hamlet that was shown on a map in the territory of O-village. Consequently, Z-village and X-hamlet lost their rights to access the disputed coastal area. The claims over the right to access and the right of ownership in coastal areas also concerned who was eligible to receive royalties and compensation from the suction-dredging, as well as who would receive a share from the small-scale mining activity.

3.1.5. Post-border conflict period (2016)

At that time, the X-hamlet chief associated with Y-village won the first case in court. The court decision clearly stated that X-hamlet and Y-village owned the rights to use and control the disputed area. A week after this decision, O-village permitted one suction dredge to operate in its territory following the commencement of large-scale tin mining activity. At the beginning of August 2016, the number of suction dredges had increased from one to three. The chief of X-hamlet confirmed that the licensing of suction dredges was neither under the control of X-hamlet, nor Z-village. A representative from Z-village confirmed that tin was being extracted with a suction dredge; the benefits from the mining resulted in both internal and external contentiousness, creating tension among stakeholders: tension that was exacerbated by the impact of large-scale tin extraction activities in X-hamlet and Y-village.

In X-hamlet, small-scale tin mining and large-scale suction-dredging have, in recent history, attracted significant numbers of laborers from the fishing and farming industries. Tin mining, however, poses an environmental threat to coastal resources, as the permitting processes do not demand that precautionary measures to be taken to protect coastal resources or local livelihoods. On Bangka Island, agricultural lands were converted to mining, consequently making them unavailable for farming in the future. Tin mining has attracted outsiders because it is profitable. They have purchased land from residents to open mines; but this has led to an imbalance in land ownership. The arrival of the Palm Oil Plantation Company in the area during the period that small-scale tin mining production had peaked exacerbated these problems. As residents were focused on mining, abandoning agricultural lands, the Palm Oil Plantation Company found itself in a position to purchase much land at low prices.

Inherited family relationships define the X-hamlet community. Social relationships and networks, based on kin, economic, political, and/or other types of personal connections, are the foundations of everyday life and day-to-day activities. Social values in the community changed, however, following the introduction of both small-scale mining and suction-dredging. For example, before mining, residents were socially-connected, their bonds strengthened by mutual understanding; actively participated in social gatherings; and helped one another during times of hardship. These points were details by HT", a 59 year-old individual, during an interview:

> "…All inhabitants of this X-hamlet were basically relatives, some are bound by blood, some are bound by local attachment, etc. Twenty-five years ago, in the beginning of every[2] east catching season when there are plenty of fish, local fishers used to build their bagan[3] with the mutual help of other fishers [the communal activity is locally called '*gotong royong*']. From cutting wood, carrying it to the construction site. I used to provide cooking for labour. Similarly, in our hamlet and village, if others need help, they call for gotong royong. After mining got here, people have started prioritizing their own activities. It becomes very hard to find voluntary human power for bagan construction. Unless we have to hire them as paid labour..."

HT's statement helps to put into perspective how mining has impacted the local value system of X-hamlet. Its residents now have more

[2] East season locally defined as the high-catch season and west season refers to the loaw-catch season.

[3] A *bagan* is a lift net linked to a bamboo frame building, normally operated at night and using a lamp light to attract fish. The area of operation for the installation of a *bagan* is clear aqueous coastal water with a depth of 7–10 m. The distance of a *bagan* from the beach is 2–4 miles; the distance between *bagans* is ~200–300 m.

individualistic, monetary, and material-oriented goals, brought about by lucrative mining activities.

4. Local perceptions of change in X-hamlet

To gain insights into how locals perceived changes, we arranged discussions with both men and women of different subsistence groups (fishers, farmers, and miners). These captured the community's diverse points of view and perceptions about the changes. A detailed description of this is presented in the following section of the paper.

4.1. Fishers' perceptions of changes

Both small-scale and large-scale coastal mining pose a dilemma for the local community, whose inhabitants compete for livelihoods while facing possible resource shortages due to resource exploitation. In X-hamlet, fishers were adversely impacted by coastal mining. Mining areas intersected with their fishing grounds. Damage caused to the sea, which is difficult to control, as it is not visible, is not comparable to damage to land. The waste disposal by suction dredgers and pontoons which resulted in sedimentation of coral reefs and depletion threats to the coastal ecosystem had a significant impact on daily income due to smaller fishing yields. Declining fish populations occurred because suction dredge operations for the underwater excavation of alluvial deposits were conducted without proper mitigation or monitoring.

The majority of X-hamlet fishers (fifty seven percent) use a *bagan tancap,* normally called a *bagan,* for fishing. Fishers without a *bagan* (forty three percent) either work as daily-wage fishers who maintain another fisher's *bagan* and divide profits or use other fishing instruments such as handlines (*rawai*), rods (*pancing*), traps (*bubu*), or nets (*pukat*). Financial capital, as well as the durability of fishing equipment, affects the fishers' choice of fishing gear. The high cost of *bagan* construction, ranging from 25 to 40 million rupiah ($2,500–$4,000 USD), depending on the *bagan*'s size and distance from the coastline, is the reason for less frequent ownership.

Compared to other methods, fishing with a *bagan* is less flexible because its catch is strongly influenced by the *bagan*'s installation position and water quality. *Bagan* owner KJ (52 years old) elaborated

> "…A *bagan* is not a movable instrument. It can only be installed once during the fishing season. Its structure is normally made of local wood, so a *bagan* has limited strength and durability. It can only be installed in shallow sea with a certain depth, between 7 and 10 m. A *bagan* also relies on light to attract fish. If the turbidity level is high, then less fish will enter the n..."

Fishers who use a *bagan* are thus more vulnerable and at higher risk from negative impacts of coastal mining. Our survey results revealed that ninety seven percent of the fishers experienced difficulties catching fish from depleted fishing grounds requiring a deeper *bagan*, with longer travel distances and limited technical capacities. MH (48 years old) stated

> "…Until 15 years ago, I could build my *bagan* within 500 m of the coastline. The yields were abundant with a variety of fish, from the low, medium, until the high quality. Within a few hours, I could catch a minimum of one and a half sacks of fish (approximately 100–150 kg). Nowadays, though the *bagan* is built almost two miles away, the yields are unpredictable and far from what we used to earn previously. These strongly affect our daily incomes and make us financially insecure…"

A 46-year-old fisher who formerly caught anchovies said that during the last decade, the quantity of anchovies had drastically decreased. He opined that the seawater used to be clean and fishers could see the coral reefs. After the operation of suction dredges, it was not possible to find fish because the seawater had become dirty and muddy. In addition, twenty three point three percent of the fishers queried in our study also experienced the scarcity of particular varieties of fish, such as kembung and yellow tail, and thirty seven percent experienced depletion of fish quality. This was described by local fisher MK (42 years old):

> "…In the beginning of the east season, normally we could catch medium- and large-size shrimp and some medium-size high-quality fish,[4] but in the last few years, they are no longer found. It certainly affects the amount of fish available in the market and that correlates with fluctuations in fish prices. Besides, many people, including myself, feel like the taste of the fish has gradually changed. The change in taste might be because of lead contamination in the sea water [as explained by an extension worker to this key informant]."

Fishers perceived that the coastal mining activity within their territory resulted in declining fish yields and resulting income. Thus, the fishers felt the greatest impact from mining activity, including the effects on the amount and variety of fish caught, the difficulty in catching fish, and the price and quality of the fish. Consequently, fishers had to increase their working hours, improve their logistics, and increase their operational costs.

In addition to the environmental changes affecting the locals' livelihoods, tin mining affected local values. One of the local elders, IP (74 years old), mentioned his anxiety about the dissolution of mutual understanding among fishers:

> "…Two decades ago, fishers built their *bagans*
> with the help of other fishers, applying the principle of mutual help. But nowadays, they have to hire labour to construct their *bagans*. These kinds of values of mutual help no longer exist in this hamlet, eroded along with the rapid development of tin-mining operations…"

4.2. Farmers' perception of the changes

Agricultural activity played an important role in the livelihood of X-hamlet. Pepper (*Piper nigrum L.*) and rubber (locally called *karet rambung* [*Ficus elastic*] and *karet hevea* [*Hevea brasiliensis*]) are two crops that were transferred within agrarian households to this hamlet. X-hamlet agrarian households have faced socioeconomic challenges from landscape changes during the last few decades. Deforestation reduced the availability of groundwater, and coupled with weather uncertainty, these changes made farmers hesitant to rely exclusively on farming. The climate-related changes experienced by residents are relatively recent, affecting seasonal cycles and subsistence activities. The problem with limited water for irrigation was explained by HJ, an elder who had engaged in agriculture since his childhood:

> "…Comparing recent farming techniques and tools to 20 years ago, they have completely changed. Moreover, in recent times farming is disturbed by unpredictable weather, shifts in rainfall, and yearly long droughts causing water scarcity for farming as well other activities. Whenever a dry season comes, we must suffer from drought. And these bring tremendous losses to us…"

One village officer, AD (27 years old), stated that rapid forest clearing in X-hamlet caused a decrease in water catchment areas, resulting in reduced amounts of available groundwater, especially during the dry season. AD added that although the population of X-hamlet is similar to those of other hamlets, the level of forest conversion is high.

In the peak mining period, massive agricultural land conversion conducted by both residents and outsiders strongly affected the local land tenure. The situation has worsened by the presence of a palm oil plantation within the hamlet that has purchased community land at a low price. The result is that thirty three percent of the total households

[4] Here, "high-quality fish" refers to the fish exported by Indonesia, such as kerapu, yellow tail, tenggiri, and other expensive varieties.

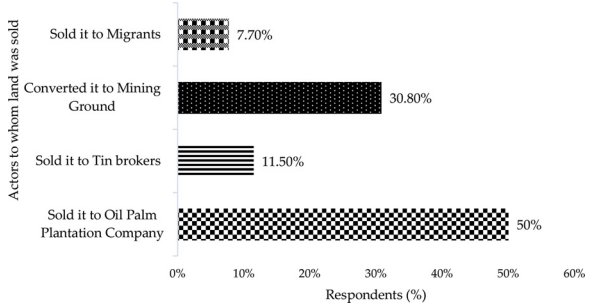

Fig. 1. Reasons why locals do not have land.
Source: Household survey, 2016

in X-hamlet do not own land. As shown in Fig. 1, fifty percent of the households sold their agricultural land to the Oil Palm Plantation Company, and thirty point eight percent converted their land from agriculture to mining.

BR (42 years old), a local farmer who was a miner, regretted transferring his land to another party:

> "…In 2004, I started mining after getting encouraged by my neighbor who was doing successful mining business. I was busy with mining and could not find time to do farming or just take care of my land. Instead of leaving the land bare, I decided to sell some parcel of my land to the palm oil company. Fortunately, I did not sell all land and can still fa..."

Some residents retain their land. AM (59 years old), a farmer, expressed pride in being a farmer. He explained that his parents reminded him that land is an important asset for food during hardship. He never thought of selling it, even with attractive offers. Unfortunately, the available abandoned tin-mining lands, formerly used for tin extraction, cannot provide a solution for the problem of land needs. Village officer BH (37 years old) explained that abandoned tin land is considered marginal, dominated by sand fractions, less fertile, and suitable only for particular crops, such as palm oil. Land abandoned after tin mining is no longer considered to be productive.

During group interviews, we noticed that a majority of farmers were older. When we asked why, FT, a 41-year-old farmer, stated that young people who grew up in the tin era were accustomed to earning money instantly. With a bowl and small bucket, everyone could easily extract tin from land. After tin became rare, people were still accustomed to earning instant income, and there was no interest in farming. Farming is difficult as it takes time to make money.

We found that the local people who still farm prefer to grow short-harvest cycle crops such as rubber. JK, a 56-year-old farmer, stated that pepper has the highest value compared to other crops. Peppers also have value in that they can be exchanged for cash for immediate needs. KL, a 42-year-old farmer, stated that high capital, maintenance cost, and risk of crop failure (due to pests and/or weather) made farmers hesitant to grow peppers. Seasonal data have shown that peppers have a yearly harvest cycle, from January to July. The local pepper farmers were not pleased with the year-long wait. Shorter harvest cycles mean farmers receive cash faster and can thus use it for their daily needs. These factors persuaded local farmers to grow rubber that is harvested daily.

To summarize, the problem of access to agricultural land creates significant challenges, particularly for those who do not have land. It is challenging for households with a limited amount of landto adjust their farming techniques. The uncertainty of income generation has therefore become a consequence of these experiences.

4.3. Miners' perception of the changes

Small-scale tin mining introduced to Bangka Island in the 2000s shifted the main source of income, attracting residents and outsiders and an influx of migrants. Some were driven to mine because of poor crop harvests, whereas others began to mine because of unfavourable weather conditions and/or to supplement income following the end of the agricultural season. Villagers began small-scale tin mining activity, locally referred to as *unconventional miner/TI*, using simple technology. Before the 2000s, only residents were involved in mining. One key informant, RT (49 years old), stated that the mining activity was considered the driver of change for the rural community. Residents could obtain money instantly by mining. He emphasized that in the early small-scale tin mining, each person could earn significant income from gathering a few kilograms of tin sand (the price of tin per kg = 110,000 rupiah, or $10 USD). However, the tin yields were unpredictable because of the unavailability of technology to identify tin-rich areas. Speculation was thus used to determine mining spots, and some individuals resortedto rituals to identify tin resources.

Small-scale mining in X-hamlet was the main income as well as supporting income for its residents. From 2002–2004, there was a significant increase in the number of households with mining as the main livelihood. However, from 2004 to 2009, there was a decrease in the number of households engaging in mining and changes in the strategies for income occurred. Depletion of tin stock and lack of capital were the main reasons that residents stopped mining. One miner, KL (43 years old), expressed his difficulty in extracting tin today:

> "…Around a decade ago, I could earn two to three sacks of tin within a day (1 sack = 50 kg) but nowadays finding even 5 kg per day is very difficult. I cannot afford the operational cost of a mining site including the fuel price, food, cigarettes, and a worker's salary…"

Eventually, mining was no longer a promising and profitable source of income. Other significant reasons mentioned by local miner AH (47 years old) were the limited amount of mining ground and incompatible technology:

> "…Mining land was abundant in the early 2000s. Former mining sites previously extracted by mining companies were still available with a reachable depth. Now, the available land is limited because most of it has been sold to outsiders, and palm oil company(..."

Extreme depletion of the land's tin stock, incompatible mining technology, and limited mining grounds were the three major causes of the decline of mining as perceived by miners. The beginning of coastal mining, accompanied by the reduction in the amount of land tin stock, influenced the livelihoods of X-hamlet residents. Although none of the residents engage in coastal mining (because it is risky and requires high capital), the influx of migrants who work as coastal miners has been followed by social inequality and conflict. The presence of suction-dredging, which was expected to bring prosperity for hamlet residents, conversely led to intra-community socioeconomic differences and resulting local tensions.

Although environmental impacts are less important to land miners because they do not directly affect income sources, the benefits of the mining are not equally distributed among the residents. One miner SH (37 years old) expressed his dislike of suction-dredging operations, which provided more benefits to the local elites. He is one of the ordinary residents who has become aspectator. He believes outsiders arrived to exploit available resources, earning huge amounts of money and providing advantages only to local elites, not to the whole community.

4.4. Adaptation strategies deployed to minimize the impacts of tin mining in the study area

A progressive decline in fish yields that has led to income uncertainty has been observed by the local fishers. To adapt, the fishers applied several strategies to improve their fishing technical capabilities,

including shifting the *bagan* fishing grounds, diversifying their fishing tools, and increasing the number of working hours daily and weekly. Depleting fish yields led to income uncertainty, the most prominent adaptation, which was based on seasonal strategies. Livelihood diversification and division of labour were also employed on the basis of the number of working household members and the capital and assets owned. The adaptations included borrowing money, mortgaging and selling assets (land, home, boat, and vehicles), and adjusting daily consumption.

Farmers considered land ownership and income uncertainty as the main changes affecting their household resilience. Crop rotation and diversification, agricultural technique improvement, and shared-cultivation strategies were applied to boost yields. Farmers also used the same adaptation as the fishers had, including diversifying sources of income, additional jobs, and migration. Pepper-growing farmers did not work throughout the year as rubber and palm oil farmers did. Instead of waiting to harvest their peppers, farmers preferred to look for other jobs within or outside the village such as fishing, mining, or any wage paying job to meet their daily needs.

Depleted tin stocks and limited mining ground severely affected the financial situation of the miners. Improving the mining techniques compatible with the depth of mining grounds, converting farming land into mining sites, migrating, and diversifying household livelihoods are among the adaptation strategies used by the miners. Several constraints affected all of the fishers, farmers, and miners while they were successfully adapting to the changes they faced. Our group discussions with the miners revealed that the most prominent constraints have been unpredictable weather, limited work options, lack of capital ownership (financial, physical, and human capital), limited water supply, poor soil quality (farmers only), limited skills and lack of education. Tables 1–3 summarize the adaptation strategies used by the three subsistence groups (fishers, farmers, and miners) to minimize the negative impacts of large-scale mining activity in the study area.

We investigated the socioeconomic differences among the subsistence groups to determine how these differences might have affected the residents' ability to adapt to changes due to tin mining extraction. We next discuss the different combinations of subsistence options among households and the factors that shaped the strategies applied.

We categorized each subsistence group's strategies into three subgroups: single strategy, diversification strategy, and seasonal strategy. The single strategy group comprised households which applied a single-income source strategy. The diversification strategy group comprised households which used double- or multiple-income strategies by diversifying their livelihood options and/or allocating household members for another strategy. The seasonal strategy subgroup comprised households which used one or more strategies based on seasonal conditions.

Seasonal disruptions are part of the fishing community's life. As shown in Fig. 2, a majority of households (17) employed seasonal strategies because fishing activity is seasonal. Fishers engage in fishing activity during the "e..." season, while they shift to other income sources during the "w..." season. Most of the other subsistence groups used the diversification strategy because their activities are not influenced seasonally. The reasons for choosing double- or multiple-income source strategies differed for each group. A majority of the miners, particularly migrants or individuals who immigrated to the area for marriage, applied single-income strategies because of the unavailability of land. For others, the reason for applying double or multiple income strategies was poverty and to increase income.

5. Discussion

> "…In the past, when there were plenty of fish yields, every day my husband brought a lot of leftover fish for us and we could also share it with neighbours. But, since tin mining has started, fish yields are not enough for our own consumption. Occasionally, we cannot catch enough fish and have to eat rice with sa..." (TG, 32 years old)

TG's insight hints at the daily challenges faced by coastal resource-dependent households in X-hamlet following the arrival of tin mining operations. Changes that occurred as the impact of tin-mining operations affected the dynamic and socially heterogeneous coastal community livelihoods were perceived differently by the affected residents (Rosyida and Sasaoka, 2018). Mechanisms of resilience do exist, with which households have tried to adapt and to reduce the shocks and stresses resulting from tin mining, while facing constraints.

Scoones (1998) argued that the livelihoods of resource-dependent households are complex because of their attachment to resources. This is inextricably linked to how community members allocate available resources to make a living, meet needs, cope with uncertainties, and respond to opportunities (Blaikie et al., 2014). The impact of multiple anthropogenic stressors such as declining resource bases and access and rights to resources is a challenge to livelihood security (Adger et al., 2011), constantly creating day-to-day uncertainty about survival (Thomas et al., 2007; Helmi and Sasaoka, 2018).

Tin mining has been a driver of irreversible environmental changes affecting the land and livelihoods in X-hamlet (Rosyida and Sasaoka, 2018), for both the communities which are directly connected to the hamlet and those which are indirectly connected (Rosyida and Sasaoka, 2018). Both groups of individuals' experience different levels of impact (positive or negative). Coastal communities respond to changes in various ways. Residents perceive and respond to changes influenced by the subsistence activity in which they are engaging, including changes in the socioeconomic structure (Few, 2003), source of vulnerability (Gallopín, 2006), and assets and property relations (Kofinas and Chappin, 2009). This perspective lends importance to understanding how the residents' perception of changes has shaped their decisions.

Fishers' households depend on the coastal ecosystem, and fishers are the subsistence group that is directly affected by suction-dredging operations and small-scale coastal mining. Fishers must tolerate declining fish quantities, which creates income uncertainty (Helmi and Satria, 2012). For farmer and miners, the changes in land tenure systems and external stressors such as unpredictable tin stocks and weather uncertainty have resulted in challenges to their household resilience.

According to Eriksen et al. (2005), livelihood strategies are the product of interactions between choice and constraint. Researchers such as Adger et al. (2009) suggested that adaptation strategies, embedded within a demographic, cultural, and economic background, vary among community groups, depending on their local values, attitudes, and expectations. Fig. 3 illustrates the fishers' adaptation strategies and ownership of *bagan*. Independent fishers own their *bagan*, while dependent fishers do not own a *bagan* but work with independent fishers. Subsistence and cash income from "non-fishing-related resour..." complements other sources.

Land is the most fundamental resource for the poor, and owning land is essential to generating income, accumulating wealth, transferring it between generations, and enabling protection from insecurity. All of the independent fishers (10 households) who owned land were able to engage in agricultural activity for additional income, by either shared or self cultivation, depending on the household financial state, size of the land, family labour, and household preferences.

Fluctuations in fishing yields are linked to necessity, and limited alternatives and constraints force fishers to use surplus labour resources. Sixty two percent of the landless dependent fishers assignedhousehold members to work in low-paying jobs. Some of the fishers who adopted a single-income strategy decided not to diversify their income source because of economic incapability. Two of the three independent fishers' households owned two or more *bagans* and additional properties outside of the village (houses and land). However, capital constraints (including financial, physical, and human capital) still determined the choices for income strategy diversification for other households. Fifty eight percent of the total number of fishers who

Table 1
Key adaptation strategies in the study area.

No.	Subsistence Group	Changes	Adaptation Strategy	Constraint
1.	Fisher	Depleting Fish Yields	Shifting their *Bagan* Place (Fishing ground)	*Bagan* has limited strength, depth, and distance; high cost of *bagan* construction (price of wood, labour cost); decreased wood quality
			Diverse pattern of fishing activities (fishing instruments; fish targets, seasonal)	Lack of capital (to buy another instrument); limited boat capacity; neighbourhood villages being polluted by mining activity; high risk and safety; unpredictable weather
			Increasing the working hours/days	Unpredictable weather, health constraints, *began* work only at night
		Depletion of Income	Seasonal Strategy: Work in agriculture/mining/labour job during west season and; in east season engage on fishing	Unfixed job availability; unfavourable weather; limited options due to skill/ education
			Diversification Strategy: Allocating family to work on own agricultural land or wage labourer to another household; Self-employment by integration with other off-fishing activity such as livestock raising	Availability of alternative income generating strategy options; Lack of willingness; Limited skill and capital; Limited technology Remote hamlet location; low accessibility; Skill and education; Gender limitation, illiteracy
			Networking Strategy: borrowing cash from fishers, family/relatives; taking loan from the fish trader (market)	Financial constraint faced by other fishers and relatives; loan interest from fish traders high
			Assets and Saving Strategy: mortgaging and selling assets (land, home, boat, vehicles or any other assets)	Hard to define value of access, access to related economic institutions, remote hamlet locations
			Consumption Strategy: reducing consumption of food, secondary needs; grow vegetables, spices yards	Limited alternative affordable food available, number of household members require more food consumption
2.	Farmer	Depleting Crop Yields	Crop Rotations (switching the crop choices)	Low soil fertility; Unpredictable weather; Lack of capital assets; Market access, pest risk, weather risk
			Technology improvement (Fertilizer, land cultivation system)	Limited skill and capital (price of fertilizer, seed)
		Limited land	Crop Diversification (combining pepper and mixed crops; or rubber and mixed crops)	Low fertility of Soil; Lack of capital (high initial and maintenance cost, especially pepper)
			Land sharing with another farmer- Shared Cultivation	Family relation constraint; possibility of distrust and economic-based conflicts
		Income Uncertainty	Seasonal Strategy: for pepper farmer: during harvest time, work on farm; and during non-harvest season: work as wage labour in construction site, or as mining labour	Unfixed job availability; Limited options due to skill and education; Family constraint; gender limitation; the number of mining sites have been reduced rapidly
			Diversification Strategy: Allocate family to work as wage labour on another household or to work as wage labour; Self-employment by altering integration with off-fishing activity such as livestock raising; migration to district capital for wage labour work, or temporal migration to work as miner during non-harvest season	Few options of available job; Lack of willingness; Limited skill, limited capital; Limited technology Remote hamlet location with low accessibility; Skill and education; Gender limitation
			Networking: borrowing from other farmer/family/relatives, borrowing from the land/farm owner, taking loan to bank or any economic institutions; food sharing with neighbour	Financial constraints faced by another farmer, community, or relatives; low literacy; difficulty accessing economic institutions
			Assets and Saving: mortgaging and selling assets (land, home, boat, vehicles, pepper)	Hard to define the value of access, access to related economic institutions, remote hamlet locations
			Consumption Strategy: reducing consumption for secondary needs; reducing food consumption	Limited alternative affordable food available, huge number of household members require more food consumption
3.	Miner	Depleting Tin Stocks	Technology Improvement (bigger machine capacity)	Lack of capital assets cost of the machine and other instruments, cost of renting excavator, cost of the excavator operator, cost of logistics for workers, etc.
		Limited Mining Ground	Convert available agricultural land into mining ground	Not all miners have land
			Join with another miner who has mining ground	High potential conflict
		Income Uncertainty	Diversification, allocate family to work as wage labour, open kiosk,	Gender constraint Low skill, Illiteracy, limited job option
			Networking: borrowing from other farmer/family/relatives, borrowing from the mine owner	Financial constraint faces by other fishers and relatives; limited access to bank or any economic institution, high interest
			Assets and Saving: mortgaging and selling assets (land, home)	Hard to define the value of access, access to related economic institutions, remote hamlet locations
			Consumption Strategy	Limited alternative affordable food available, the huge number of household members require more food consumption

Table 2
Key adaptation strategies for farmers in the study area.

No	Changes	Adaptation Strategy	Constraint
1	Depleting Crop Yields	Crop Rotations (switching the crop choices)	• Low soil fertility; • Unpredictable weather; • Lack of capital assets; • Market access, pest risk, weather risk
		Technology improvement (fertilizer, land cultivation system)	Limited skill and capital (price of fertilizer, seed)
2	Limited land	Crop diversification (combining pepper and mixed crops; or rubber and mixed crops)	• Low fertility of Soil; • Lack of capital (high initial and maintenance cost, especially pepper)
		Land sharing with another farmer- shared cultivation	• Family relation constraint; • Possibility of distrust and economic-based conflicts
3	Income Uncertainty	**Seasonal Strategy** (for pepper farmer): • Work on farm (during harvest time); • Work as wage labour in construction site, or as mining labour (during non-harvest season)	• Unfixed job availability; • Limited options due to skill and education; • Family constraint; • Gender limitation; • The number of mining sites have been reduced rapidly
		Diversification Strategy: • Allocate family to work as wage labour on another household; • Self-employment by altering integration with off-fishing activity such as livestock raising; • Migration to district capital for wage labour work, or temporal migration to work as miner during non-harvest season	• Few options of available job; • Lack of willingness; • Limited skill, limited capital; • Limited technology; • Remote hamlet location with low accessibility; • Skill and education; • Gender limitation.
		Networking Strategy: • Borrowing from other farmer/family/relatives, from the land/farm owner, and taking loan to the bank or any economic institutions; • Food sharing with neighbour	• Financial constraints faced by another farmer, community, or relatives; • Low literacy; • Difficulty accessing economic institutions
		Assets and Saving Strategy: Mortgaging and selling assets (land, home, boat, vehicles, pepper)	Hard to define the value of access, access to related economic institutions, remote hamlet locations
		Consumption Strategy: Reducing consumption for secondary needs; reducing food consumption	Limited alternative affordable food available, huge number of household members require more food consumption

adopted farming as a supporting strategy used shared-cultivation systems with relatives or neighbours for capital support and to reduce the risk. The shifting of local values in this hamlet, from mutual to individualistic, might create a significant threat to sharing relationships.

The strategies adopted by farmers are differentiated by the amount of land owned and the types of crops grown on that land (Fig. 4). The larger the land area, the more adaptation strategies the farmers can deploy to grow more crops. The greater the variety of crops grown, the more secure a household is. As suggested by Anik and Khan (2012), crop diversification and land ownership help households adapt effectively. In the present study, farmers of the four households who were growing single crops had daily wage-labour jobs, whereas the farmers who were growing multiple crops were relatively secure and allocated their capital for investments such as kiosks. Labour and financial resources are necessary for farmers' resilience even if they have secured land tenure and have viable technologies and access to inputs and extension advice. We found that not all households adopting single-income strategies can be regarded as incapable of applying diversification or seasonal strategies. Our examination of the household livelihood trajectories revealed that two of the four households owning 2–4 hectares of land chose a single income-generating activity owing to limited human labour. They are focusing on cultivating their available land.

Among the miners, some own mines, while others work as labourers (Fig. 5). The strategies they use differ depending on the miners' status. Mine owners must deal with fluctuations in production costs and the risk of inefficient extraction, whereas labourers must deal with financial loss and security risk.

As tin yields and prices are unpredictable and fluctuating, a household owning land would adapt better because it has more options for income. As shown in Fig. 5, two-thirds of the total number of mine owners also own land, whereas six out of seven of the total number of mine labourers were landless. This drives the involvement of women and children to work as scavengers, which traps them in a high-risk

Table 3
Key adaptation strategies for miner in the study area.

No	Changes	Adaptation Strategy	Constraint
1	Depleting Tin Stocks	Technology improvement (bigger machine capacity)	Lack of capital (cost of renting excavator, cost of the excavator operator, cost of logistics for workers, etc.)
	Limited Mining Ground	• Convert available agricultural land into mining ground • Join with another miner who has mining ground	• Not all miners have land • High potential conflict
	Income Uncertainty	**Diversification Strategy**: Allocate family to work as wage labour, open kiosk.	• Gender constraint • Low skill, • Illiteracy, • Limited job option
		Networking Strategy: Borrowing from other farmer/family/relatives, and from the mine owner	• Financial constraint faces by other fishers and relatives; • Limited access to bank or any economic institution, high interest
		Assets and Saving Strategy: Mortgaging and selling assets (land, home)	Hard to define the value of access, access to related economic institutions, remote hamlet locations
		Consumption Strategy	Limited alternative affordable food available, the huge number of household members require more food consumption

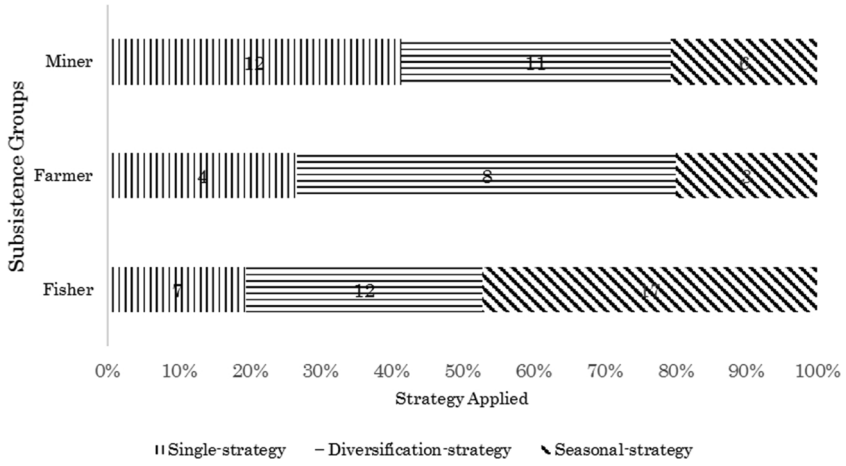

Fig. 2. Percentage of Adaptation Strategies Applied by Each Subsistence Group.
Source: Household Survey, 2016

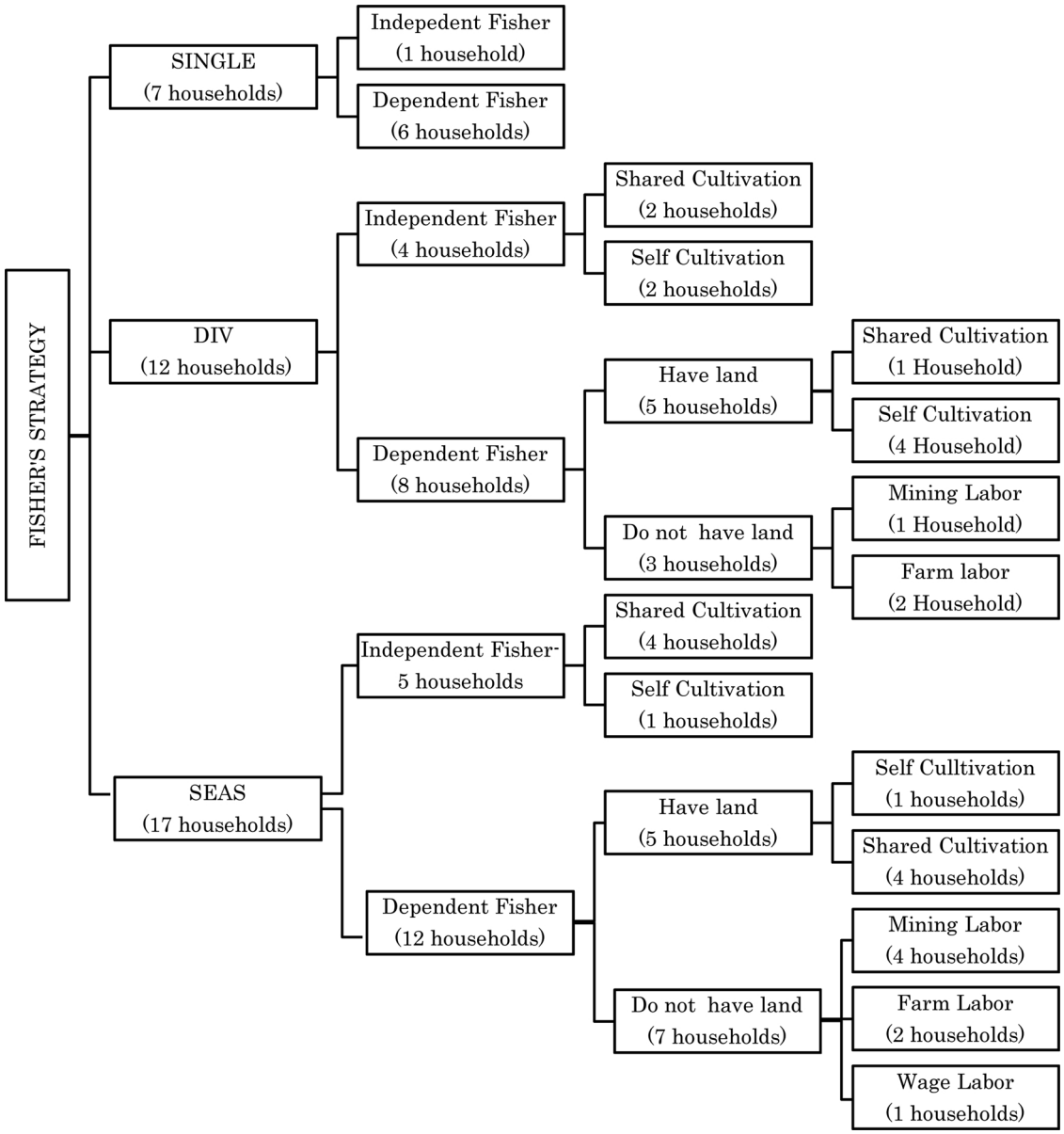

Fig. 3. Fishers' Household Strategy.
Source: Household Survey, 2016

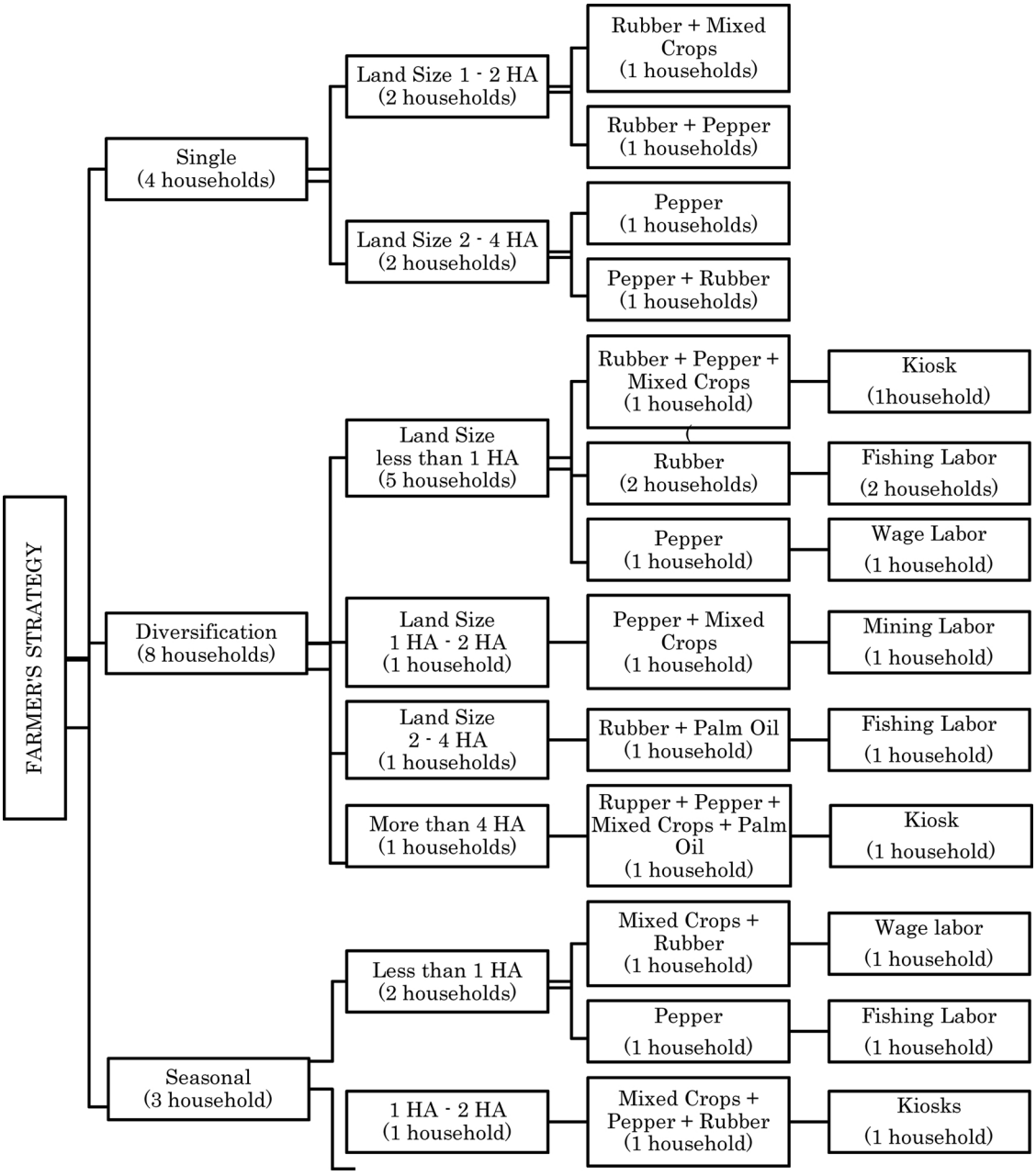

Fig. 4. Farmers' Household Strategy.
Source: Household Survey, 2016

subsistence activity extracting the easiest metal and living a precarious existence.

Our household survey results showed that three of the twelve households and one household that applied single strategies were previously engaged in fishing and farming activities before tin mining. Because of land ownership constraints, they could not readopt fishing or farming strategies as supporting income. The unavailability of land forced three miner households to adopt a diversification strategy and one household to adopt nonagricultural seasonal strategies for alternative income sources. Four of eleven households were fishers before mining activity, but rapidly depleting income forced three of them to work as miners. Only one of the households decided to work as fishing labour to support the household needs.

In summary, important factors determine income strategies, including physical and financial asset ownership (cash/land), networking and social relations, and supporting human resources availability for labourers (Adger et al., 2004; Abid et al., 2015). Households with more assets and larger and stronger networks and human resources are more adaptable, as explained by Adger et al. (2003). Short-term coping mechanisms through networking, consumption reduction, and mortgaging assets may provide options or strategies that help a household or community survive unpredictable changes.

On the other hand, as suggested by Marschke and Berkes (2006), the diversification of a household's livelihood can be both reactive and opportunistic when applied by households with no capital or assets. Capital-owning households strategize to accumulate wealth, whereas households who deal with fewer resources rely on survival strategies. Given the socioeconomic differentiation within X-hamlet, the declining resources and the declining access to resources, it is possible that barriers to livelihood diversification, limited skills, illiteracy, and low opportunity will force the poor households to focus on narrow survival strategies, resulting in resource degradation.

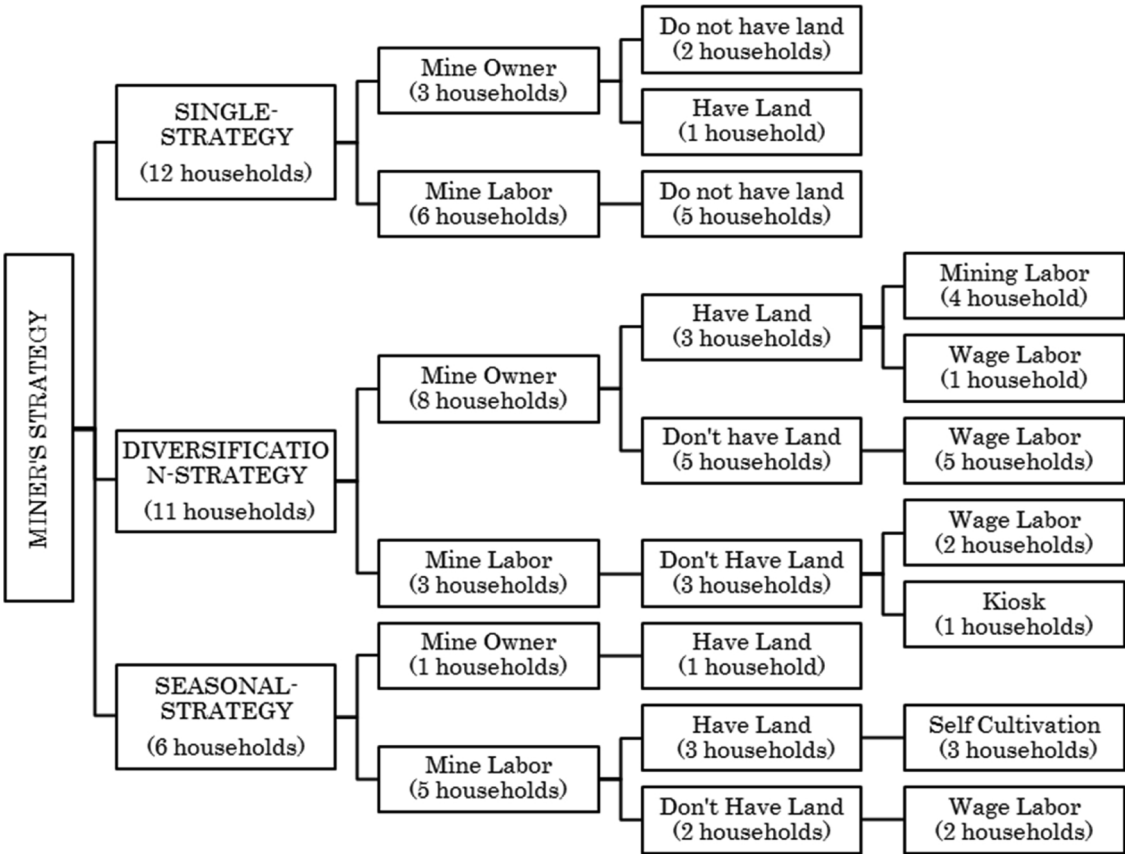

Fig. 5. Miners' Household Strategy.
Source: Household Survey, 2016

Among the three subsistence groups examined herein, the fisher group is more vulnerable to environmental changes because its economic base, food source, identity, and socio-cultural practices are reliant on coastal resources. This result is in agreement with that reported in the study conducted in Central Bangka by Rosyida and Sasaoka (2018) and Rosyida et al. (2018). They found that net fishers must accept a resource depletion threat that will have a significant impact on their daily income because they will catch fewer fish. The declining fish population will force them to extend the distance they must travel to catch fish, and these distances are not compatible with the capacity of their boat engines or with their limited daily capital. In addition, facing seasonal disruptions and ever-increasing resource depletion from suction-dredging, fishers who do not own land or other assets are highly dependent on the *bagan* owner and are potentially marginalized.

Another layer of complexity is that marginalized landless fishers are obliged to engage in mining activity as an adaptation strategy, leading them to be more vulnerable. They respond to ongoing changes and livelihood threats by shifting their livelihood from fisheries, engaging in coastal mining through profit-sharing mechanisms with the seasonal migrant miners, or potentially converting available land into mining land. Linked to socio-economic and ecological issues, adapting to ongoing changes through unsustainable mining activity reflects that suggested by Adger et al. (2004) as a maladaptation state. A short time for adaptation may further lead the marginalized groups to adapt poorly and may hinder their future choices.

Although our results are specific to the X-hamlet community, they depict the real challenges currently faced by all coastal regions in Bangka Belitung Province affected by the tin mining activity. Our previous studies conducted in West and Central Bangka Island suggested that the current mining policy fails to consider good governance that addresses people-oriented and practical approaches that are necessary to understand the multifaceted problems in complex coastal social-ecological systems.

6. Conclusion

This case study of X-hamlet offers a good illustration of how communities living in a coastal ecosystem have been exposed to environmental changes because of their dependence on coastal resources for daily subsistence, livelihoods, and related socio-cultural activity. The results of our study demonstrate that the spread of tin mining activity on both large and small scales was perceived differently among subsistence groups within this hamlet as the key driver of the coastal ecosystem and land tenure system change, leading households to income uncertainty. Most of the fishers diversify their income for survival according to the seasons, whereas the farmers and miners rely on diversification through the division of labour. Household economic condition, resource availability, and relationships/networking are three important factors influencing household decisions about income diversification. Nonetheless, lack of capital (i.e., physical, financial, and human), limited skills, and low education levels constrain the diversification of income sources. Additional coping mechanisms through networking, consumption reduction, and mortgaging assets are considered short term, but they provide immediate survival support during unpredictable situations.

Agricultural land is considered the most valuable capital, functioning as an alternative livelihood source, but its ownership is concentrated in a few hands. Landless households thus struggle to adapt — particularly fishers, who face ongoing fish depletion yields threatened by suction-dredging and small-scale coastal mining. The landless fishers are potentially marginalized, leading them into maladaptation states, engaging in mining activity, which is an economically, socially, and

environmentally unsustainable alternative livelihood activity. One of the limitations of this study is that we do not know the effectiveness of the strategies adopted by the subsistence groups, and we thus encourage researchers to further study these strategies. From our present findings, we conclude that the suction-dredging mining activity has resulted in deteriorating local resources and has affected lives and livelihoods, especially of fishers and those who do not own land but are dependent on others for subsistence and survival. A collective effort from all related stakeholders (local elites, the research community, and the local and provincial government) is needed to facilitate ongoing adaptation in response to threats and future challenges posed by large-scale suction-dredging in X-hamlet and similar communities.

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