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Adaptive strategies and transformation for community recovery – A case study of villages in Hinthada, Ayeyarwady Region, Myanmar

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ABSTRACT

Myanmar is one of the highest meteorological hazard risk countries in the world, owing to geographical factors such as a vast delta along the Ayeyarwady River. As the Ayeyarwady Region has suffered from seasonal floods in the monsoons since historical times, long earthen dykes were constructed in the 19th century during the British colonial period. As a result, one village was divided into two by a dyke about 150 years ago. The region was severely affected by floods in 2015. Most of the unprotected villages were inundated for two to three months, while villages inside of the dyke were protected. This research aims to identify strategies for long-term recovery related to housing, livelihood, and community activities in villages divided by the dyke in Hinthada Township using household surveys. The results show that unprotected villages have adapted their elevated houses against floods and planted water-resistant crops as an income source. Protected villages have relied on mitigation and maintenance of the dyke along with non-elevated houses, and have transformed their livelihoods in different ways.

1. Introduction

1.1. Background

The countries belonging to the Association of Southeast Asia Nations (ASEAN) are exposed to high risks of hydro-meteorological natural hazards due to meteorological and geological factors. Kreft et al. [9] point out that climate change risks have had an impact on this vulnerable region. This is especially true of Myanmar, which is ranked the second highest at-risk country in the world [9]. Most types of natural hazards are observed in the history of Myanmar, but Cyclone Nargis in 2008 was the worst disaster with more than 138,000 casualties including missing persons [17]. The shock was a critical wake-up call, prompting the evolution of a legislative framework on disaster risk reduction [2]. Although the *Myanmar Action Plan for Disaster Risk Reduction* (2012, revised in 2017) and *Natural Disaster Management Law* (2013) have been enacted to deal with anticipating extreme weather events and climate change [12], implementation at local levels requires further steps.

In this paper, the theory of transformation, as an adaptive response and fundamental social-ecological system change, is examined with the relationship between structure and agent concept through an empirical, micro-level case study in Myanmar. Transformation is a term considered together with adaptation and resilience, especially in the academic field of climate change [8]. Consensus regarding resilience in disaster risk management is gradually converging into being process-oriented rather than outcome-oriented [10]. If resilience is a dynamic process of returning to a stable equilibria or bouncing back to normalcy, the transitional phases that absorb external shocks need to be illustrated. The transition has been characterized as having three stages: resistance (maintaining the status quo), incremental adjustment, and transformation [15]. Incremental adjustment is defined as "marginal changes in infrastructure, institution, and practices that foster flexibility and fulfil capacity while not directly threatening system integrity" [15, p. 117]. In other words, incremental adjustment holds unresolved problems or cumulative potential risks that are associated with "systematic vulnerability."[1] Pelling et al. [15] note that transformation is a "fundamental change to the functioning of [a] system," and in this sense, disaster recovery has huge potential to reach new equilibria or to destabilize.

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[1] Pelling et al., [15], p. 117.

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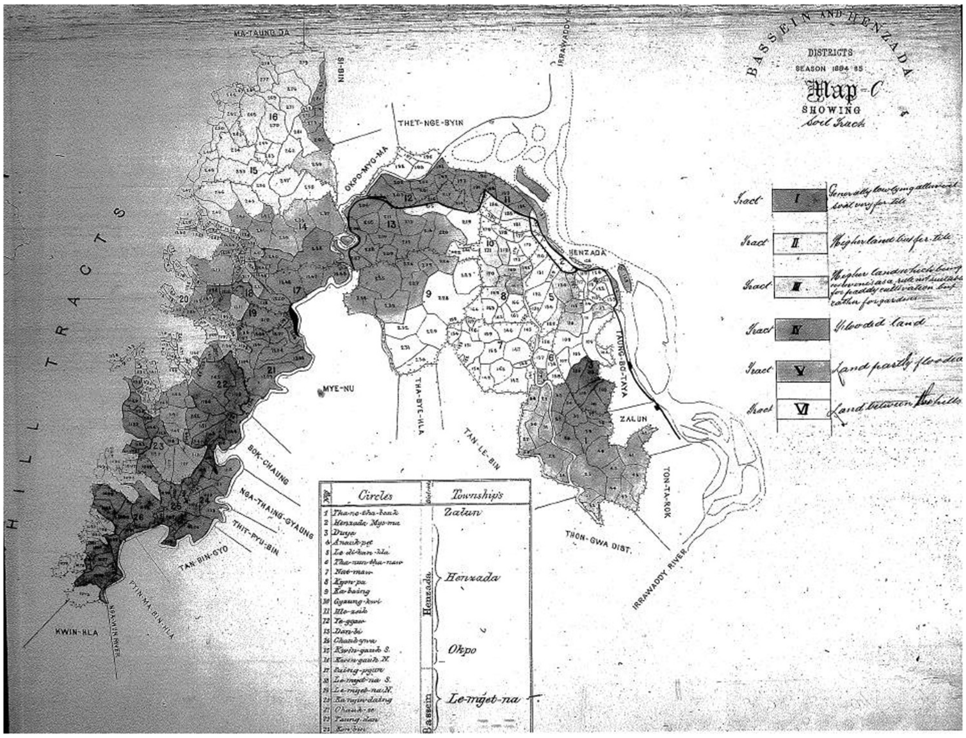

Fig. 1. Land use map in the early 1880s in Hinthada.
(Sourced from the [6])

The reason for this paper, which intends to connect the theory of transformation and the structure-agent theory, is that the relationship between structure and agent has meaningful to identify gaps between theory and practice through a case study. Although Pelling et al. [15] shows the "Adaptation Activity Space" as potential variables, practical study of transformation has still been limited due to the complexity of the independent variables. Transformation and Resilience on Urban Coasts (TRUC) conducted case studies in six cities (Kolkata, Lagos, London, New York, Shanghai, and Tokyo) to testify the concept of resilience, transition, and transformation on ground. Micro-level survey has potential as Birkmann et al. [1] succeeded to illustrate agent analysis with perception of individual households by the household surveys in Lagos. However, the research could not reach to assessment of structure in the society.

To bridge the gap of theory and practice on the transformation, this research applies an inductive case study on self-dependent communities with fewer interventions by institutional regulations. As Gibson et al. [3] points out that structure influences autonomous agent but individual may also become significant agents for transformation, looking at the relationship of structure and agent are critically important. A criticism on an inductive research is that a case study displays just only one perspective of a phenomenon, though its outcome will be a serious of "Building Block" [4]. If a structure and agent model on transformation theory has complex variables, starting from the simplest case is a valuable approach. The case study has the potential to identify inherent human adaptability and transformability because historically indigenous people had to deal with natural hazards with few external interventions. Building codes, zoning, external humanitarian relief are developed in a few centuries, however, it may adversely and unintentionally effect on declining capability of self-recovery and self-survival skills. In order to identify a focal point to maximize the capability of agent and structural interventions, a case study in inherent condition is suggested.

This research aims to identify inherent human adaptability and transformability in fewer intervened communities. It does not intend to deal with stratification and inequality directly. These issues, especially housing recovery and reconstruction, are discussed according to stratified social classes in case of disasters and the recovery pathways [13,14]. Although spatial inequality in this regard differentiates the consequences among local communities, this research specifies their adaptability in built environment over a century. Therefore, communities with fewer interventions were selected from rural areas of Myanmar. Thus, this research intends to rediscover the strategies of human adaptation to natural phenomena in an age of climate change. To examine this, this study aims to 1) understand how villagers adapt their lifestyle in flood-prone areas, and 2) identify adaptive and mitigation strategies for recovery against flooding and inundation in villages divided by dykes. This research has the potential to show that forced out-migration from a flood-prone area is not the only way to adapt, and new vulnerabilities in the future which caused by "maladaptation" needs to be identified.

1.2. Development of Hinthada Township and its impact from the flood in 2015

1.2.1. Historical development of the region

Hinthada Township, in the Ayeyarwady Region, has been one of the severely flood-affected municipalities historically. As the Township had considerable wasteland from the annual flooding, earthen dykes were constructed during the British colonial period since 1867 [11]. The dykes have been contributing to the protection of the urban area in Hinthada and transforming wetland into agricultural land over the generations. The yield of the paddy rice was dramatically increased as the colonial government planned for the expansion of exports that resulted from the opening of the Suez Canal in 1869 [11].

An official report on the settlement operations in 1883–84 published by the British colonial government noted, "These embankments protect 75,377.63 acres of the land now cultivated" [6, p. 2]. Not only were yields impacted but also the dyke construction divided one village and half of them has been remained in flood prone-area since then. Fig. 1 shows the map published in 1886 in Hinthada (Henzada at the time), which clearly indicates Tract IV as flooded land, along with the dykes [6]. A revised report five years later described the protected site where "the people live in a condition of decided comfort" whereas people living in "the flooded portion" were considered to be living poorly in less substantial houses [7, p. 11]. It is true that the dyke construction benefits the vast amount of cultivated land for the protected area, although it entails asymmetrical consequences: one is greater yields, and the other is annual floods for a long period on the unprotected side.

Although the dyke has functioned as a protection measure in the Region, the fracture of the dyke is a critical issue. For example, 0.5 miles of the dyke were broken in 1997 due to severe flood; as a result, 183 villages were affected and 8746 houses were flooded by the fracture [16]. The water reached to above floor level and some bamboo houses were washed away. The debris inflow degraded farmlands and inundation water remained as a lake. The dyke management has been highly prioritized to protect human being and their livelihoods.

1.2.2. Severe flood in 2015

Severe floods and landslides induced by a cyclone hit an extensive area of Myanmar in July and August 2015. They resulted in 172 fatalities, 1.69 million people displaced, and 1.93 trillion Kyat (equivalent to USD1.49 billion[2]) of economic impact over ten states/regions [5]. Based on the Post-Disaster Needs Assessment, published in November, and the national recovery framework and plan of September 2016, loss and damage in the housing and agricultural sectors were the highest of all sectors (48.35% of the total cost). Table 1 shows the top five types of damage and loss from the floods and landslides in 2015 in the state/regions of Myanmar. Ayeyarwady Region shows a higher population displacement, number of flood-affected houses, and amounts of destroyed farmland, although the number of totally damaged houses was relatively low. This implies that the flood in the Ayeyarwady Delta Region was a slow-onset prolonged inundation rather than a flash flood.

Even though villagers on the unprotected area are used to annual monsoon floods and inundation, the severe floods in 2015 were a challenge to survive given two months with more than two meters of inundation water. In contrast, the villages located inside of the dyke were protected, with the dykes. This illustrates the clear contrast in and outside of the dykes. It raises a fundamental question: why do people living on the unprotected side not relocate or migrate to a safer place? If villagers are willing to stay in their ancestral lands, how do they adapt or transform their living style, in terms of housing, livelihood, and collective community activities, without relocation or forced migration after more than a century of recurrent flood and metro-geological conditions?

Fig. 2 describes the schematic outlines of this research. According to the transformation theory, inside of the dyke is considered as resistance; incremental adjustment while in the unprotected area, forced transformation is due to the dyke's construction. Thus, this paper intends to identify not only adaptive strategies on the unprotected side, but to ascertain the systematic vulnerability of the protected side, as potential risks of floods are due to the dyke's fractures.

2. Research field

The research was conducted in Leik Chaung Village Tract, Hinthada Township, in the Ayeyarwady Region. Hinthada Township is located approximately 124.6 km (77.4 miles) northwest from Yangon, the capital of Myanmar. The Township holds 93 village tracts each containing 3–21 villages depending on the size. Leik Chaung Village Tract, located across the dykes, is approximately 12 km (7.5 miles) northwest from the center of the Township. One stream, Daga River on the unprotected area from the Irrawaddy River, was checked due to the dyke construction.[3] The river was remained as channels, which absorb rainwater in mild climate. The channels and scattered oxbow lakes play an awareness role for villagers to start preparations for the flooding and inundation in monsoon seasons (Fig. 3). In the monsoon seasons, boats are the main means of transportation outside of the dykes as roads are inaccessible by automobiles and bikes.

The Village Tract consists of 12 villages, of which four were selected for the case study: two were nominated from villages divided by the dyke's construction (village A is located on the unprotected side and B on the other side). Two more villages were added from both sides of the dyke (village C is representative of the unprotected area, while village D lies in the protected area). The demography and location of the research area are shown in Table 2.

Table 1
Impact of floods and landslides in 2015 in Myanmar.

	People displaced by floods	Totally damaged houses	Flood-affected houses	Destroyed farmland (acres)	Impacted population (%)
Rakhine	109,707	14,130	128,407	217,246	35.25
Chin	17,924	2951	3978	7867	25.14
Sagaing	473,365	1982	87,976	121,409	11.32
Ayeyarwady	498,759	1251	109,416	209,971	10.05
Magway	303,694	414	64,560	65,858	8.01

(Derived from Government of Republic of the Union of Myanmar, 2016).

3. Methodology

To identify the community recovery in the four villages, exploratory survey was applied for selection of questions initially, and then semi-structured interviews were conducted at the household level. A total of 80 household surveys were administered in four villages. Each survey took 30–45 min for the interview, with translation from Myanmar language to English and vice versa. A follow-up survey by the non-structured interview also applied to identify village committee structures (Table 3). In addition, historical records (*Report on settlement operations in the Bassein and Henzada Districts*, and *Burma Gazetteer, Henzada District Volumes A & B*) by the British colonial governments were utilized for analysis. The research was approved and supported by Government Administrative Department and Relief and Resettlement Department in Hinthada District. The semi-structured interviews include basic information (average income, years living in the village, and disaster damage history); information on housing (house type, floor height, years living in the house, preparedness against flood), and on livelihoods (occupation, seasonal jobs, and size of the farmland owned).

4. Results and analysis

Appendix A shows the overview of the results. The table separately indicates the position of unprotected villages located outside of the dyke (A and C) and that of the protected villages inside of the dyke (B and D). Basic demographic information indicates that all respondents were Burmese and Buddhist; the average age of the household head was 50.2 years; and there were 4.8 persons in each household. Most of the respondents (97.5%) were born in the village. As expected, the house type (timber and bamboo houses) was related to the disaster impact; therefore, the results were divided into timber and bamboo houses for each village. The details of disaster impact, housing, livelihood, and community activities are explained in the following.

[2] The Government of the Republic of the Union of Myanmar, [5], sets the exchange rate. USD 1: Myanmar Kyat 1.287.40.

[3] Morrison, [11], pp. 10–11.

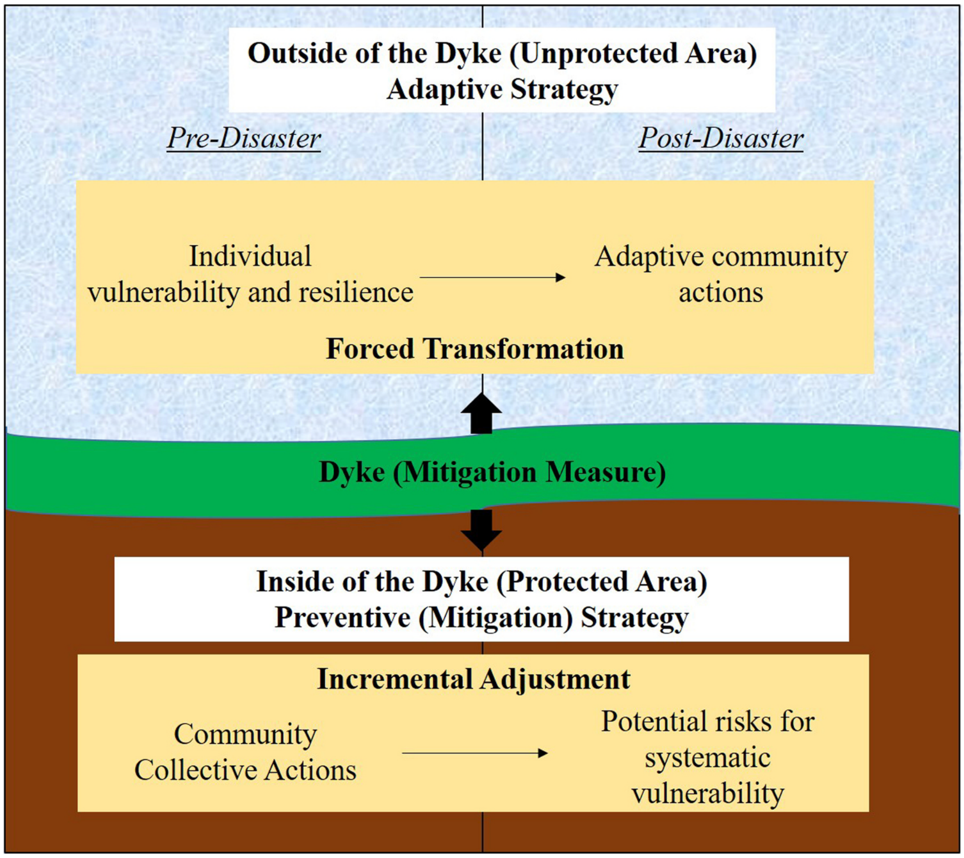

Fig. 2. Schematic outlines of the case study.

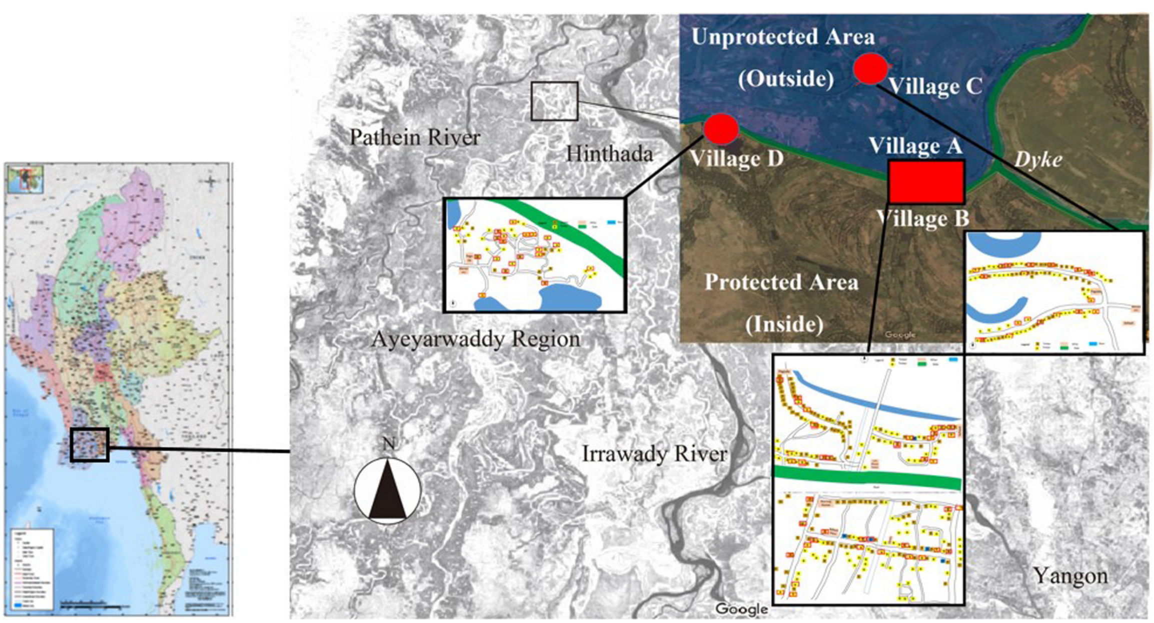

Fig. 3. Map of the research field in Leik Chaung Village Tract, Hinthada Township.[4]

4.1. Disaster impact

Among the four villages, casualties and missing persons were not reported. Most of the houses were affected by the approximately 2.2 m height of the inundation water above floor level both in timber and bamboo houses in villages A and C. There was no collapse of timber houses, although several bamboo houses were destroyed. Households that owned totally destroyed houses could receive 50,000 Kyat (equivalent to US$ 38.83) and 20,000 (equivalent to US$ 15.54) for partially damaged houses from the national government. International agencies and the Relief and Resettlement Department distributed relief

[4] National Map derived from Myanmar Information Management Unit. "T" indicates a house made by timber and "B" indicates bamboo. Red indications are respondents to the survey.

Table 2
Demography of the research area.

Village	# of Households	Population	Location
A: Leik Chaung East	146	575	Outside: Unprotected
B: Leik Chaung West	126	572	Inside: Protected
C: Na Be Kone	98	415	Outside: Unprotected
D: Daw Na Kone	57	296	Inside: Protected

Table 3
Research schedule and methods.

Schedule	Methodology	Remarks
Dec 19–21, 2016	Exploratory Survey	Pre-survey for the selection of questions
June 13–17, 2017 Oct 28–Nov 6, 2017	Semi-structured Interview	20 Households in four villages = 80 households
July 4–8, 2018	Non-structured Interview	Follow-up Survey

Fig. 4. Marks on the foot pillar for floor elevation since before 2015.

Fig. 5. Basement foundation elevation.

items, such as water and food. The school in village C was closed for almost one month because of the floods, and the inundation water prevented two months of farming.

On the other hand, villages B and D neither impacted casualties nor damaged houses because of the dyke, but inundation water reached to less than a foot from the top of the dyke. As a result, villagers had to monitor constantly not to break the dyke since the dyke security system required villagers' volunteer involvement due to the lack of manpower. Nevertheless, in these efforts, relief items were not distributed to villages B and D because they were not directly affected.

Fig. 6. Floor adjustment in a bamboo house.

4.2. *Housing*

Most of the respondents in villages A, B, and C have lived in these villages for more than three generations,[5] which indicates that they are succeeding in saving their ancestral assets rather than choosing nomadic settlement. However, houses have been periodically rebuilt every 4.9–15.8 years due to structural changes in the family or the decay of wooden structures. The periodic cycle of rebuilding is shorter for the bamboo houses, and especially for those unprotected side (Appendix A). The Timber houses also show the same short life when on the unprotected side. This implies that rebuilding houses is not a rare event in the villages.

Not surprisingly, the average floor height in villages A and C is 1.92 times higher than protected villages (B and D) to cope with inundation in monsoon seasons. Specifically, most of the floor height of timber houses is elevated higher than that of bamboo houses, except in village B. After the 2015 flood, several houses were elevated one or two feet more. The foot pillars or basement foundations are elevated by the simple method (Figs. 4 and 5). As the construction work was able to repair the houses without destroying them, elevation of the houses is a reasonable approach for timber houses.

In contrast, floor-height elevation has limitations of durability for bamboo houses on the unprotected side. According to a respondent living in village A, the house shakes because of the vibration from the motorboats used for transportation during the monsoon season. Therefore, they cannot elevate higher floor due to the shakiness of the bamboo pillars. In order to respond to the situation, villagers utilize a temporarily elevated second floor made of bamboo and reed floor sheets (Fig. 6). Bamboo house owners prepare a short corbel-receiving floor for the elevation in the house. Family members stay on the temporary second floor for two months. Since those days, they have prepared the material before the monsoon, but changing to timber houses is a better recovery strategy in this context of adaptation.

On the other hand, the floor height in villages B and D (inside of the dyke) remains at a lower elevation because they experienced no direct impact from the flood. Even though village D experienced severe damage from the flood 20 years before, floor height has not been upgraded. Actually, the floor height of the timber and bamboo houses is almost the same in village B (Appendix. A). It is unclear that floor height was higher in the past and gradually became lower over time, but floor height has not changed in at least half a century. The floor height of two houses built about 50 years ago in village B was approximately 1 m (Appendix. B).

As a summary of housing, the results imply that the houses on

[5] Village D is observed to be different only because previous generations migrated into the village just after national independence in 1948.

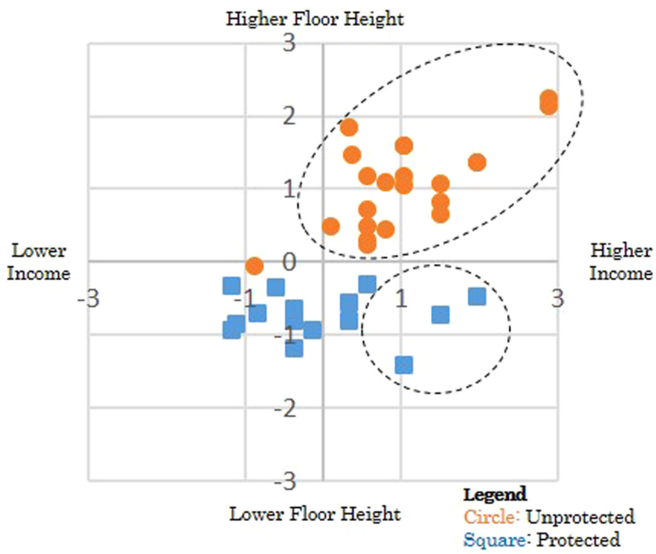

Fig. 7. Correlation of timber housing floor height and income.

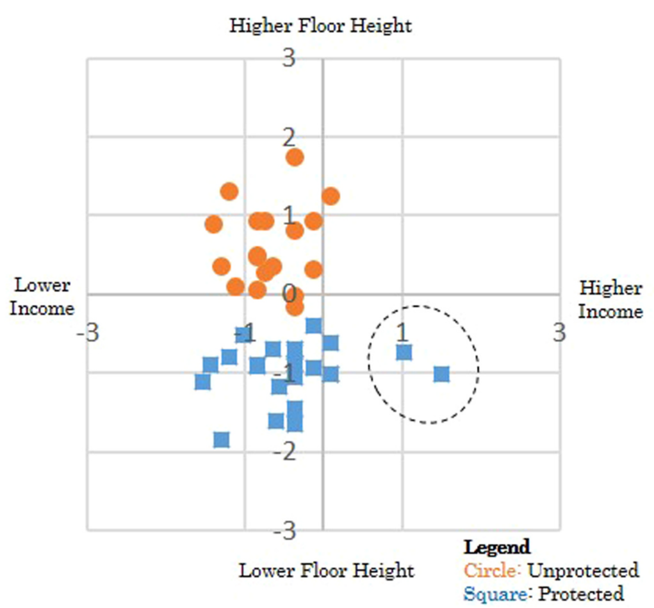

Fig. 8. Correlation of bamboo housing floor height and income.

protected side remain lower floor height because of the non-direct impacts, whereas the houses on the unprotected side are gradually adjusting their floor levels higher against annual floods. Since there is no other option so far, such as infrastructural measures against flooding in unprotected villages, continuous adaptation is the approach taken rather than being forced to migrate or accepting buy-out policies in a transformed socio-ecological environment.

4.3. Livelihood

4.3.1. Source of income

The average monthly income indicates a strong incentive for villagers to stay in a flood-prone area. Interestingly, the average incomes on the unprotected side are higher than the protected incomes for those in timber houses. This is attributed to owning wider sections of farmland in unprotected areas especially for households living in the timber houses. In fact, the average monthly income of households living in bamboo houses on the unprotected side are approximately 2.56 times fewer than households in the timber houses, and the apparent gap is observed in the size of the owned farmland too (Appendix. A). On the other hand, the average income on the protected side does not show a greater disparity between timber and bamboo households because differences in farmland size are relatively smaller than those on the unprotected side.

The crops being planted inside and outside of the dyke also indicate differential strategies being adopted in a transformed environment. A water-resistant plant, which benefits from the fertile soil brought by the floods, is a major contributor to livelihoods in flood-prone areas. Reed (*Thinn* as a Myanmar name) is one of the major sources of income in villages A and C because dried reed is used for the material for locally woven sheets and mats. The merit of weaving those items is that mat making can be done without gender or age distinctions regardless of the season. In fact, all males and females above 10 years old can weave mats in village C, according to the villagers. Daily workers can purchase or rent dried reeds from farmland owners as raw material, and they can sell it or repay the debt from the output. Beans are another source of income for farmland owners on the unprotected side. The beans are planted in the dry season after the monsoon; therefore, farmland owners have at least two source of income. This is the reason villagers have remained in a flood-prone area over the generations.

Reeds and beans are not planted on the protected side. The major crops are paddy rice and betel vines from betel palm. Betel vines are able to be harvested on small-scale land and, as a result, non-farmland owners can also cultivate within the household's land boundary. Furthermore, other professions, such as teaching, fishing, running a barbershop, carpenter, and working in government offices, are observed in the protected area while these occupations are rarely found on the unprotected side. This implies that limited farmland inside of the dyke attracts people into non-primary occupations to ensure a varied source of income rather than owning big farmlands. It is why the average income on protected side shows a relatively smaller gap between timber and bamboo households.

4.3.2. Historical analysis on livelihood

Have the sources of income changed over 150 years in the villages? It is needed to understand adaptive strategy for people living in forced transformative natural environment. Zoning management of the British colonial government aimed at obtaining stable taxes from the construction of the dykes. The government divided Hinthada district into 15 groups based on soil fertility in 1886 and this was revised into nine groups in 1901 because of updated assessments [6,7]. Each tract had different tax rates imposed on paddy and other crops according to the quality of soil, transportation cost by creeks, and the villages' living costs [6].

The protected side is designated group VI which indicates "very fertile land, but partly exposed to flooding," while the unprotected side, group VIII, is "the low-lying flooded track…which lies outside of the embankment".[6] Imposed tax rates on the output of paddies for group VI were classified as 3.25 (*soil class I*) and 2.50 (*soil class II*), whereas the rates in VIII were 1.25 and 1.00. This clearly indicates that paddies were planted on the unprotected side even though the quality of soil was relatively low for paddy. According to elderly living in unprotected side, paddy field had cultivated about 30 year ago, but they were changed into beans as increasing of frequency and severity of floods.

The report also indicated tax rates on the revenue from garden yields and miscellaneous others, which include betel vine. The yield of betel vine was indicated in Tract VI (protected side), which implies that betel vine has been cultivated inside of the dykes the same as at present. With regard to weaving mat, the report also showed that 4250 persons worked for reed mat makers in several township especially flood-prone area.[7] The mat making was considered a "subsidiary industry for large

[6] India Office Record [7], p. 37 and p. 47.
[7] India Office Record [6], p. 3.

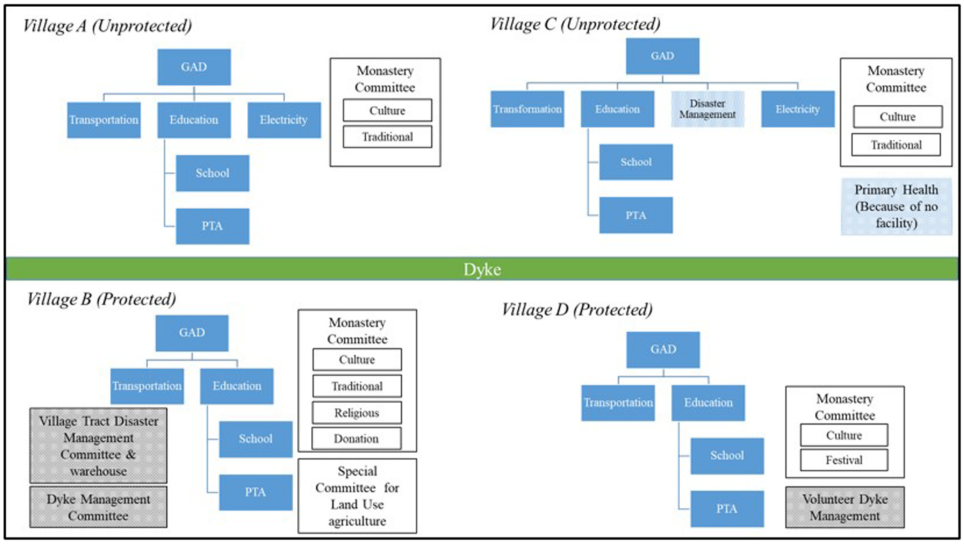

Fig. 9. Comparison of the Village Committees.

Table 4
Comparative strategies on protected and unprotected side.

Location	Agent		Structure	
	Phase			
	Pre-disaster	*Post-disaster*	*Pre-disaster*	*Post-disaster*
Protected (Inside)	No investment	At risks	Dyke management committee	
			Relying on mitigation	No proactive strategy
Unprotected (Outside)	Individual investment	Lower impact by adaptation	Practical custom of mutual help	

numbers of women of the labouring class all over the district",[8] which clearly illustrates that mat making has been traditional work on the unprotected area.

Overall, the major crops in protected and unprotected areas have not radically changed over 150 years, but paddies in flooded areas have now disappeared, and been replaced with beans due to the high frequency of the floods. The wasteland reclamation benefited the protected side, whereas people in unprotected side also obtains the benefits from flooding as low materials for reeds and wider farmlands.

4.4. Correlation of the floor height and income

In the analysis, the correlation between floor height and income between timber and bamboo houses was examined to identify the different strategies used. Figs. 7 and 8 show the correlation between floor height and income in timber and bamboo houses in four villages. Red circles indicate the unprotected villages (A and C), and blue squares stand for the protected villages (B and D). Two major findings are observed in this analysis: the correlation of only timber houses in the unprotected area, and asymmetric results in investments in housing.

4.4.1. Correlation of timber houses in unprotected area

Predictably, timber houses in protected villages are not correlated with income ($r = -0.026$), whereas those timber houses in unprotected villages are relatively correlated ($r = 0.668$) (Fig. 7). Obviously, the floor height of the timber houses on the unprotected side are higher than the protected side. The figures clearly described that relatively higher income households in the unprotected area select timber houses rather than bamboo houses. Most of the households living in timber houses are categorized as having higher income.

Contrasting results show that no significant correlations are observed for bamboo houses in both on the protected and unprotected areas ($r = 0.094$ for unprotected and $r = 0.176$ for protected villages) (Fig. 8). The majority of households living in bamboo houses have lower than average incomes both on the unprotected and protected side. In terms of the floor height, again houses on the unprotected side are higher than the protected sides. However, there is no over two meters bamboo houses because of the limitation of the height as mentioned above.

4.4.2. Asymmetric results of investment on housing

The results also imply asymmetric tendency of the investment on their houses. As mentioned above, relatively richer households prefer timber houses on unprotected side. This strongly supports the respondents' statements that they are willing to rebuild with timber houses when they have the financial capacity to do so in order to increase resilience to the annual flooding because timber houses symbolize wealth status in the flood-prone villages in this context.

On the other hand for protected side, two households of bamboo houses on the protected side are not willing to change to timber houses even they are relatively richer. Respondents who categorized the group answered that they are comfortable living in the bamboo houses. Obviously, their income has not been invested in changing the floor height because there is less likelihood of floods occurring on the inside of the dyke. This is a normal response as they have been protected by dyes for a long time. These results show that people who live in a built environment change their investments different ways; one invests on the house particularly floor height, and the other does not.

4.5. Institutional structure on disaster recovery

Practical institutional structure on disaster recovery consist of several layers: village, village Tract, Township, District, and Region in addition to external humanitarian aid groups. At the national level, "Post-disaster needs assessment floods and landslides" (Government of the Republic of the Union of Myanmar, 2015) and "National recovery framework and plan Floods and landslides 2015" [5] were published as mentioned earlier. Since the impact of the flood and landslide was large scale in the country, the comprehensive assessment and framework focused only on regional and district level, rather than village level. Besides that, two of the target villages were omitted from the flood-

[8] Morrison, [11], p. 100.

affected list provided by Myanmar Information Management Unit because they could not reach. As a result, villages A and C unprotected area could not receive emergency distribution initially. After a few weeks from the event, the district government provided relief items and funds for reconstruction for houses in the post-disaster phase.

In this section, community collective activities, also known as village committees, are identified in order to look at the effects of institutional structure on recovery from the micro-level. Village committees are the smallest institutional structure for villagers to deal with natural hazards, and we again observed different characteristics of committees in the protected and unprotected areas.

4.5.1. Village committee

The target four villages belong to a Village Tract, which organizes 11 committees (Transportation, Education, Agriculture/Livestock, Fishery, Disaster Management, Land Use, River & Channel, Electricity, Business, Budget Management, and Culture/Religion). The Village Tract Disaster Management plays a coordination role before disasters by mainly monitoring the dyke, though there is no intervention for recovery. Each village leader joins one or more committees in the tract. At the village level, villagers design their own committees based on their requirements or needs. Fig. 9 shows the committee structures in four villages. Interestingly, each of the four villages have different types of committees because of their various natural and social environments.

4.5.2. Difference in the commonness

Although transportation and education committees (including subcommittees of Parents and Teachers Association and School) are common concerns among the four villages, following floods, the villages approach these issues in different ways. To cope with prolonged inundation, most households located on the unprotected side own boats, either with or without engines. Relatively poor households that do not own boats are supported by the neighborhood to commute to school or to the central city. On the other hand, we only observed a few boats on the protected side. Villagers on the protected side do not need boats for daily life even during monsoon seasons. However, the school in Village B is shared with village A (Unprotected side) since the villages were united before the dyke construction. Boat owners in village A help children as a means of transportation every day in monsoon season. Cooperative manner is observed on transportation between villages over the dyke.

4.5.3. Contrast approach on disaster management

Even though villagers are sharing their means of transportation over the dyke, the opposite approaches are identified with regard to the disaster management. On the protected side, village B and D operate dyke management committees, which focus on monitoring and maintaining the dyke because it is the only way to avoid disaster risks from the floods. As per warnings from the Irrigation Department in the center of Hinthada Township that are issued after monitoring the water level in the Irrawaddy River, men in the villages begin voluntary observation by working 24-h shifts in the high season. The manual monitoring system requires considerable manpower as one person is required for every 1.5 miles in the dry season and for every 0.75 mile in the monsoon season. Villagers prepare sand bags, bamboo trunks, and other raw materials for making retaining walls for dyke protection. In particular, Village B is the central hub for the dyke management geologically; therefore, *Village Tract Disaster Management Committee* and *the warehouse* for emergency relief items are located at the village (Fig. 9).

In contrast, more self-survival skills are prerequisite on the unprotected side. Village A and C have not organized the dyke management committees, as a result, villagers are not involved in dyke monitoring and security; nevertheless village A is positioned just behind the dyke. As the dyke is the cause of the prolonged inundation on the unprotected side, human resources are not required on the dyke. Particularly village C is located far from the dyke; consequently, villagers need to pay attention to their evacuation rather than the dyke management. Instead of the dyke management, the *Disaster Management Committee* has newly organized in the village because of the non-government organization (NGO) intervention in post-disaster period. The committee operates the tasks such as early warning, search and rescue, shelter management, and first aid in case of emergencies. The committee undertakes these efforts because villagers have been accustomed to such practices. In other words, villagers are used to helping each other during flooding. For example, households living in bamboo houses evacuate temporarily to neighbors' floor-elevated timber houses for days or weeks. Furthermore, village C holds the *primary health committee* by themselves since there are no facilities of health care due to the isolated situation.

Consequently, self-organizing in unfavorable conditions attributes from the survival needs in both protected and unprotected villages, but the strategies are dissimilar. The contrasting have been rendered because of the development by the dyke for 150 years.

5. Discussion

5.1. Adaptive and mitigation strategies over the dyke

These contrasting collective activities, housing, and livelihood imply that villagers are selecting their strategies based upon human survivability in the built environment. One is the adaptive strategy on the unprotected side and the other is mitigation strategy: relying on the dyke. In the agent and structure theory, villagers as agents have dealt with natural disasters by self-organized committees (structure) because of the fewer external resources. Eventually, the self-survival skills (elevation of houses and boats management) are developed empirically over the centuries in the flood prone area. In other words, the developed skills for survivability are transformed from the dyke construction.

Those two different approaches co-exist within an administrative boundary, yet there is also a silent conflict on dyke monitoring: the dyke is a critical protection measure whereas it is also the cause of the inundation. The incremental stress holds potential risks if the dyke is fractured by severe rainfall in the future.

Table 4 shows the two comparative strategies on the agent structure theory in the case study. The strategies are divided by pre- and post-disaster phases. Protected villages mainly rely on mitigation measures (the dyke) and, as a result, their collective actions focus only on dyke monitoring and maintenance, but individual houses are not an object of investment. In contrast, housing investments on mitigation measures (elevated floors) depend on individuals' capacity to finance them. Financial capacity is traceable based on the farmland size possessed by the household. Individuals on unprotected have larger farm land than protected. As a result, economic disparity is greater than on the protected side, although they help each other with evacuation in case of disasters, and with transportation among villagers. In addition, an important finding is that the agent and structure are functioning inseparably for disaster risk reduction especially on the unprotected side. The villagers are victims as well as responders with self-survival skills against natural disasters.

5.2. Potential risks in protected villages

Given unexpected extreme weather events, possible fracturing of the dykes needs to take into account preparedness on the protected side. History tells us that several small and large breaches occurred in 1871, 1875, and 1878 [11]. One elderly man also remembered that fractures in the dyke occurred in the 1950s and 1970s, and those events had impact on local houses and livelihoods. Without preparedness, lower floor housing and most of the crops are vulnerable to floods. This implies that the protection offered by dykes benefits the lifestyle of some villages, but simultaneously such area accumulates systematic vulnerabilities. In other words, the strategy of depending on dykes removes other options. Such dependence may result in lost houses and sources of income by virtue of catastrophic impacts caused by climate change. Even though reinforcement of the dyke is important, raising the height of the dyke comes at enormous costs. Therefore, protected villages are subject to incremental adjustments and exposed to systemic vulnerabilities that unintentionally decrease their ability to adapt to unpredicted situations.

6. Conclusion and the way forward

This research demonstrates that recovery strategies of villages inside and outside of the dyke have been transformed by its construction. Over the course of 150 years, modifications to the natural environment have allowed villagers to transform their housing, livelihoods, and collective community activities. Villages on the unprotected side have altered their patterns of disaster risk reduction by adapting the floor height of their houses, changing from paddy crops to beans, and maintaining mat making. On the other hand, the dyke provides the benefit of greater reclaimed land inside of the dyke, but systematic vulnerability is also increasing in housing and livelihoods owing to the limited strategic options available. Given potential climate change scenarios, understanding the historical trials and the substantive life in villages is necessary to deal with unpredictable natural phenomena in the future.

In the next step of the research, similar but another independent variable case study is required to gain “building Block” as a series of the study [4]. In contrast to Myanmar's agent and structure model, the transformability of agents in a layered structure society needs to be identified as an example of the opposite pole of the agent structure theory. In addition, the scientific validity of the dyke's fractures needs to be examined to allow risk assessment of the protected villages. Houses and crops are vulnerable to inundation water, but deterioration of farmland due to the influx of silts also entails a devastating impact. To avoid the worst scenario, risk assessment of dyke fractures is strongly required as a part of the way forward.

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Appendix A

See Table A1
See Figs. A1–A15

Table A1
The Overview of the Result.

Unprotected Side (Outside)		Village A		Village C		Typical House/Livelihood Appearance
House Type		**Timber**	**Bamboo**	**Timber**	**Bamboo**	
Disaster Impact	*Flood Damage*	No casualties or injury, but mainly bamboo houses are inundated for about two months.				Figs. A1 and A2
		Above the floor (except for two houses)	Five destroyed, and all others are above floor level	Over the floor (except for three houses)	Five destroyed, and all others are above floor level	
Housing	*Ave. Floor Height*	1748.5 mm		2130 mm		Figs. A3 and A4
		1822.7 mm	1008.6 mm	2290 mm	1935.6 mm	
	Ave. Years Living in the village	72.7% are more than three generations	66.7% are more than three generations	100% are more than three generations	77.8% are more than three generations	
	Avg. Age of Built House	11.25 Years	7.33 Years	9.0 Years	4.39 Years	
Livelihood[a]	*Avg. Income (Monthly)*	279,091 Kyat	116,111 Kyat	320,909 Kyat	118,333 Kyat	Figs. A5 and A6
	Avg. Size of Owned Farmland	3.41 AC	0.22 AC	11 AC	0 AC	
	Paddy Rice	2[b]	None	None		
	Beans	8	None	11	1	
	Betel Vine Leaves	None		None		
	Mat Weaving	4	5	11	9	
	Others	2	None	None	1	
Community Activities	*Education*	Primary/Middle school in the village is shared with village B and transportation is provided by villagers' boats.		Vulnerable school was closed due to the inundation in 2015 and 2016. Villagers tried to rebuild with help from local and international donors.		Figs. A7 and A8
	Transportation	All timber house owners have boats for transportation in monsoon, and voluntary use is provided for local people, esp. for those commuting to school.				
	Disaster Risk Management	Not only elevation of the house but evacuation over the dyke is another strategy.		Adaptation strategy involves elevated housing and evacuation to the monastery.		
Protected Side (Inside)		**Village B**		**Village D**		**Typical House/Livelihood Appearance**
House Type		**Timber**	**Bamboo**	**Timber**	**Bamboo**	
Disaster impact	*Flood Damage*	None		None (Flood occurred in 1997. All houses were flooded higher than the floor).		Figs. A9 and A10
Housing	*Avg. Floor Height*	955 mm		867.5 mm		Figs. A11 and A12
		984 mm	991.1 mm	1071 mm	799.7 mm	
	Avg. Years Living in the Village	70% are more than three generations	88.9% are more than three generations	62.4 Years	44.9 Years	
	Avg. Age of the Built House	12.8 years	15.4 years	15.8 years	6.5 years	
Livelihood	*Avg. Income (Monthly)*	197,000 kyat	183,333 kyat	166,000 kyat	121,533 kyat	Figs. A13 and A14
	Avg. Size of Farmland Owned	0.6 AC	0.22 AC	1.1 AC	1.07 AC	
	Paddy Rice	None	1	2	3	
	Beans	1	1	1	1	
	Betel Vine	6	4	4	10	
	Weaving Mat	None	2	None	2	
	Others	Six (teacher, government officer, etc.)	One (barber)	None	Four (fishery, government officer, etc.)	
Community Activities	*Education*	Going to school in Village A		Children go to another village school located inside of the dyke		Fig. A15
	Transportation	Three boats in the village		Two boats in the village		
	Disaster Risk Management	Focuses on dyke monitoring by the volunteers in the monsoon season and alternates among villagers, but only inside of the dyke.		Focuses on dyke monitoring in the monsoon season by volunteers. Maintains both sides because of no village on the other side.		

[a] Number of households.
[b] Two households cultivate paddy inside of the dyke.

Fig. A1. Flood in village A.

Fig. A2. Flood in village C.

Fig. A3. Elevated timber house.

Fig. A4. Elevated bamboo house.

Fig. A5. Weaving mat.

Fig. A6. Finished product.

Fig. A7. School in Village A in monsoon.

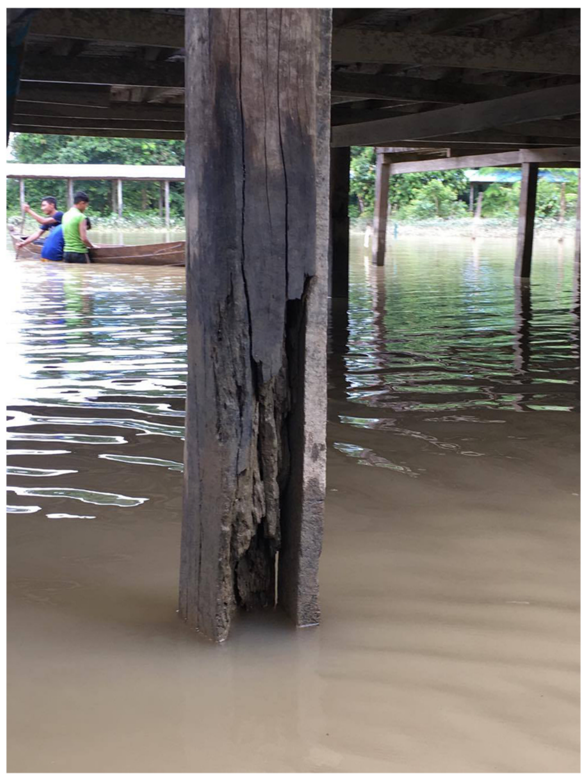

Fig. A8. School in Village C in monsoon.

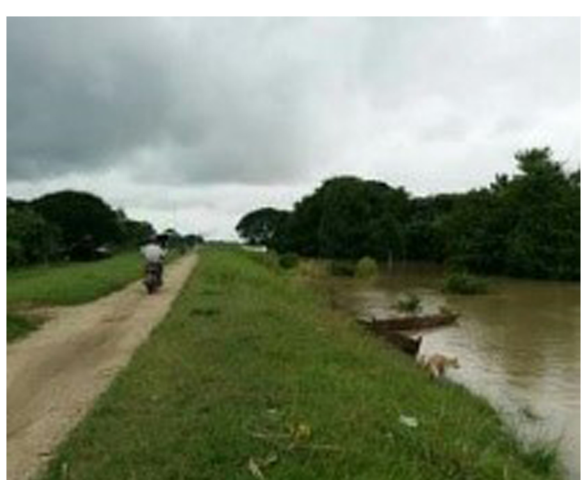

Fig. A9. Dyke near village B.

Fig. A10. Emerged lake after flood in 1997 in village D.

Fig. A11. Timber house.

Fig. A12. Bamboo house.

Fig. A13. Betel vine farm.

Fig. A14. Finished betel product.

Fig. A15. Collective transportation activities.

Appendix B

See Table B1

Table B1
The Result of the Interview.

Village Name	Control #	Age	Gender	Occupation	Size of farm Land (AC)	Seasonal Jobs	Income in a month (Ave)	Number of Household	Years stay in this village	Years of the built house	Type of House	Height	Owning or renting house
Village A: Leik Chaung East Village (Outside)	1	43	Male	Farmer	4	Paddy inside dyke, and beans outside dyke,	250,000	4	more than 100 years	2	Timber	2130	Owning
	2	64	Male	Daily labor	0	mat	40,000	5	more than 100 years	2	Bamboo	1960	Owning
	3	61	Male	Farmer	4	Beans, Mat	350,000	6	22 years	8	Timber	2065	Owning
	4	55	Male	Daily labor	0	Mat	100,000	2	more than 100 years	27	Mixing	1470	Owning
	5	53	Male	Daily labor	0	mat	95,000	5	since born	8	Timber	1410	Owning
	6	37	Male	Shop, Daily labor	0	Labor Service	100,000	4	more than 60 years	1	Bamboo	1720	Owning
	7	45	Male	Daily labor	0	Labor Service	150,000	4	more than 100 years	5	Bamboo	1430	Owning
	8	33	Male	Farmer	10	Paddy and beans	275,000	6	35 years	8	Timber	1700	Owning
	9	30	Male	Daily labor	0	Labor Service	175,000	4	more than 60 years	10	Bamboo	1980	Owning
	10	36	Male	Teacher	0	N/A	400,000	5	Over 100 years	0.5	Timber	2230	Owning
	11	29	Female	Daily labor	0	mat, agriculture	150,000	5	more than 60 years	9	Mixing	1350	Owning
	12	61	Female	Not working, but a child sending money	0	N/A	350,000	6	more than 100 years	14	Timber	1815	Owning
	13	68	Male	Generator and Farmer	2.5	Beans	250,000	2	more than 100 years	30	Timber	1580	Owning
	14	41	Male	Farmer	6	Beans	250,000	5	more than 100 years	18	Timber	1720	Owning
	15	29	Male	Daily labor	0	N/A	150,000	6	more than 100 years	2	Bamboo	1910	Owning
	16	45	Male	Daily labor	0	Mat	70,000	3	more than 100 years	8	Mixing	1500	Owning
	17	68	Male	Daily labor mechanical engineer	0	Mat	110,000	5	more than 100 years	2	Bamboo	1600	Owning
	18	42	Female	farmer	1	Beans	250,000	5	more than 100 years	2	Timber	1620	Owning
	19	77	Male	farmer	5	Beans, Mat	250,000	6	more than 100 years	20	Timber	1860	Owning
	20	56	Male	Farmer	5	Beans, Mat	350,000	5	more than 100 years	4	Timber	1920	Owning

(*continued on next page*)

Table B1 (*continued*)

Village Name	Control #	Age	Gender	Occupation	Size of farm Land (AC)	Seasonal Jobs	Income in a month (Ave)	Number of Household	Years stay in this village	Years of the built house	Type of House	Height	Owning or renting house
Village C: Na Bell Kong Village (Outside)	21	76	Male	Farmer	20	Beans, Mat	500,000	6	more than 100 years	1	Timber	2750	Owning
	22	78	Male	Farmer	10	Beans, Mat	300,000	4	more than 100 years	20	Timber	2130	Owning
	23	68	Male	Farmer	20	Beans, Mat	300,000	6	more than 100 years	25	Timber	2370	Owning
	24	75	Male	Daily labor	0	Beans, Mat	50,000	3	more than 100 years	3	Bamboo	1650	Owning
	25	26	Male	Daily labor	0	Beans, Mat	120,000	4	3 years	3	Bamboo	1650	Owning
	26	43	Male	Farmer	3	Beans, Mat, shop	225,000	5	more than 100 years	0.1	Timber	2520	Owning
	27	46	Male	Shop	0	Shop and Mat	110,000	8	17 years	3	Mixing	1980	Owning
	28	70	Male	Daily labor	0	Beans, Mat	175,000	6	more than 100 years	2	Mixing	1620	Owning
	29	62	Male	Farmer	3	Beans, Mat	200,000	5	more than 100 years	5	Timber	1720	Owning
	30	46	Male	Farmer	20	Beans, Mat	500,000	4	more than 100 years	0.1	Timber	2680	Owning
	31	51	Male	Farmer	10	Beans, Mat	300,000	3	more than 100 years	4	Timber	2370	Owning
	32	38	Male	Farmer	2	Beans, Mat, shop	200,000	7	more than 100 years	2	Mixing	2160	Owning
	33	32	Male	Farmer	5	Beans, Mat	300,000	5	more than 100 years	22	Timber	2050	Owning
	34	27	Male	Farmer	5	Beans, Mat	275,000	3	more than 100 years	10	Timber	2080	Owning
	35	35	Male	Daily labor	0	Beans, Mat	150,000	5	more than 100 years	15	Bamboo	2450	Owning
	36	42	Male	Farmer	14	Beans, Mat	400,000	7	more than 100 years	10	Timber	2230	Owning
	37	56	Male	Farmer	11	Beans, Mat	230,000	6	more than 100 years	2	Timber	2290	Owning
	38	46	Male	Daily labor	0	Labor Service, Mat, and Fish	100,000	8	more than 100 years	6	Bamboo	1980	Owning
	39	29	Male	Daily labor	0	Labor Service and Mat	100,000	4	more than 100 years	5	Mixing	1730	Owning
	40	20	Female	Daily labor	0	Mat	60,000	5	more than 100 years	0.5	Bamboo	2200	Owning

(*continued on next page*)

Table B1 (*continued*)

Village B: Leik Chaung West Village (Inside)	41	59	Male	Betel Vine	0	Betel Vine leaf, and shop	225,000	6	since born	5	Timber	970	Owning
	42	62	Male	Betel Vine	0	Betel Vine	125,000	6	since born	8	Timber	1235	Owning
	43	73	Male	Betel Vine	0	Betel Vine leaf and shop	45,000	3	since born	3	Concrete	340	Owning
	44	56	Male	Government Officer	0	N/A	100,000	3	since born	5	Timber	1030	Owning
	45	37	Male	Daily labor	0	N/A	350,000	5	3 years relocated due to dyke maintenance	3	Bamboo	850	Owning
	46	46	Male	Farmer	2	Paddy and Beans	300,000	5	more than 100 years	18	Mixing	1010	Owning
	47	74	Male	Farmer	3	Beans	250,000	3	more than 100 years	32	Timber	1255	Owning
	48	56	Female	Not working, but a child sending money	0	selling banana, coconuts	80,000	2	more than 100 years	4	Bamboo	1140	Owning
	49	72	Male	Not working, but a child sending money	0	1200 Betel Vine	70,000	2	more than 100 years	6	Timber	950	Owning
	50	66	Male	Betel Vine & Daily labor	0	mat, 3000 Betel Vine	200,000	10	more than 100 years	2	Bamboo	1080	Owning
	51	35	Female	Farmer and teacher	3	2000 Betel Vine	350,000	6	more than 100 years	50	Timber	1020	Owning
	52	53	Male	Meat	0	3000 Betel Vine	300,000	4	more than 100 years	2	Timber	620	Owning
	53	46	Male	Carpenter	0	N/A	225,000	7	more than 100 years	3	Timber	1120	Owning
	54	40	Female	Daily labor	0	Labor Service	120,000	6	more than 80 years	0.5	Bamboo	1030	Owning
	55	59	Male	Daily labor & livestock	0	farming	150,000	3	more than 100 years	6	Bamboo	1010	Owning
	56	61	Male	Barber	0	N/A	100,000	7	more than 100 years	55	Bamboo	920	Owning
	57	62	Male	Betel Vine & Daily labor	0	Betel Vine 6000	150,000	4	more than 100 years	20	Bamboo	1030	Owning
	58	63	Male	Daily labor	0	mat	200,000	7	more than 100 years	30	Bamboo	850	Owning
	59	42	Male	Palm Tree labor	0	N/A	150,000	5	more than 80 years	6	Timber	750	Owning
	60	39	Male	Teacher	0	Betel Vine, mat	175,000	5	more than 80 years	11	Timber	890	Owning
Village D: Da Na Kone Village (Inside)	61	63	Female	Farmer	3	Paddy and beans, construction labor, and 2000 Betel Vine.	65,000	4	63	35	Timber	1250	Owning
	62	45	Male	Farmer	4	Summer Paddy 4, and Betel Vine 1500 plants	150,000	8	45	5	Bamboo	920	Owning
	63	52	Male	Daily labor	0	Vender (Vegetable and Betel Vine)	35,000	6	52	2	Bamboo	920	Owning
	64	64	Male	Irrigation Dept. Staff	0	4 month for irrigation Dept. job, mat.	100,000	6	64	4	Bamboo	900	Owning
	65	29	Male	Livestock management	0	10 cows, and chicken	150,000	5	29	10	Mixing	480	Owning
	66	47	Male	Betel Vine	0	Betel Vine 1000. Before had farm land 3 acre, but lost in 1997	50,000	6	47	2	Bamboo	360	Owning
	67	34	Male	Betel Vine, and Daily labor	0	Betel Vine 1500 plants and masonry	65,000	4	68	2	Timber	900	Owning
	68	68	Female	Betel Vine, and Daily labor and livestock	0	Livestock and Betel Vine 1000 plants	60,000	6	49	12	Bamboo	980	Owning
	69	49	Male	Betel Vine, and Daily labor	0	Betel Vine 2000 plants	150,000	3	32	3	Mixing	820	Owning
	70	32	Female	Betel Vine, and Daily labor	0	Betel Vine 2000 plants, and Mat	25,000	2	32	2	Bamboo	790	Borrow from parents
	71	52	Female	Farmer	4	Betel Vine 2000, and beans	150,000	4	33	25	Bamboo	1030	Owning
	72	61	Male	Farmer	1	Better 2000 and vegetables, livestock	150,000	5	71	24	Timber	1070	Owning
	73	56	Male	Betel Vine	0	Betel Vine 1500	150,000	2	60	15	Timber	975	Owning
	74	40	Male	Farmer	5	paddy and Betel Vine	175,000	4	60	14	Bamboo	890	Owning
	75	61	Female	Daily labor	0	Children working in Yangon, and irrigation Dt.	200,000	5	40	6	Bamboo	850	Owning
	76	68	Female	Land Owner	3	Betel Vine 1000, paddy land	175,000	2	50	2	Mixing	1205	Owning
	77	42	Male	Irrigation Dept. Staff	0	N/A	128,000	8	20	4	Bamboo	760	Owning
	78	37	Female	Betel Vine & Daily labor	0	Betel Vine 2000	125,000	4	52	4	Bamboo	500	Owning
	79	27	Male	Farmer	1.5	Paddy	400,000	3	50	3	Timber	1160	Owning
	80	46	Female	Fisherman	0	N/A	150,000	2	68	2	Bamboo	590	Owning

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