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ASIAN JOURNAL OF
SOCIAL SCIENCE 43 (2015) 713–737

Asian Journal
of Social Science
brill.com/ajss

The Complexities of Water Disaster Adaptation

Evidence from Quang Binh Province, Vietnam

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Abstract

The article argues for an interdisciplinary approach to studying the complex circumstances that turn natural hazards into disasters. It takes on the ambitious task of combining a social sciences-inspired vulnerability and adaptation analysis with a natural science-based hydrological modelling analysis, and using both to investigate climate-related water disasters in two communities in the Quang Binh Province, central Vietnam. The article shows how societal capacity, notably the adaptive capacities of individual households and local and provincial institutions pertaining to the two communities, can mitigate the natural hazards. Despite differences in exposure and vulnerability, both communities have been forced to seek alternative income-generating activities. This has enhanced their socio-economic resilience but at the same time increased socio-economic differentiation and the vulnerability of certain population segments. The article finds that the government's main mitigation policies (resistant crops and improved infrastructure) are regressive in the sense that higher asset households tend to benefit more.

Keywords

natural hazards – climate related disasters – adaptation – vulnerability – Vietnam

 | DOI: 10.1163/15685314-04306004

Introduction

Quang Binh Province is, like other provinces in central Vietnam, highly prone to water hazards and other climate-related risks. This is due to its location in the tropical typhoon belt and its geographical features, notably the River Nhat Le that runs from the high mountain range forming the border with Laos PDR down rather steep mountain slopes to the flat coastal zone bordering Vietnam's Eastern Sea. This article explores the conditions under which water hazards turn into disasters, finding that this largely depends on human-induced environmental changes and management, as well as societal capacity for mitigation and adaptation. The relationships between climate-related hazards (such as typhoons, flooding, rising sea levels, changing seasonality, droughts, etc.), human-induced environmental changes (such as deforestation, dyke construction, river embankments, water reservoirs, etc.), and societal mitigation and adaptation capacity, are highly complex. This goes for the household, village, district and province levels, as well as all the way up to the national and global levels.

The article focuses on the complex causes of disasters in two communities in Quang Binh Province in North-Central Vietnam. The analysis combines a natural science approach aimed at forecasting natural hazards using hydrologic modelling of water hazards, with a social science approach consisting of a socio-economic household survey complemented by in-depth semi-structured interviews with key respondents and group interviews, as well as participatory rural appraisals carried out according to the methodological guidelines outlined in Mikkelsen's (2005) monograph *Methods for Development Work and Research*. The social science analytical framework integrates two scholarly contributions: a highly formalised disaster analysis approach designed by Wisner (2012), and a three-pronged disaster footprint model by Oven and Rigg (2015).

The article is structured as follows. The two communes will be briefly introduced, together with the methods for data collection. This will be followed by a theoretical section that situates the article within the social science and hydraulics literature on flooding disasters, with a specific focus on Vietnam. We then present the theoretical framework, which combines social science with hydrological modelling and critically integrates two social science vulnerability approaches: Wisner et al.'s (2012) analytical formalisation of disaster risk and Oven and Rigg's (2015) concepts of Hazard Footprint, Vulnerability Footprint and Livelihoods Footprint. The analytical section that follows is structured according to this framework. First, the Livelihood Footprint is investigated, followed by the Hazard Footprint and finally the Vulnerability Footprint is studied in connection with government mitigation policies, as well as individual coping strategies. The article ends with a discussion and conclusion.

Data Collection in the Two Selected Communities

Both communities are located in Vo Ninh Commune only a few kilometres apart from one another, and both are highly vulnerable to water-related hazards. However, they display slightly different vulnerability dynamics, and hence are likely to require different adaptation strategies. The community of Truc Ly is located right on the river bank of the Nhat Le River and is very prone to flooding, while Ha Thiep is located at a slightly higher elevation close to the sand dunes and consequently has very sandy soils. A total of 24 households were selected for in-depth interviews in the two communities to enable inquiry into various types of adaptation measure including: (i) improvement of homesteads (rescue rooms for people and animals, elevated homesteads and walls); (ii) changes in farming calendars and crop species, husbandry; (iii) changes in economic activities in the local area (from agriculture to aquaculture, handicrafts, casual labour); (iv) investing in sending family members abroad for work and relying on their remittances. Some households lacked the capacity to develop an explicit adaptation strategy. The article also draws on a large socio-economic household survey conducted in May 2013 (as part of the DANIDA funded project 11-P04-VIE), which also covered Vo Ninh Commune. This survey addressed a wide range of socio-economic issues, such as living conditions, productive activities, coping strategies, indigenous knowledge and migration patterns. In the two communities, 134 households were randomly selected for interviewing, which amounts to a quite substantial penetration rate considering the total population size of 276 households (150 in Truc Ly and 126 in Ha Thiep).

Literature Review of Flood Disasters, with a Focus on Vietnam

Floods are a common natural disaster that pose an ever-present danger to riparian communities, as witnessed in the recent flood events in Hue in 1999, Bangkok in 2011 and Jakarta in 2013 (Mukolwe et al., 2014). In order to ensure a better response and the safe habitation of floodplains, there is a need to reduce vulnerability to floods and gain a better knowledge of the spatial distribution of flood hazards (Loucks et al., 2005). One-dimensional (1D) hydraulic modelling is commonly used in applications for large river networks where flood water is confined between the banks, and it provides information about the discharge, average velocity at each cross-section, and water level/depth in the river. But in the downstream regions where the ground surface is usually low and flat, such as in coastal areas of central Vietnam, flood water tends to overflow river levees and banks, spreading onto the nearby floodplains. This calls for 2D modelling approaches as 1D models cannot simulate the spatial distribution of velocity and flooding depth over floodplains (Beffa and Connel, 2001; Khai, 2005, 2007; Nandalal, 2009; Pramanik; Panda et al., 2009; Long et al., 2010; Morankar, 2012; Rahman et al., 2011; Timbadiya et al., 2014). The selection of hydraulic models for each application is typically based on a trade-off among different factors, namely: physical realism, computational efficiency, the availability and quality of input data, as well as the objectives of the specific study (Mukolwe et al., 2014). 2D hydraulic models are able to reproduce the velocity and inundation depth at every location in the study area, but they require detailed surface elevation data and consume a large computational capacity especially for the long periods of flooding. However, overland flows onto the flood plain only occur on days when the water level rises above a certain level. On other days, 1D modelling suffices. Thus, to reduce computational costs, 1D and 2D models can be dynamically coupled. One example is the Mike FLOOD modelling package (Danish Hydraulic Institute), which is an effective tool for analysing downstream river regions, such as those in central Vietnam (Vanderkimpen et al., 2009; Kha et al., 2013; Duc et al., 2014; Anh, 2011).

Descriptions and analyses of natural hazards, such as floods, mainly fall into the category of what has been termed *outcome vulnerability* (O'Brien et al., 2007). This is considered a linear result of projected impacts of climate change on a particular exposure unit (which can be either biophysical or social), offset by adaptation measures (O'Brien op. cit. p. 75). This is in contrast to *contextual vulnerability*, which is premised on a processual and multidimensional view of climate-society interactions. Both climate variability and change are considered to occur in the context of political, institutional, economic and social structures and changes, which interact dynamically with the contextual conditions associated with a particular "exposure unit" (op. cit. p. 76). O'Brien et al. emphasise that these two depictions of vulnerability are not simply different interpretations of the same word, but fundamentally different framings of the climate change problem. The *outcome vulnerability* frame regards climate change as a problem of human impacts on the global climate system, the negative outcomes of which can be quantified, measured and reduced through technical and sectoral adaptation measures, as well as by reducing greenhouse gas emissions. The *contextual vulnerability* frame, conversely, views climate change as a transformative process that affects humans in different ways. In this view, nature-society relationships are conceptualised in terms of mutuality, rather than duality, which enables a far broader conceptualisation of climate change which emphasises its connection to multiple change processes (ibid.: 76).

Several scholars have argued that the Vietnamese government understands climate change as a bio- and geophysical problem that can be grasped by conducting increasingly complex scenario analyses, and which can subsequently by addressed by implementing technical solutions, such as dykes, higher bridges, water reservoirs, resilient infrastructure, and so on (Rubin, 2014; Bruun, 2013; Fortier, 2010).

Rich, developed countries like the Netherlands have, for centuries, developed highly sophisticated technical solutions to address the problem that much of the country is below sea level. Because the Netherlands has the capacity to implement and rely on sophisticated technologies, an outcome vulnerability approach is sufficient to ensure that people and their assets are well protected through new technical solutions that address increasing climate variability and extremes and rising seawater levels. This is not the case in a developing country like Vietnam. The already extreme weather and climate variability in Vietnam, especially along the coastline—a situation predicted to worsen in the future—requires that people become empowered to adapt to these hazards as they occur. This calls for a contextual vulnerability analysis, which will be described below.

The Theoretical Framework

In order to shed light on the real-life complexities of water disasters in the two communities, the article relies on an integrated framework inspired by two useful contributions: (i) the analytical formalisation of disaster risk outlined in Wisner et al.'s extensive (2012) anthology, the *Routledge Handbook of Hazards and Disaster Risk Reduction*; and (ii) Oven and Rigg's (2015) concepts of Hazard Footprint, Vulnerability Footprint and Livelihoods Footprint, presented in this special issue. The integrated framework will be structured according to Oven and Rigg's (2015) three footprint types but will also include the variables borrowed from the analytical formalisation of disaster risk presented in Wisner et al.'s (2012) model. The argument is that such an integrated framework is better able to capture both the underlying socio-economic currents, as well as the synergetic effects between Wisner et al.'s variables. This will be expounded in the following section.

In Chapter 3 of the anthology, "Framing Disaster—Theories and Stories Seeking to Understand Hazards, Vulnerability and Risk" (Wisner et al., 2012), the relationship between disaster risk, vulnerability and various adaptation measures, both at the individual and state level, is expressed as a formula. Having defined disasters as a "situation involving a natural hazard which has consequences in terms of damage, livelihoods/economic disruption and/or casualties that are too great for the affected area and people to deal with properly on their own," the authors move on to identify the likely determinants of disaster risk (Wisner et al., 2012: 30). According to their framework, the risk of disasters is determined by the vulnerability of the individual household and community, expressed as a simple equation where disaster risk (DR) is a function of the severity of a hazard (H) and the vulnerability of a given household in a specific location (V). We draw on this expression of disaster risk in this article, which first sets out to gauge the risk of water-related hazards in the two communities (hydrological modelling) and then addresses the vulnerability dimension. Wisner et al. (2012), however, further disaggregate the vulnerability (V) variable. Vulnerability is mitigated by the capacity to cope with, and adapt to, hazards. The authors provide examples of two such adaptation dynamics: the capacity of households to endure and adapt, which is expressed by the variable (C); and the larger-scale risk mitigation, preventive action and social protection offered by the state, which is expressed by the variable (M). This further qualification is expressed by an equation where the vulnerability of a given household (V) is divided by its socio-economic capacity to cope with, and adapt to, the hazards (C). From this is subtracted the capacity of the authorities at the various levels to mitigate the hazards (M). In purely mathematical terms, this can be expressed thus: $DR = H \times \{(V/C) - M\}$ (Wisner et al., 2012: 24).

It is important to emphasise that the authors do not consider this to be a mathematical equation as such. Rather, they are careful to stress that it is a mnemonic device. As such, the framework emphasises a close relationship between the natural environment (H) and the economic, social and political systems ranging from the local, to the national and international ((V), (C) and (M)) levels. However, vulnerability (V) has both a natural dimension in the form of unsafe locations and lack of productive land and natural resources; and a societal dimension that pertains to fragile livelihoods (Wisner et al., 2012). The capacity of individual households to adapt to climate-related hazards depends very much on their socio-economic status. Richer households can afford to construct strong, multi-storey houses that can save lives and protect vital assets. Poorer households have to rely on their commune or district to rescue them during flooding or other extreme weather conditions. If the various administrative levels are sufficiently robust in socio-economic terms and have put in place relevant disaster prevention policies, they can manipulate and manage the environment to minimise the risk of climate-related hazards turning into disasters (Baez et al., 2013; Adger et al., 2001; Beckman, 2006). This interrelationship is clearly expressed in the above-mentioned equation. The economic and social status of individual households and communities (C), combined with the political power of the administrative entities (M), influences the differential impact of natural hazards and the social processes that maintain the status quo (Wisner et al., 2012: 21). A high capacity for personal protection (such as strong multi-storey houses) in the household (C), coupled with good preventive actions and social protection on the part of the government (M), minimise the risk that a natural hazard will turn into a disaster. Of course, the complexities of adaptation call for some qualifications with regard to the above equation—its parsimonious qualities notwithstanding.

One qualification relates to the Janus-faced character of the natural environment. On the one hand, the natural environment offers *opportunities*, i.e., locations and resources for human activities in the form of agricultural land, water, minerals, energy sources, sites for construction, places to live and work, and means of communication and mobility. On the other hand, it presents *hazards* in the form of climatological, geomorphological, geological and biological conditions affecting human activities. These opportunities and hazards are unequally distributed in different regions. It is social processes that determine unequal access to livelihoods and locations, uneven exposure to hazards, and inequitable access to means of protection. Wisner et al. (2012) are fully aware that these inequalities are refracted through a multi-layered social system of class, gender, ethnicity, religious affiliation, age group, physical and mental health status, immigration status and so on. And the social system is, in turn, shaped by power relations and governance structures, ranging from the international, national and sub-national to the local level (Wisner et al., 2012: 21). This brings us to the core argument of this article: That there is a need to expand the analytical framework to more explicitly capture the socio-economic systems in which the variables (V), (C) and (M) play out. In other words, there is a need to contextualise the equation into an overarching socio-economic frame.

Another qualification relates to the interaction among these variables. Even if the socio-economic capacity to mitigate climate-related hazards is present both at the household/community level (C) and at the various administrative levels (M), the right policies and organisational structures must be in place to facilitate adaptation at the various levels, and to ensure that general socio-economic progress is used to enhance resilience. Understanding vulnerability includes assessing physical exposure (e.g., altitude in relation to changing water levels in the rivers), as well as socio-economic characteristics (e.g., the height of the homesteads; the quality of the houses; and whether there is access to a safe, elevated area where people, the harvest and domestic animals can take refuge during flooding). As we shall see in the analysis, socio-economic development does not automatically translate into increased resilience. Resilience is here understood along the lines of Adger (2000: 347) as "… the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change." Such resilience depends not only on the size and nature of (C) and (M), but also on their dynamics and interrelationships. In other words, the variables (C) and (M) are introduced additively (or subtractively) in Wisner et al.'s (2012) equation. This article will argue, however, that the variables are interrelated and that synergetic effects (or the opposite) are therefore to be expected. As we shall see, wealthy farmers with more farmland and elevated storage facilities (C) benefit more from government policies that seek to develop agricultural crops or practices that are more resilient to climate-related disasters (M). In contrast, poorer households with high physical exposure to flooding hazards (C) might be trapped in a vicious cycle of ecological vulnerability by government policies (M) that provide limited relief after floods (emergency packs of rice and noodles) but that do not provide the means to fundamentally mitigate their vulnerability (V). While we do appreciate the parsimonious qualities of Wisner et al.'s (2012) equation, and while we acknowledge that the equation is intended as a mnemonic device, the need to construct an expanded framework capable of capturing the mutual interdependence between the variables (C) and (M) appears pertinent.

These two qualifications bring us to Oven and Riggs' (2015) conceptual tripartition of disaster risks introduced elsewhere in this issue. In their article, Oven and Riggs (2015) present, in passing, three different footprints that influence the risk and impact of disasters: (i) a Hazard Footprint, (ii) a Vulnerability Footprint, and (iii) a Livelihood Footprint.

The Hazard Footprint has much in common with Wisner et al.'s (2012) variable (H) that provides a proxy for the severity of the hazard. Both concepts relate to a demarcated physical locality and measure exposure to a given disaster, in this case, floods. The Hazard Footprint is thus addressed in this article using hydrological modelling of the flooding risks for the two communities.

The Vulnerability Footprint is not necessarily tied to the same physical location as the Hazard Footprint. It expresses the different channels through which a hazard can turn into various forms of vulnerability. Inspired by Wisner et al. (2012), we will focus on two such channels: household coping strategies represented by the variable (C); and government disaster mitigation policies expressed by the variable (M). The analysis will pay due attention to the interaction between the two factors, as well as the structural factors that shape these two variables.

The Livelihood Footprint could be seen as an attempt to situate Wisner et al.'s (2012) equation in a broader setting. In what kind of socio-economic contexts do households adapt to water related hazards (C) and state policies attempt to mitigate their adverse impacts (M)? Concretely, the article will provide a brief overview of the economic profile and livelihoods in the two communities in Vo Ninh Commune, through analysis of the three footprints.

The analysis will be structured as follows: (i) the Livelihood Footprint will describe the overarching context in which water hazards and vulnerability in the two communities is analysed; (ii) the Hazard Footprint will be used to provide an assessment of the physical vulnerability of the commune as a whole, as well as the two communities, based on hydrological modelling; (iii) the Vulnerability Footprint will provide the frame for analysing both household and community adaptation and disaster policies that seek to mitigate the impact of water hazards, as well as the interaction between these. This key analytical section will look at "vulnerability" both in terms of government mitigation policies (M) and household coping strategies (C).

The Livelihood Footprint

During the past 25 years, Vietnam has experienced a rapid transition from almost complete dependence on the direct exploitation of natural resources in fisheries, forestry and agriculture, to rapid industrial growth and expansion of the service sector. The outcome of this transition has been high economic growth that has enhanced social resilience in the face of extreme climate conditions, but has also exacerbated social differentiation. This has, at the same time, made the country more ecologically vulnerable (Adger, 2000): The high income earners and engines of the rapid economic growth, such as hydro-power generation, aquaculture farming and acacia plantations, are especially vulnerable to extreme weather events. In the case of hydro-power generation and other hydrological constructions, the creation and management of the water reservoirs inevitably adds to the ecological vulnerability of other activities, such as agriculture and forestry. While economic growth can increase overall resilience to extreme weather events, provided that growth does not depend on increasing ecological and social vulnerability, the accompanying socio-economic differentiation is reflected in the different social groups' varying resilience (Buch-Hansen et al., 2013). As a consequence, the predicted increase in climate variability and extremes may further add to socio-economic differentiation and risk differentiation in the future.

TABLE 1 *Comparable income distribution in Vo Ninh Commune (1,000 VND)*
SOURCE: QUANGBINH STATISTICAL OFFICE, 2013; HOUSEHOLD SURVEY 2013

	Vietnam 2012	Quang Binh Province 2012	Respondents in household sample
Average	1,999.8	1,409.8	1,753.9
Median	1,499.6	1,064.1	1,333.3
Poorest quintile	511.6	423.0	425.0
Richest quintile	4,784.5	3,174.0	4,379.0

The Household Survey in Vo Ninh Commune showed that most households are better off today than before 2010, the year of the latest major flooding event. This suggests that, overall, more households now have higher socio-economic resilience, enabling them to invest in enhancing their ecological resilience by building stronger, multi-storey houses and rescue rooms, and by extension to better secure their lives, health and assets. However, if these households invest in high income generating but ecologically vulnerable economic activities, such as acacia tree plantations and shrimp ponds, they risk enhancing their socio-economic resilience at the expense of their ecological resilience. So, while these activities enhance their immediate beneficiaries' social resilience, they simultaneously lower overall ecological resilience since they are very vulnerable to extreme weather events. They may even also exacerbate socio-economic differentiation (Buch-Hansen et al., 2013).

However, the household survey mentioned above reveals that the average, median and richest quintile incomes of the respondents in the two communities were substantially higher than for the province at large, almost equalling income distribution levels for the entire country. However, the income of the poorest quintile was at the same level as the province as a whole, indicating a generally richer population in Vo Ninh commune but also a more skewed income distribution compared to the province in general. This might be explained by the fact that the Truc Ly community has specialised in collecting and manufacturing products from a rare species of Aloe tree that is threatened by extinction; and both communities are characterised by a large number of migrant workers. The lower social resilience of poorer segments among respondents in the two communities forces them to adapt to flooding and other natural hazards as they arise.

The Hazard Footprint (H)

Vo Ninh commune is located on the south bank of the Nhat Le River, between the conjunction of its two largest tributaries, the Kien Giang and Long Dai Rivers, and the river mouth (see Figure 1). The Nhat Le River system is one of the two largest in Quang Binh province and, with a total catchment area of 2,650 km^2, it covers about 33% of the province's area and poses the highest flood risk (Anh, 2014). The total annual rainfall of Quang Binh Province has oscillated between 1,750 mm and 2,900 mm in recent years, with very irregular annual distribution (Quang Binh Statistical Office, 2013).

Floods in the Nhat Le River basin are generally of pluvial origin. Since there is almost no buffer zone between mountainous areas and flat coastal areas, storm water concentrates very quickly in the river delta. Historically, the floods of November 1999 and October 2010 are considered to have been the most devastating ever to strike Quang Binh. During the first weeks of November 1999, heavy rainfall (460 mm at Dong Hoi Station) caused three consecutive floods in the Nhat Le River system, flooding all the riparian villages. In total, about 12,000 hectares of agricultural land in the Nhat Le River basin were flooded, causing substantial economic damage. During the first days of October 2010, a tropical cyclone with heavy downpour caused major flooding. The month of October 2010 saw more than half the usual annual precipitation (Quang Binh Statistical Office, 2013). As a consequence, all seven districts of Quang Binh province and its 159 communes with 169,943 houses were either submerged or surrounded by flood water. Among them, 119 communes (74%) were flooded to levels of over one metre.

In 2010, Vo Ninh commune was heavily affected by flooding, which resulted in inundated houses, fields, roads and irrigation canals, and created havoc with the electricity system and administrative offices, *inter alia*, as seen in Figure 1.

The rainy season normally runs from September to December and accounts for 80–93% of annual precipitation. The dry season lasts up to eight months, from January to August (DOST Quang Binh, 2013, Chapter 4). The heavy rainfall events during the rainy season are usually caused by tropical cyclones over the Vietnam Eastern Sea, which result in storm surges at the river mouths. When these coincide with heavy water flow in the rivers, flooding occurs in the lowland regions, resulting in serious flooding hazards across the entire Quang Binh Province. Table 2 shows the total damage due to natural disasters during the past 20 years. The number of dead and injured persons has increased drastically in the period 2009–2013 and economic losses even more so. The latter is, to a large degree, due to the larger assets possessed by households, not least among the richest segments.

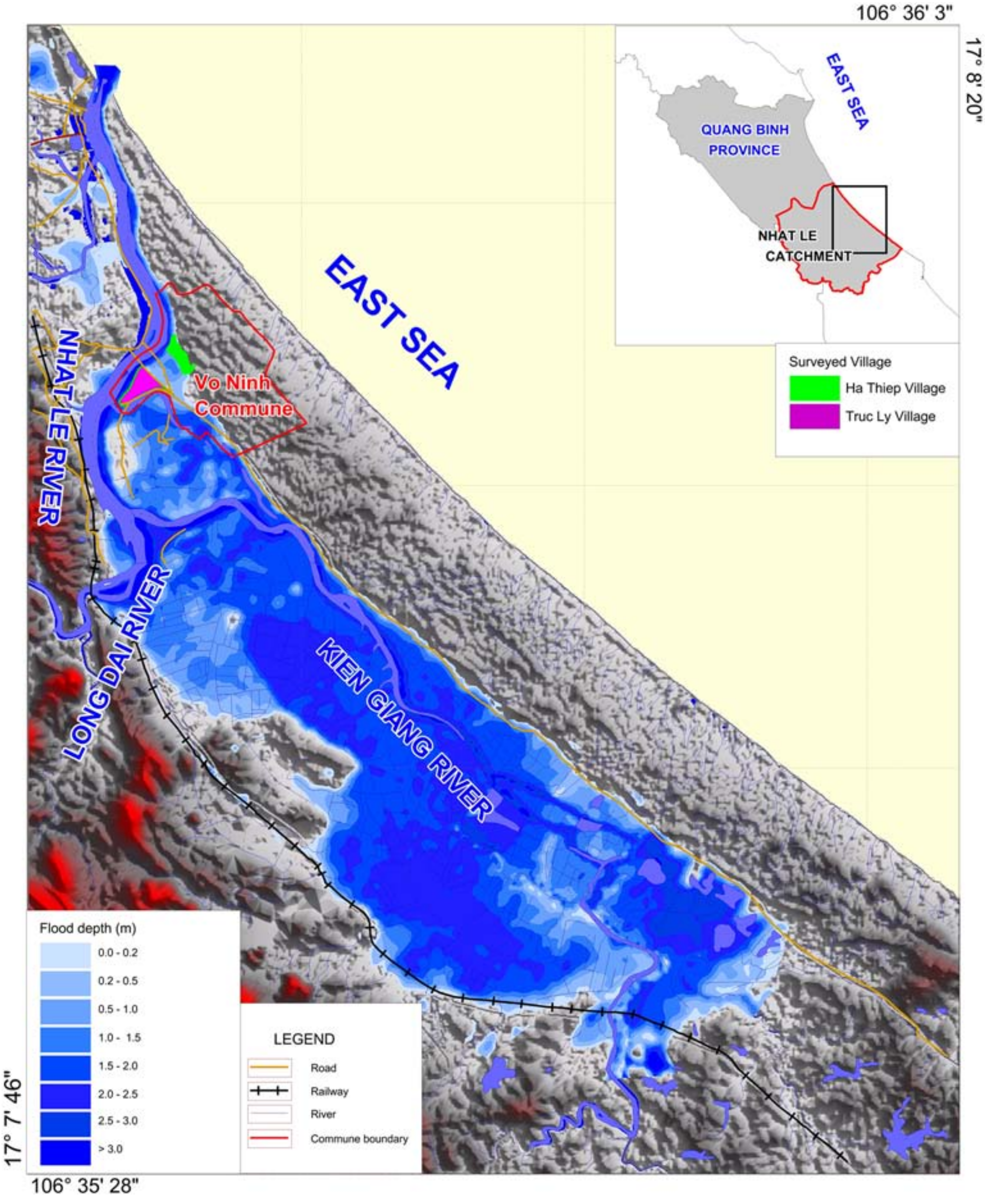

FIGURE 1 *Inundation map of the downstream Nhat Le River system and Vo Ninh Commune, 2010*

TABLE 2 *Fatalities, injuries and economic losses due to natural disasters in Quang Binh, (1989–2013)*
SOURCE: DEPT. OF WATER RESOURCE MANAGEMENT AND FLOOD AND STORM CONTROL, QUANG BINH PROVINCE, 2013

Year	1989–1993	1994–1998	1999–2003	2004–2008	2009–2013
Death tolls	72	77	58	76	110
Injured	54	20	14	213	764
Economic losses (bil.VND)	214.03	149.61	166.58	1,869.01	12,192.4

According to the Department of Natural Resources and Environment in Quang Ninh District (2014), land use in Vo Ninh Commune is dominated firstly by protected forests, and secondly by production forests and agricultural activities, of which paddy is the most important. Following government recommendations in 2007, poor agricultural land prone to flooding has slowly been transformed into aquaculture. More than 80% of the population in Vo Ninh Commune is dependent on primary production, working mainly in the agricultural, forestry and fishery sectors (Quang Ninh District Department of Natural Resources and Environment, 2014). This introduces a high degree of ecological and consequently also socio-economic vulnerability, as the primary sector is directly affected by climate variability and extremes, as well as the geo-physical structure of its location.

Due to the steep topographical features and flooding tendencies in Central Vietnam (inundation in lowland regions caused by local rainfall and water surges in river estuaries due to cyclones), the river dike system was not developed to the same extent as in Northern Vietnam. However, in order to protect crops from early floods, as well as to prevent river bank erosion in the flood season, low-level dike systems were built together with river embankments. One such system in the Nhat Le River basin (in Le Thuy and Quang Ninh Districts) was completed in 2012; and the My Trung culvert for the prevention of salinity intrusion (built in 1998, renovated in 2011) has met its goal of mitigating damage to local communities. However, at the same time, the system also reduced the flood passage and is therefore increasing flooding depth as well as the duration of the high-water level in the region.

As there are no hydropower plants with reservoirs along the Nhat Le River, the lowlands of Quang Binh Province do not suffer from flooding due to the opening of reservoir gates during heavy rainfall, as do Quang Nam and other provinces in Vietnam (Buch-Hansen et al., 2013; Talkvietnam, 2012). However, the forest cover of the Nhat Le River catchment has, as in most of Vietnam, been heavily reduced, especially during the first decades after Reunification. In recent years, the area of protected forest decreased from 233.788 ha in 2005 to 204.665 ha in 2011 (Quang Binh Statistical Office, 2013), resulting in decreased water infiltration. This has led to landslides, soil erosion and an increased sediment load in the river, reducing its drainage capacity during flooding.

The provincial capital of Dong Hoi is located close to the sea on the Nhat Le River mouth behind high sand dunes (see Figure 1), with its urban drainage system leading into the Nhat Le River. As the urbanisation process in Dong Hoi City has been quite rapid during the past two decades, the flow of wastewater has increased the problem of inundation in the Nhat Le River basin lowland, for instance, in Vo Ninh Commune. Furthermore, infrastructure development in the flood plain, such as the national highway 1A, new Quan Hau bridge, rural access roads, etc., seems to be making the flooding even worse. In order to simulate the historical flood events, as well as to project future scenarios for the region to account for the predicted increases in climate variability and extremes, a hydrologic/hydraulic model system was developed (see Anh, 2014). This model system was also used to assess the impact of climate change in terms of increasing maximum rainfall and rising sea levels. The results of the simulation for the 2010 flood event are shown in Figure 2.

The results show that in Vo Ninh Commune, 32% of its area was affected by floods, and according to predicted climate change scenarios this percentage will increase by up to 39.1%. Especially in Truc Ly village, the whole area built with houses will be flooded by 2100 (A2 scenario). With its slightly elevated location, Ha Thiep village is not as prone to inundation as Truc Ly, but floodwater might still cause damage to the village's agricultural fields and aquaculture facilities.

The Vulnerability Footprint—Mitigation Policies (M)

Guidelines for how to adjust to the changing crop calendar were communicated to farmers, including a recommended break in shrimp production from the beginning of September to the beginning of February. There is ongoing research into developing (genetically manipulating) crop species and domestic animals that are better adapted to the increasing climate variability and extremes. Short-stem rice varieties that mature faster and can be harvested before the rainy season have now been adopted by many farmers, who also farm

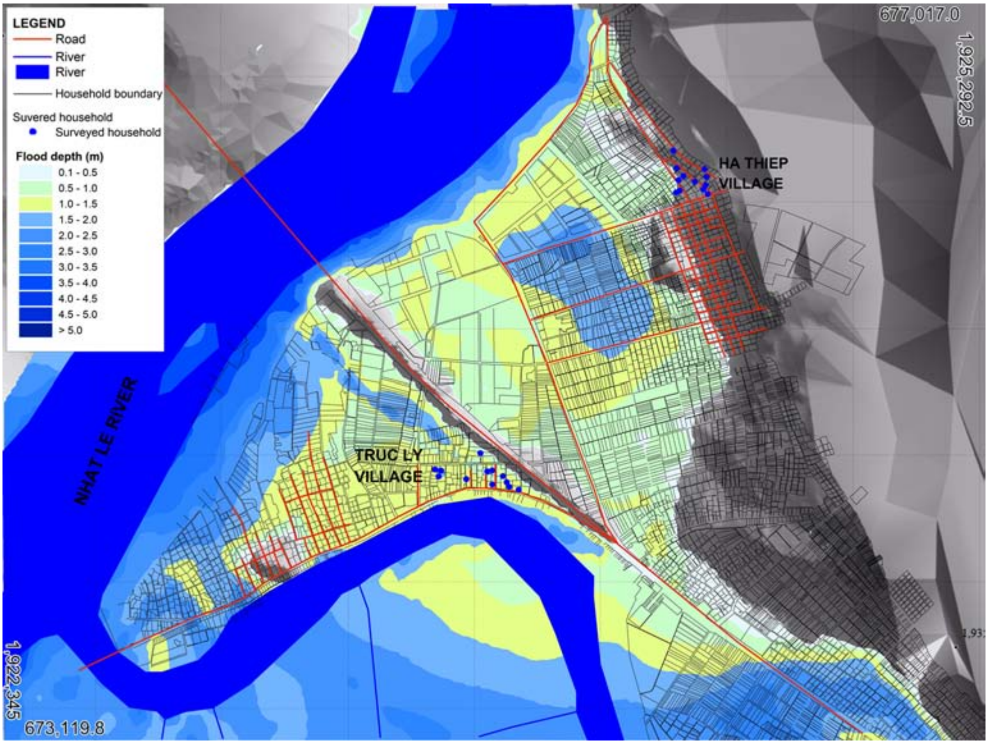

FIGURE 2 *Model Simulation of Inundation for Truc Ly and Ha Thiep villages in Vo Ninh Commune*

crabs, snails and pennywort plants that are better suited to the increased soil salinity that has resulted from salt water intrusion.

Alerts about imminent typhoons and heavy precipitation are broadcast on the radio and television, and farmers refer to these as their main source of information on imminent natural hazards. Indigenous knowledge involving reading signs in flying ants, young bamboo shoots, certain kinds of flowers, and the trees and clouds, is also still widely used. Although this kind of indigenous knowledge is purported to be more efficient at predicting approaching hazards, modern media seem to be the main source of warnings, according to our in-depth interviews with local farmers and officers from the commune and district.

There are Flood and Storm Management Committees at provincial, district and commune level that help the communities to prepare for possible hazards. They can take immediate action when typhoons and flooding are imminent, by providing each village with a boat for evacuation, putting sandbags on top of the dikes and distributing emergency rations of rice and noodles after the disasters have occurred. Households are advised to construct rescue rooms to protect people and animals, as well as to acquire their own boats.

The Vietnamese Government has a policy of supporting poor households whose houses are destroyed or seriously damaged during natural hazards by offering them a loan with an interest rate of 10–12% p.a. These loans are, however, only given to households with children or other household members who work outside the communities and who send remittances that can repay the loan and interest. Apart from a minimal emergency food supply (typically 1–2kg of rice and some noodles, but no cash to repair houses) provided after disasters have struck, there is little assistance to households that are unable to cope with the natural hazards themselves.

In assessing government adaptation policies, it is pertinent to distinguish between *outcome vulnerability* and *contextual vulnerability* (O'Brien et al., 2007). The first involves vulnerability that is directly linked to climate-related hazards, and it can lead to investments in major infrastructure projects, such as the construction of dikes, higher bridges and roads, protected harbours, etc. However, this approach does not take account of socio-economic vulnerability in terms of poverty and lack of economic opportunities that, if alleviated, could enable the various households to adapt to climate-related hazards as they occur and prevent them from turning into disasters (O'Brien et al., 2009; O'Brien, 2010; Buch-Hansen, 2013; Bruun, 2013). Apart from promoting research into new crop and animal varieties that are better adapted to the changing farming calendar and increasing salinity of the soils, together with meteorological early warnings about imminent natural hazards and distribution of limited food supplies after disasters (which are all policies mostly related to lowering outcome vulnerability), the authorities do not have the capacity to mitigate hazards or to help the population adapt to natural hazards (lower contextual vulnerability). The (M) is therefore not necessarily numerically low, but has limited scope for synergy with individual capacities (C). Many of the mitigation policies (resistant crops and improved infrastructure) are regressive in the sense that higher asset households tend to benefit more from them. In this way, the impact of water hazards is inversely distributed in relation to individual capacities (C), which exacerbates the risk of hazards turning into disasters for many poorer households. Jonathan Ensor has pointed out that the unpredictability of climate variability and extremes should lead the government at its various levels to invest only in no-regret investments, i.e., ones that will be useful for society with or without climate changes (Ensor, 2011).

The Vulnerability Footprint—Household/Community Adaptation (c)

Because the Vo Ninh Commune region studied here forms part of the low-lying coastal zone of Central Vietnam, it is unequivocally highly vulnerable to climate-related natural hazards, notably flooding and typhoons. These are predicted to become worse with increasing climate variability and extremes. Truc Ly is located right on the river bank at a lower elevation than Ha Thiep, in a somewhat waterlogged position. It is consequently very vulnerable to flooding, and this seems to have been exacerbated by new infrastructure projects in the vicinity. Ha Thiep is less vulnerable due to its slightly higher elevation and its close location to high sand dunes, which are used as rescue areas for animals. However, within the two communities, there are substantial differences in ecological vulnerability due to very different levels of social resilience. The richer households have constructed strong, multi-storey houses on elevated ground that are safe from natural hazards, while poorer households must turn to spontaneous, simple adaptation measures. However, fields and fish and shrimp ponds in both communities are inundated during flooding (although water levels are higher and remain so for longer in Truc Ly) and villagers have therefore had to adapt to a changing cropping calendar, including growing new crop varieties and perhaps shifting from agriculture to aquaculture or other activities in order to make a living. Their capacity to make such shifts very much depends on the social and economic strengths of the individual households. This applies all the more to long-term investments, such as education or sending household members to Ho Chi Minh City or abroad to work. Securing household members a university education or a job abroad through an agent is very costly and can only be afforded by the better off.

The majority of the households consist of farmers who grow rice as their main crop. Usually, they harvest two crops a year, with the first crop from December to April and the second from May to September. However, many households have started to harvest before August to reduce the risk of losing their crop to floods, even though this can reduce the yield. Apart from rice, many farmers grow a few vegetables around their homesteads, although in Ha Thiep this is limited by the sandy soils. Land plots are, moreover, rarely large enough to sustain the households. Many farmers go fishing to supplement their diets, and many households have their own small fish ponds adjacent to their houses. The 130 farmers in the household survey have an average of 1,800 m^2 of agricultural land, with a median of 1,210 m^2, signifying an unequal distribution of 750 m^2 each among the poorest quintile and 1,950 m^2 each among the upper quintile. Thus, due to scarcity of land and insufficient fish in the river, most households have to look for alternative sources of income.

The households in the two communities pursue different adaptation measures in order to enhance their social resilience, which in turn allows them to mitigate natural hazards as they occur. The main factor accounting for the difference in the adaptation strategies pursued by households is their social and economic capacity, namely: the age composition and health of household members, and the strength of their social networks, including access to formal and informal institutions. Well-to-do households pursue planned adaptation strategies, while poor households adopt spontaneous strategies, at best.

As more than 80% of the surveyed households base their livelihoods on nature-dependent activities, they do not have much economic surplus to invest in improvements. As a consequence, most of them adapt more or less spontaneously to the natural hazards, securing their homesteads as best they can by placing sand bags on the roof and building elevated platforms under the roof to store food and assets during flooding.

Most households comply with local authority recommendations to adjust their farming calendar and grow species with shorter maturation periods and/or that are resistant to salty soils. Out of 130 households, 89 (65 in Truc Ly and 24 in Ha Thiep) have transformed poor and salty soils into ponds for aquaculture, which they all claim is more profitable than agriculture. This, however, also requires an investment that not all households can manage, thereby further heightening socio-economic differentiation. Surprisingly, rather few households have shifted to keeping ducks instead of chickens, despite the fact that many chickens typically die during flooding. A few households are also putting greater efforts into the production and marketing of handicraft products, or engaging in casual labour in the neighbourhood or in the provincial capital city of Dong Hoi. However, non-agricultural economic activity is low and so are the commercial opportunities, availability of and salaries associated with casual labour.

The households that are making a difference are those breaking away from a traditional lifestyle of dependency on variable natural resources and conditions. Households with young, skilled and able-bodied children who can seek migrant work in Korea, Taiwan, Malaysia or the Arabic countries can send substantial remittances to their parents. However, the costs of paying an agent to arrange for a job, visa, work permit, etc. are between 200 and 600 million VND (10,000–30,000 USD). There are similar costs involved in having a son or daughter admitted to a university, as well as paying tuition fees and "under-the-table" fees for getting the well-paid jobs they are qualified for. According to information from key respondents in the commune and villages, only about 6% of the households earn the majority of their income from trade, while one quarter of the households sells things occasionally at the market. About one quarter of the surveyed households have children studying away from home. Of the 510 households in Ha Thiep community, approximately 110 youngsters are studying elsewhere, and 140 already have an education and are looking for jobs. Between 110 and 120 are working in Ho Chi Minh City, and 80 have gone to work abroad.

The community of Truc Ly has, for many years, pursued a strategy of finding and felling aloe trees, first in Vietnam where aloe is now purported to be extinct, and later in the wider Southeast Asian region. One major merchant in the village organises the aloe trade and has 20 villagers working directly for him, making sculptures from the aloe wood and distilling it for its oil, which fetches very high prices on the international market. He pays the 20 workers 3–4 million VND each per month and the aloe business is a major factor in the Truc Ly economy. Those who have been lucky enough to find the rare aloe trees have made substantial fortunes, which they invest in building big, strong multi-storey houses that are safe during major flooding and typhoons. One respondent has been less lucky, as she was left a widow with three children after her husband died searching for aloe trees in Malaysia. She did not receive any insurance payout and can barely survive on the pittance her 20-year old son can send home from his casual work outside the community. She can't get a loan from the government bank for building a safe house, as the bank does not believe that she will be able to repay it.

More than 80% of respondents are pursuing some kind of planned adaptation strategy with a view to enhancing their livelihoods in order to mitigate natural hazards. Almost all respondents pursued spontaneous adaptation strategies as hazards occurred, securing their house, food and domestic animals and possibly acquiring a boat that could rescue them during flooding. A few of the respondents in the two communities had neither the social, nor the economic capacity to pursue any adaptation strategy at all; they just stayed put in their houses or possibly moved in with family or friends, or if their lives were in danger they were rescued by the authorities.

The individual capacities of the households in the two communities are very different, based on their highly differentiated socio-economic resilience, as shown in Table 1. As the ecological vulnerability of the two communities is pushing the inhabitants towards pursuing high income-generating activities like shrimp ponds, further economic differentiation is resulting. In Truc Ly, some community members have been pursuing an unsustainable strategy of searching for the increasingly rare aloe tree in Southeast Asia. This has helped them strengthen their economic resilience, and by extension their ecological resilience, by enabling them to build taller, stronger houses that protect their lives and health during the typhoons and flooding. A more sustainable livelihood seems to be based on migrant work and remittances sent to the families who stay behind in the communities. It is highly likely that this strategy will become even more widespread in the future.

Conclusion

This article has argued strongly for a transdisciplinary approach to understanding and mitigating climate related disasters caused by flooding. As shown in the literature review, most studies on flooding disasters are hydrological studies involving 1-D models and—more specifically in the case of Vietnam—2-D models of episodes when rivers flow over dikes and river embankments and create havoc in the low-lying floodplains. These studies do not, however, explain how natural hazards like flooding turn into societal disasters, nor how these could be mitigated.

The article subsequently introduced an integrated framework for disaster analysis inspired by Wisner et al.'s (2012) disaster risk equation and Oven and Rigg's (2015) model consisting of Hazard, Vulnerability and Livelihood Footprints. Wisner et al.'s (2012) variables provide a useful and succinct analytical entry point for disaster analysis. In particular, the disaggregation of the vulnerability variable into households' adaptation capacity (C) and government disaster policies (M) appears productive. The article argued, however, that due analytical attention should also be paid to the overarching socio-economic development process in which the variables play out, as well as the interaction between the two variables (C) and (M). Hence, Oven and Rigg's (2015) footprint categorisation was included to provide an analytical structure capable of addressing these two factors.

The Hazard Footprint analysis showed how the natural environment in Vo Ninh Commune presents both opportunities and risks for the inhabitants of the two communities. This is reflected in the uneven spatial distribution of the Hazard Footprint in the two communities, where Truc Ly is located right on the river bank at a lower elevation than Ha Thiep and in a somewhat waterlogged position. Ha Thiep is less vulnerable due to its slightly higher elevation and its close location to high sand dunes that are used as rescue areas for animals. The hydrologic modelling showed that Vo Ninh Commune is, overall, likely to be much more susceptible to flooding in the future and that Truc Ly village could be totally immersed by 2100. As argued by Rigg and Owen (2015) in this issue, the Hazard Footprints of disasters are quite localised, while their causes and effects are not, suggesting a need for a broader socio-economic analysis of the capacity of individual households (C) and government disaster policies (M) to mitigate the hazards.

The Livelihood Footprint section briefly outlined the socio-economic developments underlying the disaster analysis. The two communities (as well as Vietnam as a whole) have experienced rapid economic growth and expansion of production activities but also increased socio-economic differentiation. More than 80% of inhabitants still work primarily in the agricultural, forestry and fishery sectors. Some aspects of this socio-economic development have increased disaster resilience (by enabling the construction of better and elevated houses/barns), while others appear to have exacerbated the communities' vulnerability (aquaculture farming, road construction, and potentially also migration, which leaves children and the elderly behind).

In terms of the Vulnerability Footprint, the article documented how households try to enhance their economic resilience by breaking away from on-site dependence on natural resources for farming, forestry and fishing, a strategy that they then exploit to protect their livelihoods during natural hazards. In Truc Ly, for instance, households pursued the unsustainable strategy of searching for aloe trees and manufacturing aloe-based products. In both communities, household members migrated to the urban areas (notably in the south, in and around Ho Chi Minh City, or abroad) and sent remittances back to the families remaining in the communities. It seems obvious that this trend will increase, which will leave the two communities, like other areas under threat of increasing climate variability and extremes, with a population of elderly people taking care of the children left behind by the younger migrant workers. Within the two communities, there were substantial differences in vulnerability due to very different levels of social resilience. The richer households have constructed strong, multi-storey houses on elevated ground that are safe during natural hazards, while poorer households must turn to spontaneous, simple adaptation measures during floods. Fragile livelihoods and unsafe locations are unequally distributed, reflecting the households' different social and economic capacities (C). This uneven vulnerability, it has been argued, is likely to worsen, not just because of the predicted increase in climate variability and extremes, but also because government policies merely intensify household adaptation capacities (C) for better or worse. The Vietnamese government is investing heavily to mitigate what O'Brien et al. (2007) call "outcome vulnerability", by elevating roads and building higher bridges across rivers and streams, yet investments to reduce contextual vulnerability among poorer segments of the population by attempting to prevent natural hazards from turning into disasters are obviously inadequate. Thus, government disaster policies (M) have a direct impact not just on vulnerability (V), but also indirectly on poorer households' coping capacity (C). The highly differentiated household coping capacities impact the extent to which households can benefit from disaster policies, and poorer households appear to be caught in a vicious cycle where government relief alleviates the worst immediate consequences of the repeated floods but does not fundamentally address their vulnerability. On the contrary, some policies (new infrastructure projects in the vicinity of Truc Ly, for instance) appear to further exacerbate vulnerability among poorer households, while increasing resilience for households with the capacity to benefit from such infrastructural investments.

This article illustrates the crucial role of social science in understanding how the societal capacities of individual households and institutions can play a role in minimising the impact of natural hazards and/or preventing them from turning into disasters. Comprehensive disaster analysis requires transdisciplinary approaches that combine natural science understandings of climate related natural hazards, and social science analysis of adaptive capacities. Our approach shows how economic development can be used to enhance resilience—both from a household (C) and government (M) perspective. Given the predicted increases in climate variability and extremes, it is to be expected that typhoons, droughts and flooding events will become more severe. This, combined with the unpredictability of the farming calendar, makes strengthening societal capacities an urgent matter if communities are to cope with, and adapt to, future climate changes.

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