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ORIGINAL ARTICLE

Community-based adaptation in low-lying islands in the Philippines: challenges and lessons learned

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Abstract

Community-based adaptation (CBA) seeks to address climate risks and socio-economic drivers of vulnerability simultaneously. However, as CBA activities appear very similar to standard development work, difficulties in identifying good practices arise. To clarify the role of CBA, this study elucidated how climate change can impact pre-existing development problems by investigating the experiences of four low-lying island communities in central Philippines. The islands currently suffer from frequent and extreme tidal flooding (following an earthquake-induced land subsidence in 2013, with a magnitude that is broadly similar to sea-level rise projections under a 1.5 to 2 °C global warming scenario), and endured a dry spell in 2016. The study also identified various publicly and privately initiated adaptation strategies, and evaluated their resilience against actual biophysical events. The study conducted focus group discussions with local leaders and in-depth interviews with government officials and residents in March 2016. Results show that tidal flooding impacted almost all aspects of daily life on the islands, while the dry spell completely depleted their limited water supplies. The strategies implemented by governments and NGOs (e.g., seawalls, rain-water collectors) were found to be inadequate in preventing tidal flooding and compensating for the dry spell. Also, communities used coral stones and plastic waste for raising the floors of their homes, which have an erosive effect on their capacity to adapt in the long term. Lack of community participation in publicly initiated projects and lack of adaptation funding for community-based strategies were the greatest obstacles to implementing climate-resilient solutions.

Keywords Sea-level rise · Drought · Vulnerability

Introduction

Climate change is expected to severely affect coastal communities, especially those in Small Island Developing States who are considered ill-prepared to tackle its impacts due to serious socio-economic constraints existing in these countries (Mimura et al. 2007; Kelman 2014). Considering that climate vulnerability is more influenced by socio-economic rather than environmental factors (Nicholls and Tol 2006; Ayers and Forsyth 2009), scholars and practitioners alike are seeking to elucidate the corresponding linkages between climate change adaptation and development. Nowadays, climate change adaptation policies are being mainstreamed into development plans at the national and even local government levels, aiming to reduce climate vulnerability, increase adaptive capacity, and, in so doing, secure sustainable development gains (Ayers and Huq 2009). In line with this, development agencies are implementing various adaptation programs with the specific goal of helping at-risk communities adapt to projected climate

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change impacts. However, there are many challenges to achieving this goal.

Designing adaptation projects based on climate vulnerability can be problematic, as it remains difficult to actually measure vulnerability and to understand how it is distributed across space and social groups (Adger 2006). On the one hand, as the projected impacts of climate change are still uncertain at the local level, there is simply not enough data to quantify and disaggregate climate vulnerability (Ayers and Forsyth 2009). On the other hand, as climate change can occur simultaneously with other hazards such as political conflict (Kelley et al. 2015), or processes such as globalization (O'Brien and Leichenko 2000), it is necessary to consider a constellation of stressors (McCubbin et al. 2015). Thus, a siloed approach to adaptation often proves limited and ineffective.

In particular, engineering approaches often fail to address the underlying socio-economic drivers of vulnerability (O'Brien et al. 2007). Engineering solutions for coastal adaptation typically include soft measures such as planting mangroves and conserving coral reefs, as well as hard measures such as building seawalls and reclaiming land (Donner and Webber 2014; Klein et al. 2001; Takagi et al. 2016; Takagi et al. 2017). However, if incorrectly designed and constructed, many of these hard measures can fail (Yamamoto and Esteban 2016). For example, in Kiribati, South Tarawa has become a "graveyard" of poorly maintained coastal defense structures built through the Kiribati Adaptation Project II (Donner and Webber 2014).

Providing a means to overcome uncertainties relating to climate vulnerability and impacts, Community-based adaptation (CBA) has increasingly gained traction among national governments and international non-government organization (Reid and Huq 2014). Taking the approach that adaptation is development (Ayers and Forsyth 2009), CBA designs adaptation projects consistent with long-term development goals. In particular, it implements "no regrets" solutions that aim to address projected climate change impacts, while improving living standards and reducing disaster risks at the same time (Donner and Webber 2014). CBA is therefore in line with the 3rd IPCC Report, which calls for solutions that seek to address climate change by resolving development issues, such as through increasing access to resources, reducing poverty, promoting equality, improving education and infrastructure, encouraging public participation, and developing institutional capacity and efficiency (Smit et al. 2001). By framing climate change as a human security issue, CBA can allow for multiple points of intervention (O'Brien et al. 2007) and "no regrets" solutions can promote investment in adaptation (Donner and Webber 2014) despite uncertainty regarding actual environmental change impacts.

In theory, CBA projects are different from standard development projects, in the sense that the earlier are specifically designed with an awareness of potential climate risks at the community level, which is then expected to factor in to their activities (Huq and Reid 2007). In other words, unlike pure development, CBA seeks to address both environmental and socio-economic risks simultaneously (Forsyth 2013). However, in practice, CBA looks very much like "development as usual," with additional adaptation components being difficult to distinguish (Reid et al. 2009). Part of this difficulty is due to the lack of clarity regarding the precise aim of CBA, given the limited understanding of how climate risks (especially of slow-onset impacts) and socio-economic problems actually interact to produce climate vulnerability especially at the community level (Forsyth 2013; McCubbin et al. 2015). In effect, the resilience of "no regrets" solutions against climate change has barely been tested (Huq and Reid 2007), and good CBA practice has been hard to recognize (Ayers and Forsyth 2009).

To address these challenges to CBA, the present study has two main objectives. First, it aims to help elucidate the vulnerability of low-lying island communities, in terms of both climate risks and underlying socio-economic drivers, based on empirical qualitative data. Second, it seeks to identify the corresponding adaptation strategies that have been initiated by public and private actors at the community level, and to test the climate resilience of these strategies against actual biophysical events. In order to achieve these objectives, the study will look into the experiences of low-lying island communities in Tubigon, Bohol, Philippines.

Due to the 2013 Bohol earthquake, the island communities of Tubigon have suffered from significant land subsidence. As a result, they are currently partially or completely inundated during high tides throughout the year, thereby representing one of the most severe cases of tidal flooding in an island environment in modern history (Jamero et al. 2017). Observations from these islands can serve as a proxy to understand the consequences of flooding that future sea-level rise could bring to other densely urbanized coral islands, if the natural morphological processes and coral growth that allow for islands to compensate for rises in sea level become less effective (Webb and Kench 2010; Yamamoto and Esteban 2014). In particular, results from this study can provide insight into possible "no regrets" solutions applicable to a 1.5 to 2 °C cap in global warming, as the degree of land subsidence suffered by the islands of Tubigon is similar to the sea-level rise projections of various studies for such warming scenarios (see the "Study sites and methods" section for details). Given that these islands are already experiencing extreme tidal flooding, which other places in the planet are only expected to suffer in the future, they therefore present a rare opportunity to evaluate the climate resilience of adaptation strategies based on actual biophysical events, which has been a common limitation for previous studies on CBA (Ayers and Forsyth 2009).

In April 2016, Bohol declared a state of calamity following a 4-month-long dry spell caused by an El Niño event, severely impacting the water supply of the island communities of Tubigon, as they mainly rely on rainwater harvesting. Again, this dry spell will be used as a proxy to study the effect of future changes in rainfall that can be brought about by climate change (Church et al. 2013).

To elucidate community vulnerability, the paper begins by outlining the island communities' pre-existing socio-economic problems and the impacts of tidal flooding and dry spell. Based on an understanding of how these different kinds of problems interact, the study will then explore the adaptation strategies implemented by public and private actors. Finally, the authors will evaluate the climate resilience of these strategies in terms of how they are able or unable to prevent (residual) loss and damage, and discuss good practices for ensuring the long-term sustainability of island communities in the face of future sea-level rise and drought.

Study sites and methods

This study was conducted in the small islands of Pangapasan, Bilangbilangan, Batasan, and Ubay in Tubigon, Bohol, Philippines (see map in Supplementary Material). The islands are low-lying, with highest elevations of only about + 2.0 m above water during low tides. Each island forms one local community (also known as "barangay") under the municipality of Tubigon and is governed by their respective Barangay Councils. The communities only have about 60 to 250 households each, with most residents being close relatives.

As part of a double barrier reef called the Danajon bank, the islands are teeming with marine resources. Thus, although the settlements are very poor, many of the residents are able to find sustenance in fishing and other fishing-related activities such as shellfish gleaning and fish vending (see Supplementary Material). The number of households with incomes below the income poverty threshold of PhP 9064 (or ~USD 180) per month ranges from 34 to 74% of the respective total populations of these islands, which is far higher than the national average of 16.5% (PSA 2016). Similarly, the number of households with incomes below the food poverty threshold of PhP 6329 (or ~USD 125) per month (a measure of extreme or subsistence-level poverty) ranges from 22 to 62% of the total populations, which is again much greater than the national average of 5.7% (PSA 2016). Furthermore, the communities have very high dependency ratios, as about 30% of their populations are less than 15 years old. Although the islands have high literacy rates, the majority of residents have only completed elementary-level education. In terms of poverty incidence, Ubay and Bilangbilangan are the poorest communities and have the smallest land areas and lowest number of households.

According to the 5th IPCC report, the global mean sea level is likely to increase by 0.28–0.61 m (median value of 0.44 m) by 2100 under RCP2.6 or a low emission scenario (Church et al. 2013). On the other hand, a broad survey of 90 experts indicated that the median "likely" range of sea-level rise resulting from a < 2 °C increase in temperature above pre-industrial level is 0.4–0.6 m by 2100 (Horton et al. 2013). Forecasting a more dire scenario, another study using a semi-empirical model estimated that limiting global warming by 1.5 to 2 °C above pre-industrial level could still lead to sea-level rise of 0.75–0.8 m by 2100 (Schaeffer et al. 2012). In view of these projections, the four islands of Tubigon can serve as a proxy to study the consequences of future sea-level rise for a 1.5 to 2 °C cap on global warming, particularly its flooding effects. However, for the authors, note that at present it is not clear whether current mitigation efforts will allow such targets to be reached (Raftery et al. 2017), and thus there is the prospect that sea-level rise could be much greater than 1 m by 2100 (Vermeer and Rahmstorf 2009).

Following the 7.2-magnitude Bohol earthquake in 2013, the islands of Tubigon experienced land subsidence, which in turn resulted in partial or complete flooding during normal high tides. Essentially, the land subsidence that these islands experienced is approximately similar to the range given in the studies above, as median flood height measurements alone fall between 0.2 and 0.4 m and could range up to 0.9 m (it should be noted that the degree of land subsidence the islands experienced is likely greater than their current flooding levels). Furthermore, the frequency of occurrence of flooding clearly represents a scenario that is far more extreme than what is currently being experienced elsewhere in the world. It should also be emphasized, however, that the analogy between land subsidence and sea-level rise does not account for other interrelated impacts of climate change, such as coral bleaching and ocean acidification.

Tidal flooding in the islands of Tubigon lasts several hours across a number of days close to the new and full moon phases of each month. During Habagat (southwest monsoon), which runs from April to September, flooding often happens during daytime. On the other hand, during Amihan (northeast monsoon), running from October to March, flooding often happens at night. In Batasan, flood heights ranged from + 20 to + 69 cm above ground level (median of + 36 cm), and in Ubay, from + 25 to + 73 cm (median of + 43 cm), during an actual flooding event in June 2016. Both islands were partially or completely inundated for a total of 135 days in 2016 alone. In Pangapasan, flood heights ranged from + 4 to + 44 cm above ground level (median of + 20.5 cm), and in Bilangbilangan, from 0 to + 93 cm (median of + 24.5 cm). While Pangapasan was also completely inundated, a small area of Bilangbilangan (about 10%) was spared from the flood. Both islands were flooded for 44 days in 2016 (Jamero et al. 2017).

From January to April 2016, Bohol experienced a dry spell, where rainfall measurements were 21–60% lower than average, due to an El Niño event (IFRC 2016). El Niño is a temporary natural event where trade winds blowing from the east to the west in the tropical Pacific Ocean weaken or collapse, causing warm water from western Pacific to move to the east. This affects the climate and weather throughout the region, thought its influence can be felt throughout the rest of the world. The dry spell resulting from the 2016 El Niño created a water crisis in the islands of Tubigon, as they mainly rely on rainwater harvesting for their daily water needs.

In March 2016, the authors of the study engaged various stakeholders from governments and NGOs, as well as from the affected communities, in focus group discussions and in-depth interviews (see Supplementary Material for details). Since then, the authors have conducted field work on the island communities of Tubigon on three other occasions, spending up to 1 month there during each visit. Site observation during actual tidal flooding events and participant observation of residents have allowed authors to gain a deeper understanding of their daily lives and struggles and to verify qualitative data gathered in March 2016.

Impacts of environmental changes on pre-existing socio-economic problems

Focus group discussions with local leaders and in-depth interviews with residents revealed a great number of pre-existing problems across different aspects of daily life on the islands, aggravated by tidal flooding and dry spell (Table 1). At the root of these pre-existing problems are socio-economic and geographic constraints such as poverty, limited natural resources and infrastructure, remote location, and poor government services. By distinguishing pre-existing development problems from the impacts of recent environmental changes in the islands of Tubigon, it also becomes possible to understand the vulnerability of similar low-lying islands more holistically, in terms of both climate risks and their socio-economic drivers.

Tidal flooding

Tidal flooding has exacerbated many pre-existing problems on the islands, including issues regarding land, electricity, and infrastructure. Given their small land areas, the islands barely have any space left for new families to build their houses or for existing families to relocate theirs. Also, farming activities cannot extend beyond the scale of small backyard gardens. However, essentially, all of the islands and their gardens now become flooded during high tides, affecting all families and killing all non-salt-resistant vegetation.

Electricity supply on the islands, provided by the Philippine National Power Corporation (NAPOCOR) through expensive diesel generators, only lasts for at most 8 h a day, until midnight. The lack of electricity supply complicates disaster risk management efforts, particularly when typhoons make landfall at night. However, the disaster risk significantly increases when typhoons coincide with nighttime flooding, especially because community halls and school grounds designated as evacuation centers also become flooded.

The majority of the seawalls that had been built before the earthquake have already been severely damaged during the passage of past typhoons and are no longer functional. Presently, as the level of tidal flooding surpasses the height of these seawalls, high waves can easily penetrate the islands during normal high tides.

Tidal flooding also puts the health and environment of the islands at risk. Even before the earthquake, the trash of Ubay, Pangapasan, and Bilangbilangan was no longer being collected by municipal authorities due to poor government solid waste management services and the remote location of the islands. In response, residents bury, burn, or simply litter their trash instead, potentially creating long-term health and environmental problems. With flooding, loose trash items are easily carried indoors by floods, while dirt from garbage pits, livestock pens, and communal toilets is inevitably mixed into the floodwater, heightening the risk of an outbreak of water-borne diseases.

Dry spell

There are no fresh water wells available on the islands. Thus, residents usually import purified drinking water from the mainland (Php 20 per 20-L container if bought directly from Tubigon, Php35–40 if bought from stores on the island). Furthermore, they rely mostly on rainwater for their domestic needs such as cooking, washing clothes, and taking a bath. Due to this, almost all households harvest rainwater in their own backyards.

The local governments of Batasan, Pangapasan, and Bilangbilangan also maintain public water tanks to ensure water supply in their communities. Residents can buy rainwater from these public tanks for a cheaper price (Php 2–3 per 20-L container), compared to privately owned tanks, where rainwater is sold for Php 5–8 per 20-L container. In the case of Ubay, residents can only buy rainwater from privately owned tanks, as their only public tank was damaged.

However, due to the dry spell in early 2016, rainwater supply from public water tanks quickly ran out, while the prices of rainwater from privately owned ones nearly doubled. When rainwater from both public and private sources on the island ran out, residents then had no choice but to import water for domestic use from the mainland at very high prices (Php 10–12 per container). They also started to conserve water better, by reusing the water they used for taking a bath for washing their clothes. Nonetheless, the price and accessibility of purified drinking water remained the same.

Table 1 Pre-existing development problems and the impacts of flooding, dry spell, and earthquake and land subsidence

Root cause	Socio-economic problems	Impacts of tidal flooding	Impacts of dry spell	Impact of earthquake (EQ) and land subsidence (LS)
Poverty	Degraded marine ecosystem			EQ: Coral reefs show cracks and physical damage LS: Intertidal zone deepened
	Illegal fishing			
	Overfishing			
	Limited alternative livelihood options	Livestock pens flooded		
Limited resources				
• Water	Reliance on rainwater for domestic needs		Rainwater supply completely depleted	
	Lack of access to other potable water sources		Resorted to importing water from mainland instead	
• Land (residence and agriculture)	Overcrowding	No higher ground for available for relocation		
	Poor diet (lacking vegetables)	Vegetable gardens flooded and destroyed		
• Electricity	Limited electric supply (4–8 h/day only)	Nighttime flooding especially dangerous during typhoons		
• Infrastructure	Dilapidated community buildings (hall, school, chapel)	Activities of school children and churchgoers affected by flooding		EQ: Private houses and public buildings damaged/destroyed
		Halls/schools also serving as evacuation centers flooded		
	Damaged seawalls, scouring along roads	Flooding surpasses height of seawalls		
		During tidal flooding, waves easily penetrate island		
Remote location	High prices of goods imported from mainland		Price of imported water increased dramatically	
	Education mostly limited to elementary level			
Poor government services	Poor solid waste management	Uncollected trash used as filling for raising floors, littered, or burned		
	Poor health and sanitation	Lose trash items carried by floods		
		Communal toilets damaged/flooded		

Earthquake and land subsidence

The majority of the islands' residents engage in small-scale artisan fishing for their livelihood, catching reef fish and crabs using small motorized boats. However, due to illegal fishing, overfishing, and the growing number of residents who rely on the sea for their food and livelihood, the marine ecosystem of the islands of Tubigon has started to degrade. Still, as a result of the 2013 Bohol earthquake, the islands' reef underwent further physical changes, including underwater cracks and traces of avalanches (Nellas et al. 2015). In particular, about 1.2 has of Batasan's mainland-facing house reef was damaged (Nellas et al. 2015). Its live hard coral cover declined significantly, while its dead coral cover correspondingly increased (Nellas et al. 2015). Focus group discussions with island residents revealed similar observations. For example, fishermen from Pangapasan have complained about their fishnets being damaged by broken coral stones that have rolled out of the reef cliff where they fish, forcing them to go further away. Fishermen from Batasan were also concerned by toppled coral stones within their fishing grounds, which negatively affected their fish catch.

In addition, due to the earthquake-induced land subsidence, the intertidal zone where island residents glean seashells and other invertebrates deepened, reducing the area accessible for this activity. Reduced catch from gleaning in turn placed further stress on the diet of these communities, as they typically sell their fish (which fetches a higher price than the shells) and eat seashells instead.

Community-based adaptation to socio-economic problems and environmental changes

As discussed in the previous section, tidal flooding, dry spell, and land subsidence aggravated the pre-existing

socio-economic problems of the island communities of Tubigon. To address both development problems and environmental changes, government and non-government organizations, as well as community members themselves, have implemented various types of adaptation strategies.

In this study, these adaptation strategies are classified into "planned" and "autonomous" measures, the latter relating more closely to "no regrets" solutions of CBA (Table 2). While "planned" adaptation measures are initiated by public actors such as government and non-government organizations, "autonomous" measures are initiated by private actors such as individuals and households (Smit et al. 2001; Monnereau and Abraham 2013). In simpler terms, whereas planned measures start from a top-down approach, autonomous measures start from a bottom-up approach. By clearly distinguishing between planned and autonomous measures, this study can help understand the complex yet complementary roles that communities, government agencies, and NGOs play in adaptation, and how they can better align their strategies.

The various measures are further characterized in terms of their temporal scope as either "short-term" or "long-term."

Planned adaptation measures

Immediately after the earthquake, the communities received various types of external aid from the National Government. Construction materials worth Php 10,000 (or around USD 200, see Jamero et al. (2016)) were provided for the repair of partially damaged houses. Through the Kapit-Bisig Laban sa Kahirapan-Comprehensive Integrated Delivery of Social Service (KALAHI-CIDSS) program, the island communities of Tubigon were also given the opportunity to select their own priority projects based on their specific needs.

Highlighting water as a critical issue for their residents, Batasan, Pangapasan, and Bilangbilangan acquired new rainwater collectors through the KALAHI-CIDSS program to supplement their existing public water tanks (Fig. 1a). On the other hand, indicating tidal flooding as a more pressing problem, Ubay decided to use funding available through KALAHI-CIDSS to build a 9-m seawall (Fig. 1b). As discussed previously, Ubay has the highest flood height median (+ 43 cm) among all four islands and experienced flooding across 135 days in 2016.

Non-government organizations were also active in providing assistance to the island communities after

Table 2 Different types of adaptation measures implemented by various public and private actors

	Actor	Short term	Long term
Planned	National Government	Provide construction materials for housing repair	Acquire new water tanks
			Build new seawall
	Municipal Government		Relocate island residents to mainland
			Provide funds for road maintenance
	NGO	Build make-shift temporary classrooms	Donate stilted houses
			Elevate floors of classrooms
			Create rice cooperative
			Establish microfinance
Autonomous	Barangay Council		Elevate and extend roads
			Repair and elevate damaged basketball court
			Fix community hall
			Repair and elevate damaged seawalls
			Acquire large evacuation boats
			Increase electricity supply
	Community	Clean chapel and other shared spaces after tidal flooding	Elevate floors of classrooms using coral stones*
			Elevate existing chapel using coral stones or build new one*
			Hold classes in private house
			Share food with neighbors
	Household	Burn or bury trash	Use trash as foundation for new houses*
		Clean own house and backyard after tidal flooding	Elevate floors using trash or coral stones*
			Elevate vegetable gardens
			Gleaners learn to dive

*indicates that adaptation measure has negative environmental consequences

the earthquake. About 100 households (43 of which are in Ubay) were recipients of a stilted housing project implemented by the local Diocese of Tagbilaran (Fig. 1c), which were found to be effective against tidal flooding (Jamero et al. 2017). International NGOs also helped build make-shift temporary classrooms, particularly in Batasan where some classrooms were totally damaged by the earthquake. Also, as of June 2017, the floor of one classroom in Pangapasan has already been elevated through the assistance of the Tzu Chi Foundation (Fig. 1d).

Prior to the earthquake, the Municipal Government has been providing funds to the islands of Tubigon for road maintenance on an annual basis, as part of their development budget allocation. However, after the earthquake, the islands re-aligned these funds from development to adaptation, working on road elevation instead. Still, as these funds are limited, the elevation work is progressing rather slowly, with only one section being completed every year (e.g., road section in front of community hall and chapel).

Even before the earthquake, NGOs have also been actively supporting various community-based organizations on the islands, mainly through the implementation of livelihood projects. In particular, NGOs work with closely women in the island communities, as they are greatly interested and highly participative in creating alternative livelihood opportunities. Doing this, NGOs have been able to set up rice and microfinance cooperatives together with existing women's organizations. The NGOs have also helped create new associations (especially where old ones were no longer functional) to promote broad-based participation in their livelihood projects.

Autonomous adaptation measures

Annually, Barangay Councils are provided by the National Government with an Internal Revenue Allocation (IRA), calculated based on the population and land area of each barangay. Out of this IRA, 20% is dedicated to development projects. However, in view of the recent environmental changes they have experienced, the Barangay Councils of the island communities of Tubigon have decided to re-align this 20%

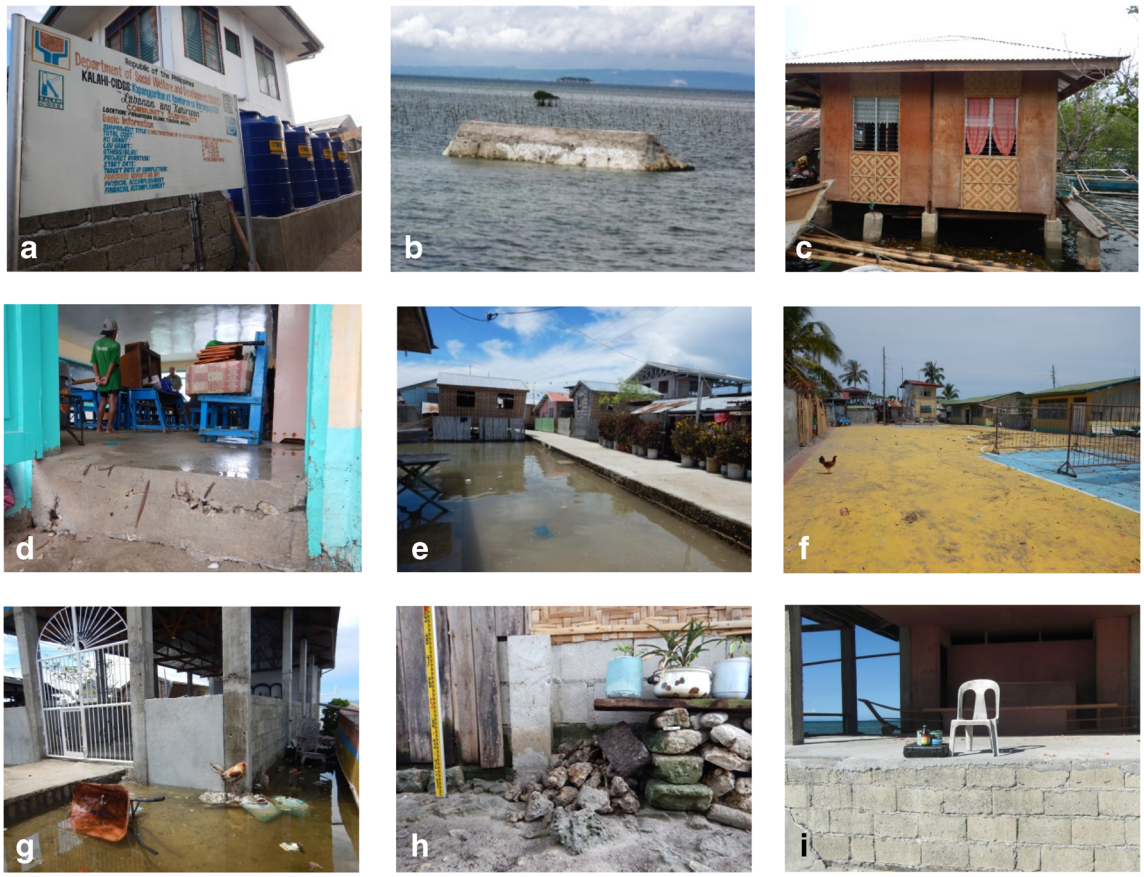

Fig. 1 Potential community-based adaptation strategies to climate change. **a** Rainwater collectors in Pangapasan, and **b** 9-m-long seawall in Ubay acquired through the KALAHI-CIDDS Program. **c** Stilted house donated by Diocese of Tagbilaran. **d** Floor of primary school in Pangapasan elevated by Tzu Chi Foundation. **e** Raised road in Ubay. **f** Repaired basketball court in Pangapasan. **g** Newly built chapel in Ubay. **h** Raised potted plants in Batasan. **i** New stage in Bilangbilangan elevated using plastic wastes as filling material

development budget for implementing adaptation measures instead. This re-alignment is not always sanctioned by the Municipal Government, which remains constrained by the strict rules on how this budget should be used. In this sense, although the Barangay Council is technically still a part of the Philippines' formal government structure, the councils of the island communities of Tubigon can be considered to be implementing autonomous rather than planned adaptation strategies.

Roads

Using its annual development budget, Ubay has already raised its roads (Fig. 1e) by a median height of + 70.5 cm, so that people may remain mobile during flooding events (Jamero et al. 2017). Using the same budget, the community is planning to extend the road to the lower areas of the island in the coming years. On the other hand, Batasan used its budget for fixing the community hall, while Pangapasan mainly focused on buying food and repairing several damaged community properties, such as the basketball court (Fig. 1f).

In the future, using their annual development budgets, as well as their annual road maintenance allocations, the Barangay Councils of Batasan and Pangapasan are also planning to raise their roads. It is worth noting that both communities envision these raised roads to also serve as seawalls, preventing high waves from penetrating into their islands during flooding events.

Disaster risk management

All of the Barangay Councils of the islands of Tubigon are hoping to slowly repair and elevate existing seawalls in their communities, especially Bilangbilangan whose seawalls have already been severely damaged by previous typhoons, although they are struggling to find sufficient funding sources. Being farthest from the mainland, Bilangbilangan is also planning to acquire large evacuation boats to avoid relying on the disaster management team of the Municipal Government. Bilangbilangan is also hoping to coordinate with NAPOCOR in extending the supply of electricity on the island from only 4 h a day to 24 h.

Schools

To enable children to continue going to school during flooded days, some islands have raised the floors of their school buildings, mainly through funds collected from parents. Batasan has elevated the floor of one of its classrooms and no longer holds classes in buildings that can be flooded. Similarly, Ubay has elevated its old primary school classroom (shared by grade 1–4 students), although it can still be slightly flooded whenever there are high waves. Ubay is also planning to elevate its newly constructed primary school classroom, which currently becomes severely flooded during high tides as it was not specifically designed for flooding. However, school buildings in Bilangbilangan have not yet been elevated, and children simply squat on their chairs when the floods come. Moreover, as the grade 4 classroom in Bilangbilangan was damaged by tropical depression Queenie in November 2014, classes were held in a private house on the island instead.

Chapels

Chapels are an important part of the island communities' lives. For this reason, they were one of the first buildings on the islands to be repaired and elevated following the 2013 Bohol earthquake. The floors of the chapels in Batasan and Pangapasan have been elevated, while an entirely new chapel was constructed and elevated in Ubay (as the old one was completely destroyed) through the funding and efforts of parishioners (Fig. 1g). However, the chapel in Bilangbilangan has yet to be elevated, although parishioners diligently collect any garbage items carried inside by the flood.

Food

The typical diet on the islands consists of fish, seashells, steamed rice, and, whenever available, some vegetables. Prior to the earthquake, many residents grew their own vegetables in small gardens, where they mainly planted malabar spinach and moringa. However, due to tidal flooding, the number of vegetable gardens has significantly decreased.

Women are especially affected by the impacts of tidal flooding on food sources, as they are mostly in charge of the households' vegetable gardens and overall nutrition. Every barangay has a team of trained female health workers who regularly and systematically monitor the nutrition of school children and, with funding support from the government, implement a feeding program for malnourished children. Women also mostly take care of procuring food items for the family within the islands or from the mainland, and gleaning seashells from the reef flat during low tide. Due to this, any threat to food sources concerns women the most. Nonetheless, many women have begun to plant vegetables in pots and plastic containers, which are then placed on elevated planks or furniture (Fig. 1h). On the other hand, in order to adapt to changes in the depth of the reef flat, some women have also started to learn how to dive (just to be able to harvest seashells).

Despite their poverty, island residents are usually able to eat three times a day, with almost no household experiencing food shortage. Because they can easily catch fish or glean seashells, they mainly worry about acquiring rice, which is also central to their diet. Nonetheless, sharing food with relatives and friends is also a common practice on the islands, which becomes a highly valuable support system in times of need. Small convenience stores on the islands are also helpful in providing food on credit.

Solid waste

During tidal flooding, the lack of a proper management system becomes an acute problem, as garbage pits are also flooded and rubbish gets carried inside houses. Since flooding typically occurs for 3–5 days at a time, residents do not start cleaning their houses until the end of this period. This means that garbage carried by floodwaters can stay inside houses for days, posing risks to health and sanitation. Insects such as cockroaches, ants, and centipedes also enter houses during flooding. Due to the dirty floodwaters, some residents have complained about itchiness and rashes on their feet.

To address both solid waste and tidal flooding problems, the residents of Pangapasan, Ubay, and, to a much larger extent, Bilangbilangan have started using garbage, particularly plastics, as foundations for their new houses or as filling materials for their elevated floors. In Bilangbilangan, a new stage was constructed in front of the basketball court using plastic waste as fillers (Fig. 1i). A local leader from the island commented that "We are happy with it as we now have less garbage around." However, the effectiveness and long-term stability of these landfills is at present unclear, and there may be room for improving the way in which they are constructed and compacted. When plastics are not properly trapped due to poor construction techniques, they can easily find their way into the marine environment especially during the passage of destructive typhoons. Plastics can harm marine animals primarily through entanglement and ingestion (Derraik 2002).

Elevated floors

Historically, Batasan and, to some extent, Ubay have used coral stones for reclaiming land where new families could build their new homes. Coral mining was thus done gradually, as the communities' populations grew organically. However, after the earthquake many households (especially from Batasan) concurrently mined corals from the reefs to elevate their floors (Jamero et al. 2017). Excessive coral mining destroys the reefs, which serve as natural barriers against high waves, and reduces the sediment budget necessary for enabling the natural adaptation of islands to changing environmental conditions (Webb and Kench 2010). However, residents justified coral mining by arguing that they are only harvesting dead corals, not knowing that under the right conditions these can still potentially serve as settlements for coral recruits (Vermeij et al. 2009).

Climate resilience of adaptation measures

In this section, the climate resilience of the planned and autonomous adaptation measures discussed above is evaluated based on how they are able or unable to prevent (residual) loss and damage, described as the "negative effects of climate variability and climate change that people have not been able to cope with or adapt to" (Warner and van der Geest 2013). There are four paths to these negative effects: (1) adaptation to biophysical events is inadequate, (2) adaptation entails irrecoverable economic and non-economic costs (i.e., loss of culture and identity), (3) specific strategies have erosive effects on adaptive capacity in the long-term, and (4) adaptation options are not available or possible (Warner and van der Geest 2013). It is important to note though that the succeeding discussion refers to potential—rather than actual—loss and damage. Indeed, so far, despite the many challenges and limitations to their adaptation strategies, the communities of Tubigon have been able to continue their daily lives on the islands with no perceivable changes in their cultural and social relations.

Planned strategies

Many of the planned strategies funded by the government and NGOs were implemented in response to the 2013 Bohol earthquake. Thus, the assistance they provided mainly focused on earthquake-induced damages and did not directly address the tidal flooding due to land subsidence. For example, the type and amount of construction materials provided by the National Government only allowed residents to repair the damages caused by the earthquake, but not to re-design their houses to counteract the effects of flooding (e.g., by building them on stilts). Furthermore, the island communities of Tubigon were not allowed to participate in the National Government-funded program for on-site reconstruction, which provided new houses to households whose homes had been totally damaged by the earthquake, in the same location where they were originally erected. Rather, in response to tidal flooding, the National Government simply advised island residents to relocate to the mainland, and tasked the Municipal Government with developing and implementing the relocation program.

However, due to lack of financial resources, the relocation program has been greatly delayed and, as of June 2017, no construction has been started yet. More importantly, many residents of the island communities are refusing to migrate to the mainland to preserve their fishing-based livelihood (Jamero et al. 2017). At the same time, as the coastal areas in the mainland where the government plans to build the relocation sites are also affected by tidal flooding, many residents view them as a poor alternative to the islands (Jamero et al. 2017). Thus, especially in Ubay and Batasan, where many households have aggressively implemented a variety of adaptation measures as a result of frequent and extreme tidal flooding, many residents no longer find permanent relocation to the mainland necessary (Jamero et al. 2017). The experiences of the islands of Tubigon thus show that sea-level

rise does not directly lead to relocation, as otherwise assumed by the mass migration theory, and that the final decision to relocate is influenced more by social factors rather than by environmental factors alone (Jamero et al. 2017). Despite coming face-to-face with a degree of sea-level rise not expected until 2100 immediately after the earthquake, the island communities of Tubigon have apparently not yet breached the social limits to adaptation. In fact, whether the limits to social adaptation do exist or are immutable still remains a question (Adger et al. 2009). Thus, governments should re-consider the priority of island abandonment (which can be taken as a failure to adapt) and focus more on developing and implementing climate-resilient in situ adaptation strategies.

Although the government and NGO-funded programs in the islands of Tubigon mainly focused on the earthquake, community participation in the selection of priority projects (e.g., KALAHI-CIDSS scheme) and suitability of the housing design to the local context (e.g., stilted houses for islands) have to a certain extent also allowed for some adaptation to tidal flooding and dry spell. For example, the stilted houses that were donated were found to be effective against tidal flooding (Jamero et al. 2017). However, even these "more appropriate" strategies were still greatly limited in supply.

The new water tanks provided by the National Government were unable to meet the water needs of residents, especially during the dry spell, when they were eventually forced to import water from the mainland (at higher prices). Also, the new seawall built through KALAHI-CIDSS was only 9 m long and was thus too small to offer any real protection against the incoming high waves. Similarly, the annual funds for road maintenance provided by the Municipal Government were not enough to promptly complete the elevation work envisioned by the Barangay Council. Furthermore, construction work for the relocation program has not yet started, although it is arguable whether the program will be implemented at all. As for NGO-funded projects, not all of the households were able to receive the donation of stilted houses. Also, none of the public actors provided technological assistance on how households can raise floors in an environmentally sensitive and economical manner, and because of this, many of them resorted to using coral stones and plastic waste as filling materials.

Overall, the path to potential (residual) loss and damage—despite the implementation of planned measures—can be the inadequate adaptation to tidal flooding and dry spell.

Autonomous strategies

Many of the autonomous strategies implemented by the Barangay Councils may eventually prove to be climate resilient. By repairing and elevating the floors of important public buildings, such as community halls, schools, and basketball courts (all of which are also used for evacuation), the residents are able to continue with their daily activities even during floods. By raising and extending the roads, the residents are also able to maintain their mobility during flooding events. By acquiring large evacuation boats, the residents can readily evacuate to the mainland when weather conditions worsen. However, it is important to note that the implementation of many of these strategies is progressing at a very slow pace, and the lack of funding is proving to be a great obstacle (currently available development funds are difficult to re-align and limited). This is especially true when considering the more expensive projects planned by the Barangay Councils, such as repairing and elevating their damaged seawalls. Thus, the autonomous measures envisaged by Barangay Councils are currently still inadequate for adapting to tidal flooding and dry spell.

On the other hand, in terms of the autonomous strategies implemented by community members and households, potential (residual) loss and damage may result from the erosive effects of using plastics and coral stones as filling materials for raising floors, making the islands vulnerable in the long term.

In Batasan, residents have also used coral stones for raising the floors of their homes, as alternative building materials are not available on the island. There are 251 households in Batasan as of 2015. Assuming (based on site observations) that each home has a floor area of 5 m × 5 m, then at least ~ 1800m^3 of coral stones need to be mined in order to raise the floors of all 251 households by 30 cm. However, this is only a conservative estimate, as many houses have floor areas greater than 5 m × 5 m, which in many cases have been raised higher than 30 cm (Jamero et al. 2017; Supplementary Information). If the coral stones that they had used before the earthquake for land reclamation are also taken into account, the estimated volume of mined corals can easily be much greater.

Furthermore, assuming that 1 m^2 of reef can supply 0.2 m^3 of coral stones (Caras and Pasternak 2009), then at least 0.94 ha of reef needs to be mined for 251 houses with a 5 m × 5 m floor area to be raised by 30 cm. A survey of a mined reef section in Batasan revealed a live hard coral cover of less than 10%, with a further 30% of dead coral with algae, indicating that the area is already severely degraded (Jamero et al. 2017). While seawalls only offer line protection, coral reefs can provide area protection against waves, dissipating their energy before they reach the shoreline where the seawalls are constructed (Mimura and Nunn 1998). Thus, while raising floors using coral stones may have short-term merits, its negative effects may prove far greater in the long term. In this sense, coral mining can be considered as a maladaptive strategy (Jamero et al. 2017).

Lessons learned

This study built an analogy between land subsidence and sea-level rise in terms of flooding effects (although other interconnected climate impacts such as coral bleaching and

ocean acidification are not accounted for). Given that the island communities of Tubigon are already currently experiencing the degree of sea-level rise projected under a 1.5 to 2 °C global warming scenario, there are important lessons that similar at-risk communities can learn from their adaptation experiences.

First, planned measures initiated by public actors can become more climate resilient by increasing community participation in problem identification, scope definition, and solution design in order to better align planned measures with actual needs and local conditions. To be able to effectively provide assistance for adaptation, governments and NGOs should develop a clear understanding of their target communities and their vulnerabilities. They need to clearly establish the pre-existing socio-economic problems of the communities and how these can be affected by the projected environmental changes, in order to clearly define additional adaptation components to be integrated into standard development projects. Public actors also need to acknowledge that communities are capable of implementing adaptation strategies autonomously. With few livelihood options, poor education, high poverty incidence, inadequate utilities and infrastructure, and small areas and populations, the island communities of Tubigon would normally be considered to have low adaptive capacities. Despite these constraints, the community members and households of the islands of Tubigon were still able to implement a good number of adaptation strategies based on their own initiatives. This shows that island communities are far more resilient than otherwise assumed by the mass migration theory that suggests that sea-level rise will directly lead to relocation. Public actors, including policy-makers, should therefore consider how to measure adaptive capacity more accurately in order to supplement it more effectively.

Second, additional financial and technical support are critical for increasing the climate resilience of autonomous or CBA strategies. As shown by the experiences of the island communities of Tubigon, when the impacts of climate change become more apparent and intense, even impoverished communities will earnestly find ways to adapt. This indicates that, rather than non-adaptation, maladaptation may be a bigger challenge for CBA in the future. In Tubigon, the main drivers of using coral stones and plastic waste as filling materials were the lack of financial resources and information about alternative solutions, thus underscoring their importance for preventing maladaptive practices.

Conversely, however, it is also possible that practices considered to be adaptive at present may become maladaptive in the future, especially those that were originally conceived as short-term fixes only. Nonetheless, with good planning, such short-term strategies can be improved or replaced before they cause any adverse effects. In this sense, technical support for ensuring that the measures implemented evolve dynamically along with the situation of the communities is important, rather than simply labelling interventions as adaptive or maladaptive in binary terms.

Furthermore, although the Barangay Councils were able to implement more promising strategies autonomously, these strategies are still currently inadequate for adapting to tidal flooding and dry spells. While the councils made numerous internal arrangements to re-align existing development funds towards adaptation, these funds were simply not enough (although this should not come as a surprise considering that the funds were not truly intended for adaptation in the first place). This demonstrates the importance of dedicated additional adaptation funding for implementing climate resilient strategies. Such dedicated funding will also ensure that development efforts are not neglected, especially when climate impacts are already being experienced by the communities.

Third, it is interesting to note that none of the planned and autonomous adaptation strategies identified and evaluated in this study were entirely new. Rather, through appropriate changes made to their design and implementation (based on the specific needs and experiences of the communities), well-established solutions can be used to address extreme cases of tidal flooding.

In the future, more examples of climate resilient community-based adaptation strategies need to be examined in order to identify good practices, which can help formulate appropriate strategies that promote the long-term sustainability of coastal areas.

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