Original article

Post-disaster recovery linked with pre-disaster land development and damage density of Typhoon Yolanda: Toward better land-use planning in Tacloban City, the Philippines

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Abstract: Coastal cities in Asia face increasing risks of extreme climate events and urgently need to develop risk-reduction plans to mitigate the harmful socioeconomic consequences of such events. In this study, we undertook geographical analyses and conducted interviews with stakeholders in the Tacloban City area, the Philippines, to investigate the relationships among building types, storm-surge inundation and post-disaster recovery after 2013 Typhoon Yolanda. Squatter settlements in low-lying urban and coastal areas were destroyed by the typhoon, but were rapidly rebuilt by squatters using debris from the typhoon. Government programs relocated some of the affected squatter populations to new socialized housing developments on safe higher ground that were some distance from the squatters' former urban and coastal livelihoods, thus causing reluctance to relocation. Our GIS analysis of available geo-spatial data, coupled with extensive stakeholder interviews, showed that there were enough vacant lots within pre-existing housing subdivisions to house more than 7000 squatters and provide them with plots for urban vegetable farming that would provide their livelihood. Interviews with stakeholders suggested that this approach would not encounter excessive resistance. Thus, our study demonstrated that comprehensive GIS analyses and stakeholder involvement can contribute to effective land-use planning for community resilience.
Key Words : Slum, Subdivision, Storm surge, Resilience, Vacant lot

INTRODUCTION

Many Asian cities lie on alluvial floodplains and flood-prone coastal lowlands (Yeung, 2001) that were previously areas of intensive rice cultivation. Rapid urbanization without appropriate urban planning in these areas has led to inherent building practices, for example, the use of fill as a foundation to raise new housing above potential flood levels (Hara *et al.*, 2005). Unplanned urbanization has also removed large areas of rice fields that previously constrained the flow of flood waters and has thus increased the likelihood and severity of flood damage (Hara *et al.*, 2002). In particular, unplanned and densely populated slum areas with poorly constructed buildings on weak foundations have expanded rapidly (Braun and Aßheuer, 2011). Previous research has emphasized the importance of land-use planning for urbanization in coastal lowland areas (e.g. Dewan *et al.*, 2007). Implementation of effective zoning and regulation of informal slum developments have been difficult because of issues related to social class segregation and rapid self-building by squatters on public and private land (Kobayakawa, 2016). For example, in Metro Manila in the Philippines, many lots in large-scale land subdivisions intended for middle and upper class urban housing have remained vacant because of their proximity to informal squatter communities (Hara *et al.*, 2011). On the urban fringe of Metro Manila, low-lying areas originally reserved for flood water retention and riparian ecosystem conservation have been occupied by squatter communities (Hara *et al.*, 2008).

In developing countries in particular, a lack of both available geographical information and adequate methods for detecting and monitoring the dynamic development of informal settlements

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make effective land-use planning difficult (Owen and Wong, 2013).

Relocation of slums and the provision of social housing to mitigate the effects of future disasters is difficult because of budget limitations and the desire of slum dwellers to live near the source of their livelihood. Many informal slum communities have good social networks that strengthen their resistance to relocation (Saiyot and Matsuyuki, 2016). Researchers in urban geography and sociology have stressed that effective long-term urban planning for disaster mitigation in slum communities requires a participatory approach to planning that draws on the social capital in those communities (e.g. Ahmed, 2016).

For successful planning, it is important to map areas of slum developments as well as other land uses and natural land conditions, and to integrate these data with statistical and community social data, so that areas of informal development can be prioritized for improvement. Methods of disaster mitigation might include participatory bottom-up strengthening of infrastructure in existing settlements, total relocation of communities into social housing in disaster-safe areas, identification of evacuation routes, and training of residents in low-lying disaster-prone areas where quick construction of hard infrastructure is difficult.

In view of the limited amount of geo-spatial, statistical, and field-based social data in developing countries, it is important that planners take into account the amount of available data to ensure workable plans are formulated (Thomson and Hardin, 2000).

The Philippines is typical of countries that lack sufficient geographic and statistical data to plan effectively for mitigation of future disasters predicted to be caused by global warming (Birkmann and von Teichman, 2010).

In November 2013, Typhoon Yolanda formed in the central Pacific near the Chuuk Islands and travelled eastward to cause extensive damage in the Philippines. Its central atmospheric pressure reached 895 hPa, and maximum wind speeds of 90 m s^{-1} were recorded. Typhoon Yolanda was one of the most intense tropical cyclones on record. There were 6300 deaths, 1062 people reported missing, and the estimated total cost to repair the damage caused was estimated to be about 896 billion Philippine peso (PHP) (National Disaster Risk Reduction and Management Council, 2013).

In the Philippines, the greatest damage was in Tacloban City, a coastal city in a low-lying area in the northeastern part of Leyte Island. Of the city's population of about 220,000, 2646 people were reported dead or missing. In terms of size, geomorphology and urban form, Tacloban City is typical of medium-sized cities in developing countries in areas of tropical monsoonal climate where future disasters related to global warming and sea level rise are likely to occur. We therefore studied the effect of Typhoon Yolanda on Tacloban City as a case study for such events, focusing on the relationships between land use and typhoon damage, the processes of urbanization and land-use change, and pre- and post-disaster planning.

We used Geographic Information System (GIS) technology to map landforms and spatiotemporal changes of land-use, land-use field surveys, available planning and post-typhoon restoration documents, and field interviews seeking the views of local people on disaster management and their past and future living conditions.

Based on our investigations, we propose an alternative approach to land-use planning and post-disaster restoration to create a city that is more resilient to natural disasters. We also considered the amount of available geographic data that is necessary for effective land-use and restoration planning. The results of our study are applicable to other low-lying cities in the Philippines and to medium-sized cities in other developing countries in regions of tropical monsoonal climate.

1. METHODS

1.1 Study area

Tacloban City is in the low-lying northeastern coastal part of Leyte Island, about 580 km southeast from Metro Manila (Fig. 1). It has an area of 201.72 km^2 with approximately 220,000 people and is the center of commerce, politics and tourism for the Eastern Visayas region. The city has 138 barangays (local governments) that have administrative, judicial and legislative functions. Like many medium-sized regional cities in the Philippines, Tacloban City has experienced rapid development of areas of unplanned urbanization, fed by an influx of people from surrounding rural areas into low-lying agricultural lands. This urbanization has caused considerable environmental problems, particularly flooding in squatter communities where basic housing infrastructure such as water supply and drainage are lacking. In contrast, middle and upper class communities in the city occupy safer subdivisions where their basic infrastructure needs are met. During Typhoon Yolanda, a huge storm surge struck the coast of the Tacloban area (Tajima *et al.*, 2014) causing extraordinary damage to buildings and the death of 1.2% of the city's population (Kure *et al.*, 2014).

1.2 Collection and calibration of geo-spatial data

In August 2014 we acquired the following city-wide coverage of geo-spatial data from the National Mapping and Resource Information Authority (NAMRIA):

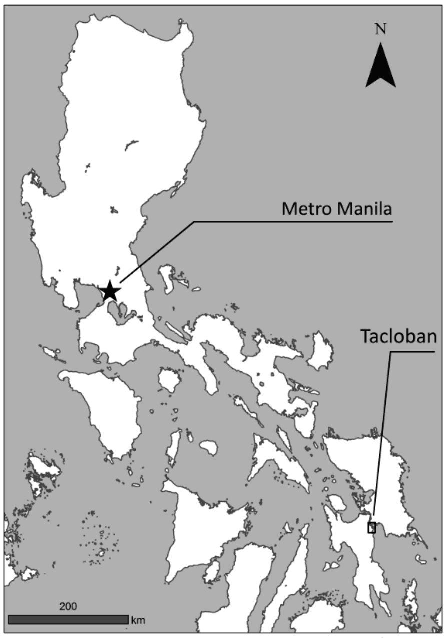

Figure 1 Study area (the rectangle corresponds to Fig. 2)

- black and white, raster-image aerial photographs taken in 1996 (1:25,000 scale) and 2001 (1:10,000 scale)
- topographic maps (1:10,000 scale) published in 2006 in 300 dpi raster (JPEG) format and original CAD files geo-referenced in DWG format
- a paper topographic map (1:50,000 scale) of the Tacloban area published in 1956
- geo-referenced, raster-format, 5-m-resolution interferometric synthetic aperture radar (InSAR) digital surface and terrain models (produced in July 2013, just before Typhoon Yolanda)
- hazard maps (1:50,000 scale) in JPEG format published in 2007
- maps of damage caused by Typhoon Yolanda (NAMRIA, 2014) interpreted from Google Earth images of Tacloban City and indicating four levels of damage for buildings (possibly damaged, moderately damaged, highly damaged, and totally damaged) that were initially released in November 2013.

We also purchased a QuickBird multi-spectrum satellite image of the Tacloban City area that was acquired in June 2006.

We used ArcGIS version 10.1 (ESRI, Redlands, CA) to amalgamate the various datasets and geo-referenced the 1996 and 2001 aerial photos using the already geo-referenced QuickBird image and the ArcGIS online basic image as controls. We used UTM Zone 51N and WGS 1984 in this process. We extracted individual vector layers for rivers, roads, houses, and buildings (larger than houses) from the CAD files, and converted them to shape-file format. We also created detailed topographic contours (1 m contour interval) from the InSAR data and used them for analyses of the geomorphologic environment.

1.3 Classification of housing

We used the amalgamated GIS data to define three classes of housing: slums, subdivision and socialized housing.

1) Slums

First we used the geo-referenced aerial photos to identify densely inhabited areas of small houses, most of which were in low-lying areas along river courses and in coastal areas. To identify slums among these areas, we then used the ArcGIS house layer and aerial photos to construct polygons enclosing all houses in these areas that were less than 75 m^2 in area. We then overlaid the slum areas so defined on the house layer, and calculated the total area, number of houses, area of building coverage, and house density for each slum area. During our field survey, we visited each of these slum areas and verified that they were densely occupied illegal slums.

2) Subdivisions

In the Philippines, creation of housing subdivisions is the most widespread legal method for provision of housing. With government approval, large areas of land are developed by private contractors to provide housing and basic infrastructure, although the land-use planning and regulation of these developments needs improvement.

To identify areas of housing subdivision, we looked for gridded patterns of roads and housing on 1996 and 2001 aerial photos, the 2006 QuickBird image, the 2014 ArcGIS online basic image, and the GIS layers we created for roads and houses. We then polygonised these areas and attributed them with likely years of construction, and used these data in our spatiotemporal analysis.

3) Socialized housing

The aim of socialized housing in the Philippines is to provide accommodation for landless slum dwellers. For example, a Community Mortgage Program (CMP) in Cebu City helped slum dwellers to relocate by enforcing ceilings on land and building costs and providing them with low-interest mortgages repayable over 25 years (Kobayakawa, 2016). CMPs have been implemented in the Tacloban area by the National Housing Authority (NHA) to assist people displaced by Typhoon Yolanda.

In May 2015, we obtained from Tacloban City Hall a list of applicants for socialized housing by victims of Typhoon Yolanda (under the Yolanda Permanent Housing Project). We used the postal addresses provided by applicants to identify the locations of their proposed new dwellings by using Google Map, local government maps, aerial photos, and Google Earth images. However, it was difficult to locate many addresses because the socialized housing projects were in the early stages of land development and exact addresses were not identifiable from aerial images and maps. Consequently we defined the subdivisions according to the boundaries shown on local government maps. For each polygon representing a socialized housing area, we attached attributes indicating average elevation, housing project number and, where available, house numbers.

1.4 Post-typhoon data collection

We devoted a total of almost two weeks to field surveys in August 2014 and March 2015, during which we interviewed 5 slum dwellers in each derived slum area, representative residents at a clubhouse in each subdivision derived through our GIS analysis, and local government officials involved in both rehabilitation planning and preparation of socialized housing for victims of Typhoon Yolanda. We asked about matters including the behavior of residents during the typhoon, the relocation of housing to higher elevations after the typhoon, the willingness of victims to relocate, general awareness of hazard maps, land-use and evacuation planning, and land ownership and land-use changes.

We also addressed 2 slum and 1 subdivision residents, and obtained some time- and location-stamped digital photos taken by them on their smart phones before and after the typhoon.

We obtained comprehensive land-use planning documents (digital format) from Tacloban City Hall that were compiled in 2013 not long before the typhoon but were not revised because the post-Yolanda focus was on preparation and execution of rehabilitation plans. We obtained these plans from the Tacloban City Planning and Development office in May 2015.

In August 2014 we obtained documents detailing a coastal mangrove reforestation project (an important countermeasure for storm surges) from the Provincial Environment and Natural Resources office and inspected a reforestation site near their office.

1.5 Review of land-use and rehabilitation planning before and after Typhoon Yolanda

We reviewed all of the pre- and post-typhoon maps and planning-related documents we collected (as detailed in section 1.4), identified interrelated structures and vertical administrative gaps (bringing ineffectiveness in holistic planning) among them and noted any changes of planning approach before and after Typhoon Yolanda. We considered their effectiveness and practicality in light of the views expressed during our field interviews and the results of our spatiotemporal land-use analysis and considered whether changes or improvements could be made.

2. RESULTS AND DISCUSSION

2.1 Distribution of different classes of housing

We identified 15 slum areas located in low-lying areas along the rivers and coast, the largest of which were along the coast, and 17 subdivisions, mainly on the urban fringes (Fig. 2, Table 1).

2.2 Land condition and living environments in slum areas

Most slum areas are situated on flood-prone land less than 2 m above sea level (asl). We identified 3702 houses (average floor area 45 m^2) and calculated the total area occupied by slums to be 58.38 ha. The density of slum housing was 63.80 houses per hectare, considerably denser than in housing subdivisions (e.g. in local government area 109 where the housing density was 37.69 houses per hectare).

During our field survey in slum areas, we observed that “NO BUILD ZONE” signs had been erected, stating that construction of dwellings within 3 m of the river or 40 m of the shoreline was banned by Presidential Decree 1067 (Fig. 3). Nonetheless, these areas were occupied by numerous well-established squatter dwellings. We assumed that these areas were chosen by squatters because they were close to the sources of their livelihoods (e.g. fishing and caged fish farming), land prices there were low, and the “no build zone” decree was not effectively policed. Because of a lack of reliable statistics on slum areas, there was little knowledge of their locations, sizes, and populations, and it appears that the government had ignored their existence because they were a source of considerable numbers of votes during elections (Kobayakawa, 2016). During our field interviews, we discovered that some local government officials charged squatters rent for the land they occupied and indicated that if the squatters did not vote for them they would not have access to government support for Typhoon Yolanda victims.

2.3 Intensity of damage caused by Typhoon Yolanda in slum areas

Houses in the slum areas at the time of Typhoon Yolanda were built close together, with narrow alleys between them that did not allow vehicular access. They were also distant from evacuation facilities on higher ground. The houses were roughly constructed by the squatters using debris,

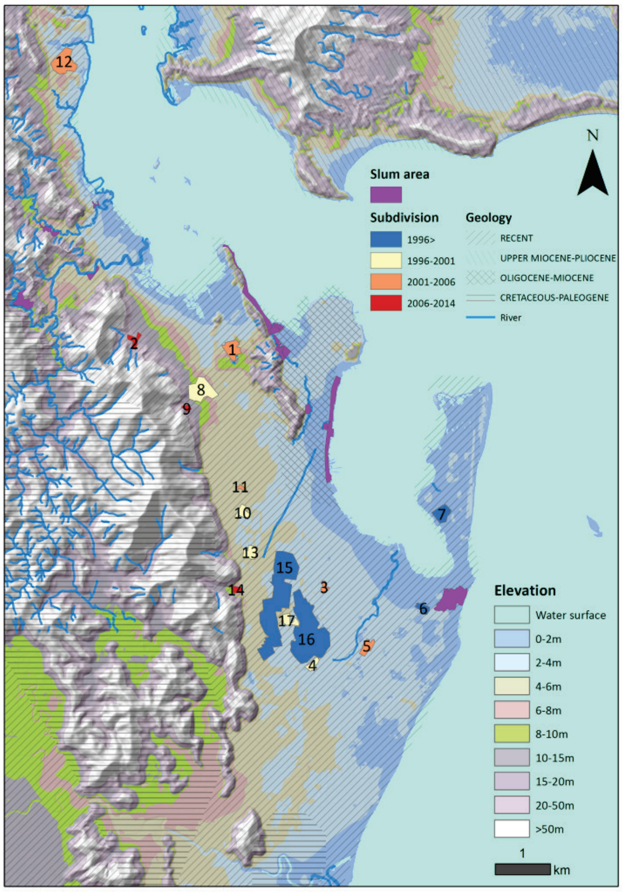

Figure 2 Distribution of slums and housing subdivisions in the Tacloban area and geomorphology. Subdivisions numbers correspond to those in Table 1

(a) (b)

Figure 3　Photos of "NO BUILD ZONE" signs (a) beside a stream and (b) near the coast. Note that in (b), "NO" has been removed from the sign by local squatters, indicating their strong opposition to this decree. See Fig. 4 for locations of photos.

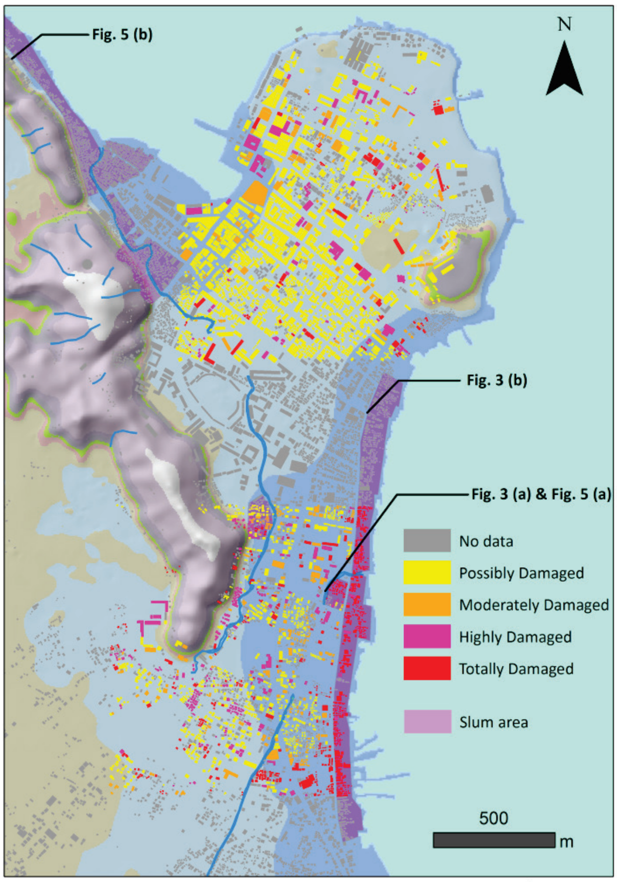

Figure 4　Map showing intensity of damage due to Typhoon Yolanda in slum areas derived by overlaying the damage intensity map (NAMRIA, 2014) on our GIS dataset of housing and slum dwelling polygons. See Fig. 2 for elevation legend. Locations of photos in Figs. 3 and 5 are also shown.

(a) (b)

Figure 5　Resident's photos of slum areas soon after Typhoon Yolanda (a) beside a stream (same view as in Fig. 3a) and (b) near the coast. See Fig. 4 for locations of photos.

Table 1　Summary of subdivisions compiled from pre-Typhoon Yolanda comprehensive land-use plan and GIS analysis; 1956 land use interpreted from 1956 topographic map.

No	Barangay	Subdivision Name	Brgy population (as of may 1,2010)	Area(ha)	Open space(ha)	1956 Land use	Development age	Elevation
1	66-A,67,71	Kristina heights Subdivision	1236,1213,5526	7.2884	1.6192	Woods-brushwood	2001～2006	4～12m
2	74	Regina Hills Subdivision	7231	3.2737	0.7273	Tropical grass	2006～	15～25m
3	78	Unnamed	1788	1.6913	0.3757	Orchard	2001～2006	2～4m
4	82	Villa Dolina Township	1321	2.9801	0.6621	Orchard	1996～2001	2～4m
5	83-B	Villa Lolita	2665	4.2007	0.9332	Orchard	2001～2006	2～4m
6	84	RJD Home Subdivision	5959	2.8362	0.6301	Orchard	～1996	0～2m
7	88	Cancabato Village,Fisherman's Village	9806	6.5587	1.4571	Tropical grass	1980s	0～2m
8	91	Kassel City Subdivision	6738	14.4953	3.2203	Woods-brushwood	1997	8～10m
9		Regina Heights Abucay		1.1928	0.2650	Woods-brushwood	2006～	16～30m
10	92	Lolita Heights Subd. Apitong	3889	3.6486	0.8106	Rice paddy	1996～2001	4～6m
11		Villa Innes		1.0495	0.2332	Rice paddy	2001～2006	4～6m
12	93	Peerless Village	3936	13.1854	2.9293	Tropical grass	2004	4～8m
13	95	Beriso heights 1,G&B Homes	4361	4.532	1.0068	Rice paddy	1996～2001	4～6m
14		Villa Mayor		1.7766	0.3947	Orchard	2006～	6～10m
15	109	V&G Subdivision	5473	62.0795	13.7917	Orchard	1960s	2～6m
16	109-A	V&G Subdivision	8163	52.8102	11.7324	Rice paddy	～1996	2～4m
17		Lolita Village(V&G Subdivision)		3.5499	0.7887	Orchard	1996～2001	2～6m

construction waste and other low-quality building materials that caused not only day-to-day safety issues, but also an inherent vulnerability to destructive forces such as typhoon winds and storm surges.

Fig. 4 shows a map of four levels of damage intensity overlaid on house polygon data. Because the damage intensity map (NAMRIA, 2014) did not cover the entire city area, there are considerable areas shown as "No data". Nevertheless, of a total of 6761 house polygons originally surveyed, 39% were destroyed, 21% were highly damaged or moderately damaged, and the remainder were possibly damaged.

Most of the serious damage was concentrated in slum areas along the coast and rivers on land less than 2 m asl. Photos taken by slum residents soon after Typhoon Yolanda (Fig. 5) show the extent of the damage. Watanabe *et al.* (2011) reported that many of the victims of 2009 Typhoon Ondoy lived in low-lying areas along rivers and lake shores in the central part of Luzon Island. There may be many similarly vulnerable areas in the Philippines.

According to our field interviews, provision of information by local governments about the impending Typhoon Yolanda and evacuation plans were poorly distributed in the slum areas in particular. Interviewees believed that both the 2007 hazard maps and the more detailed 2013 hazard maps (based on InSAR data) that were produced only months before Typhoon Yolanda were not well used for disaster prevention. Slum residents told us that they did not know the term "storm surge" before the typhoon (though they knew the word "tsunami"), as was also noted by Esteban *et al.* (2014). Hence many lives were lost because people did not understand what was happening before and during the typhoon. During our field survey in August 2014, about nine months after Typhoon Yolanda, we saw that slum dwellers had rebuilt many homes, mainly by using debris, demonstrating the dynamic nature of slum settlements and their inherent vulnerability to future natural disasters.

Figure 6 Photo in a developed subdivision (subdivision no. 16) showing adequate basic infrastructure (e.g. drains, electric power, and sufficiently wide paved roads)

2.4 Development of subdivisions

Between 1996 and 2014 the number of subdivisions developed in Tacloban City increased steadily (Fig. 2). Our field survey verified that the subdivisions were provided with adequate basic infrastructure, such as roads, water supply and electricity, and that the houses were of sturdy concrete construction (Fig. 6). The subdivisions were farther inland than most of the slum areas and most were more than 2 m asl. Subdivisions 15 and 16, the largest and oldest subdivisions (Fig. 2, Table 1), were developed in the late 1960s, according to interviews with local people. Subsequent subdivisions were on the urban fringe as the population continued to increase and large tracts of land suitable for subdivision in the core of the city became scarce. As the city expanded, squatter communities occupied the vacant inner city areas that were less than 2 m asl.

We noted during our field survey that a new subdivision was being constructed in the area around subdivision no. 5 (2–4 m asl, Fig. 2), confirming the continued pressure for subdivision development in the city. However, some subdivisions are less than 2 m asl (subdivisions 6 and 7; Fig. 2 and Table 1); these were seriously damaged during Typhoon Yolanda.

Figure 7 Examples of vegetable farming in vacant lots within subdivision no. 16

We noted a considerable number of vacant lots within the subdivisions in Tacloban City (Fig. 7), confirming the findings of Hara *et al.* (2011) who reported that vacant lots within subdivision developments were common in the Philippines, and that these lots were sometimes occupied by squatters. To avoid illegal occupation or dumping of rubbish in such lots, some absentee landlords have assigned caretakers to supervise vegetable farming in them (Hara *et al.* 2013), which was also the case in Tacloban City. During our field surveys we came across quite a few vacant lots that were being used for vegetable farming (Fig. 7).

2.5 Estimation of unused residential capacity of existing subdivisions

We wanted to use our GIS datasets (polygons representing subdivisions and the roads and buildings within them) to estimate the total area of available vacant land (including that used for vegetable farming) within the subdivisions, but complete coverage of these datasets was available only for subdivision 15 (Fig. 2), the oldest of the subdivisions. We therefore assumed that land use within subdivision 15 was representative of all of the subdivisions. The GIS data for subdivision 15 indicated that 22.2% (13.79 of 62.08 ha) of the area of the subdivision was available vacant land. During our interviews at the local government hall, we ascertained that the population of subdivision 15 was about 8500 in 2014, indicating that the per capita requirement for residential buildings was 56.8 m^2 (48.29/8500). Therefore, there was capacity for at least 2400 additional people (13.79 ha/56.8 m^2) in the subdivision. We then assumed that 22.2% of the area of the other subdivisions (Table 1) was available, giving a combined total area of available land within subdivisions of 41.6 ha. This area equates to about 7300 additional people on the basis of the above per capita land requirement (41.6 ha/56.8 m^2).

Figure 8 Resident's photo of subdivision 16 showing wind damage and flooding soon after Typhoon Yolanda

The above estimates of the area of available land within subdivisions appear to be reasonable on the basis of the amount of vacant land we observed during our field observations and recent Google Earth images that we examined.

2.6 Damage caused by Typhoon Yolanda in subdivisions

The following descriptions of damage caused by Typhoon Yolanda are based on our interviews with residents of subdivisions in Tacloban City in May 2015.

The inland locations of subdivisions 15 and 16 saved them from damage by storm surge, but there was some wind damage and serious flooding there due to the heavy rainfall (Fig. 8). These subdivisions, which are less than 4 m asl (Fig. 2 and Table 1), were flooded to a depth of about 1 m for few days because of poor drainage, but no deaths were reported.

Subdivision 5 (2–4 m asl), which is close to both a river and the coast, suffered considerable damage from the storm surge and strong winds.

Subdivision 8, inland on high ground (8–10 m asl), experienced no flood damage but suffered serious wind damage and many people were injured. This subdivision was developed by cut-and-fill on a natural slope, which may have contributed to wind damage and increased the probability of landslides after heavy rain.

Parts of subdivision 12 (4–8 m asl) face either the river or the coast and were built on landfill; storm surge caused 31 deaths in these areas.

The position of subdivision 7 on the coast resulted in tremendous damage due to the storm surge and about 1000 deaths. According to our resident interviews, government officials decided after the typhoon that the residents of this subdivision would be relocated to inland socialized housing on higher ground.

Thus, the intensity of damage to subdivisions differed depending on their locations and the micro-landforms within them. Subdivisions close to the coast were severely damaged by storm surge, and there was substantial loss of life. In contrast, there were few injuries and no deaths in the subdivisions in inland lowlands that were flooded for a few days because their drainage systems did not cope with the high rainfall associated with the typhoon.

Because roads within the subdivisions were well-constructed and wide enough for vehicular transport, large local-government-owned trucks and temporary rafts constructed from metal drums and wood (Fig. 8) were used to evacuate people and save lives. Moreover, medical clinics and temporary evacuation shelters in some of the subdivisions reduced the number of injuries and deaths. Nevertheless, as was the case in slum areas, residents felt that the available hazard maps and InSAR data were not effective in mitigating the typhoon disaster; in particular, the 1:50,000-scale storm surge hazard maps (published in 2007) did not adequately identify as hazardous much of the coastal areas that were struck by storm surge.

2.7 Socialized housing projects after Typhoon Yolanda

Most of the information presented in this subsection was gathered during interviews with local government officials in August 2014. At this time, a total of 15 socialized housing projects were underway (under the Yolanda Permanent Housing Project) within seven local government areas that were considered safe from flooding, landslide, storm surge and tsunami (Fig. 9). To be eligible for accommodation in one of the project areas (Ridgeview Park) in the Cabalawan local government area (Fig. 9), applicants must be victims of Typhoon Yolanda and be registered residents of Tacloban City.

Officers at the Tacloban City Housing and Community Development Office told us that before Typhoon Yolanda some of the housing within these 15 project areas was intended to be used to relocate squatters in coastal settlements, but had since been acquired by the NHA for relocation of victims of Typhoon Yolanda.

Site selection for socialized housing projects was based on several criteria. They must be areas where:

- no deaths had occurred associated with Typhoon Yolanda
- there were no records of serious damage caused by past natural disasters
- there were no active faults that might cause earthquakes
- elevations were more than 5 m asl
- very few past flood or landslide events had occurred
- there were no records of past storm surge or tsunami activity.

Prospective areas were assessed against these criteria by the Mines and Geoscience Bureau (Philippine Department of Environment and Natural Resources) and the Philippine Institute of Volcanology and Seismology. The Japan International Cooperation Agency supported storm-surge simulations that were used to assess vulnerability to these events. Planning for the socialized housing projects also referred to the pre-Yolanda comprehensive land-use plan documents compiled in 2013 and selected locations for proposed socialized housing projects close to a major road north of the city that passes through planned locations of future business, commercial and industrial areas (Fig. 9) Thus, planning for the construction of socialized housing projects took advantage of planning documents compiled before Typhoon Yolanda.

We used 2014 Google Earth images to verify the locations and elevations of five of these project areas. We obtained elevations of 11–13 m and 15–17 m for two areas in Sto. Niño, 10–14 m for each of two areas in Cabalawan, and 5–6 m for one area in Tagupuro (Fig. 9). Thus the elevation criterion (at least 5 m asl) was met for these five socialized housing project areas.

At the time of our field survey in May 2015, 300 of the planned 2000 dwellings in the Ridgeview Park socialized housing project in Cabalawan had been built and occupied by victims of Typhoon Yolanda (Figs. 9 and 10). Applicants for housing were required to pay 25 years of rent in advance (200 PHP per month) to gain occupancy.

For previous slum dwellers, the main benefit of this scheme was access to a better standard of housing in safe areas. For administrators, the benefit was that it allowed mangrove reforestation projects to begin without serious opposition from the few remaining slum dwellers (see section 2.8). However, because the relocated slum dwellers were now far from the sources of their livelihoods (the sea, river and city center) income security was problematic. Residents also expressed concern about traffic congestion on access roads to these sites, the increased likelihood of disease or infection due to the high density of housing, high costs and possible future shortages of water, and the reliability of electricity supply.

Some concerns for administrators were the availability of land for more socialized housing projects and their limited budget for acquiring it, and the considerable length of time required to plan and build new socialized housing. The Philippine governments (national and local) did what they could to relocate slum dwellers to socialized housing developments, but were hampered somewhat by bureaucratic processes.

During our field surveys we came across several other types of housing projects including Community Mortgage Program (CMP) sites and projects managed by national and international non-government and non-profit organizations (e.g. Christian and Buddhist organizations). A Buddhist group (Tzu Chi) from Taiwan used volunteers from Manila and also hired coastal victims of the typhoon as construction workers. These people were introduced to the project managers by relatives and received a house to live in as payment for their work. Another CMP project we encountered was not directly linked to the Yolanda event. It had started during Marcos regime (1965-1986) and had already provided house and land to many local poor, requiring advance payment of 25 years rent (616.14 PHP monthly). From our interviews we learned that the American non-government organization "Global Habitat" were providing housing free of charge for individual victims of Typhoon Yolanda.

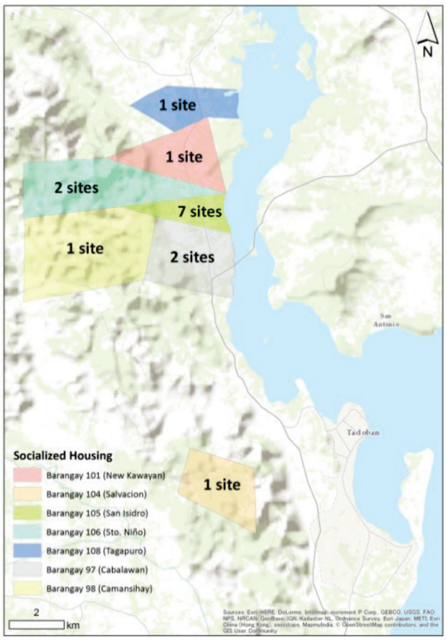

Figure 9 Locations of 15 socialized housing projects for victims of Typhoon Yolanda

2.8 Issues to overcome in planning for a disaster-resilient Tacloban City

Not long after Typhoon Yolanda, a mangrove reforestation pilot project was started on a small area of coastal public land as a damage-mitigation measure for future typhoons or tsunamis. However, to expand the project along the entire coast of the Tacloban area, the many dwellings in coastal slums must be removed. We found, however, that slum dwellers were reluctant to leave their coastal communities, largely because of the disadvantages they perceived in having to move away from their urban and coastal livelihoods to the government-provided socialized housing on higher ground. After Typhoon Yolanda, they were very quick to rebuild their slum houses by using debris from the typhoon.

Other issues of concern for government administrators include uncertainties about the future sustainability of socialized housing developments, for example, provision of basic municipal services, acquisition of land for new projects and other budget-related issues.

2.9 An alternative approach to social housing in Tacloban City

Our observation of vegetable gardens on vacant lots in subdivisions led us to the view that such vacant lots could be used (1) to provide houses for landless slum dwellers and victims of natural disasters such as Typhoon Yolanda, and (2) as areas for them to grow vegetables, thus providing

Figure 10 Example of socialized housing developed for victims of Typhoon Yolanda in Cabalawan (location shown in Fig. 9)

them with both housing and livelihood.

We thought that opposition from the current residents of the subdivisions could be an obstacle, but our interviews revealed their acceptance of this concept as a temporary or even permanent measure. In fact, as well as the vegetable gardens we saw, some of the subdivisions that were built before Typhoon Yolanda were raising livestock on their vacant land with support from paid labor supplied by coastal slum dwellers. Interviews with coastal slum dwellers indicated that they felt moving into such subdivisions to live and grow vegetables was acceptable to them.

As Hara *et al.* (2013) noted in their study of the urban fringe of Metro Manila, using detailed land-use investigations to identify and maximize the value and productivity of vacant lots that are formed in the process of urbanization requires a balance between formal institutional regulation and making use of existing social capital

CONCLUSIONS

This study reinforced the importance to effective land-use planning of applying comprehensive GIS analysis to all available land-use, geomorphologic and geographic datasets. This approach, coupled with extensive stakeholder consultation, can underpin practical and efficient land-use and disaster-mitigation planning that takes into consideration local sociocultural systems.

Our main conclusions are as follows.

1) Structurally weak slum dwellings built by squatters using debris and other cheap materials occupy low-lying areas in inner Tacloban City and along the coast and rivers. Typhoon Yolanda caused massive destruction in these communities. After the typhoon, many squatters quickly re-built their houses by using debris as building materials.
2) Since the 1980s, privately funded subdivision developments for middle- and upper-class housing have expanded on the urban fringe of Tacloban City where acquisition of broad areas of suitable land has been relatively easy. In parallel, low-lying land (less than 2 m asl) in the inner city and along the coast and rivers has been occupied by squatters and become slums.
3) There are enough vacant lots in existing subdivisions to house 7300 residents.
4) Public socialized housing developments located on high ground in the northern inland part of the city have provided safe housing for previous lowland slum dwellers but have been problematic for residents because their relocation has removed them from easy access to their urban and coastal sources of livelihood.
5) Clearance of coastal slum areas along the coast to allow mangrove reforestation as a damage-mitigation measure for future natural disasters has been hampered by the reluctance of squatters to move from their slum communities and the nearby sources of their livelihoods.
6) There is potential for vacant spaces in subdivisions to provide housing (temporary or permanent) for slum dwellers and plots for vegetable farming that will give them work and a source of income.

This paper was based on our previous research report of the Center for Education and Research of Disaster science, Wakayama University.

ACKNOWLEDGEMENTS

This study was supported by the Mitsui & Co. Environment Fund (R13-0105).

REFERENCES

Ahmed, I. (2016) Building Resilience of Urban Slums in Dhaka, Bangladesh. *Procedia – Social and Behavioral Sciences*, No. 218, 202–213.

Birkmann, J., and von Teichman, K. (2010) Integrating disaster risk reduction and climate change adaptation: key challenges—scales, knowledge, and norms. *Sustainability Science*, No. 5, 171–184.

Braun, B., and Aßheuer, T. (2011) Floods in megacity environments: vulnerability and coping strategies of slum dwellers in Dhaka/Bangladesh. *Nat Hazards*, No. 58, 771–787.

Dewan, A.M., Islam, M.M., Kumamoto, T. and Nishigaki, M. (2007) Evaluating Flood Hazard for Land-Use Planning in Greater Dhaka of Bangladesh Using Remote Sensing and GIS Techniques. *Water Resource Management*, No. 21, 1601–1612.

Esteban, M., Matsumaru, R., Takagi, H., Mikami, T., Shibayama, T., de Leon, M.P., Valenzuela, V.P. and Nguyen, T.D. (2014) Study on disaster information dissemination and people's response for evacuation: the case of the 2013 typhoon Yolanda (Haiyan). *Journal of Japan Society of Civil Engineers, Ser. B3 (Ocean Engineering)*, Vol. 70, No. 2, I_1218–I_1223, (in Japanese with English abstract).

Hara, Y., Haruyama, S., Okubo, S. and Takeuchi, K. (2002) Flood hazard response to the urbanized bank up areas of Laguna Lacustrine Plain, Metro-Manila. *Journal of Rural Planning Association Japan*, No. 21(S), 19–24, (in Japanese with English abstract).

Hara, Y., Takeuchi, K. and Okubo, S. (2005) Urbanization linked with past agricultural landuse patterns in the urban fringe of a deltaic Asian mega-city: a case study in Bangkok. *Landscape and Urban Planning*, No. 73, 16–28.

Hara, Y., Takeuchi, K., Palijon, A.M. and Murakami, A. (2008) Landfill development in the urban fringe of Metro Manila. *GeoJournal*, No. 71, 127–141.

Hara, Y., Furutani, T., Murakami, A., Palijon, A.M. and Yokohari, M. (2011) Current organic waste recycling and the potential for local recycling through urban agriculture in Metro Manila. *Waste Management & Research*, No. 29, 1213–1221.

Hara, Y., Murakami, A., Tsuchiya, K., Palijon, A.M. and Yokohari, M. (2013) A quantitative assessment of vegetable farming on vacant lots in an urban fringe area in Metro Manila: Can it sustain long-term local vegetable demand? *Applied Geography*, No. 41, 195–206.

Kobayakawa, Y. (2016) Socialized Housing for Sustainable Community Development Using a Revolving Fund to Achieve Millennium Development Goals. *Journal of Sustainable Urbanization and Regeneration*, No. 1, 53–62.

Kure, S., Suppasri, A., Yi, C.J., Mas, E., Bricker, J.D., Koshimura, S. and Mano, A. (2014) Human loss due to storm surge disaster caused by typhoon Haiyan in the coastal region of Leyte island. *Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering)*, Vol. 70, No. 2, I_1446–I_1450, (in Japanese with English abstract).

National Disaster Risk Reduction and Management Council (2013) FINAL REPORT re Effects of Typhoon "YOLANDA" (HAIYAN).
http://www.ndrrmc.gov.ph/attachments/article/1329/FINAL_REPORT_re_Effects_of_Typhoon_YOLANDA_(HAIYAN)_06-09NOV2013.pdf

National Mapping and Resource Information Authority (2014) 2013 Super Typhoon Yolanda (Haiyan) Maps. http://www.namria.gov.ph/jdownloads/Maps/haiyan_files.zip

Owen, K.K. and Wong, D.W. (2013) An approach to differentiate informal settlements using spectral, texture, geomorphology and road accessibility metrics. *Applied Geography*, No. 38, 107–118.

Saiyot, S. and Matsuyuki, M. (2016) A Quantitative Analysis of Community Resilience towards Flooding in Thailand. *Journal of Sustainable Urbanization and Regeneration*, No. 1, 145–153.

Tajima, Y., Yasuda, T., Pacheco, B.M., Cruz, E.C., Kawasaki, K., Nobuoka, H., Miyamoto, M., Asano, Y., Arikawa, T., Ortigas, N.M., Aquino, R., Mata, W., Valdez, J. and Briones, F. (2014) Initial Report of JSCE-PICE Joint Survey on the Storm Surge Disaster Caused by Typhoon Haiyan. *Coastal Engineering Journal*, No. 56, 1450006, 1–12.

Thomson, C.N. and Hardin, P. (2000) Remote sensing/GIS integration to identify potential low-income housing sites. *Cities*, No. 17, 97–109.

Watanabe, A., Nakasu, T. and Inokuchi, T. (2011) Representations over a Tropical Storm Disaster and the Restoration of Everyday Lives for Urban Poor Victims in the Philippines: The Case of Typhoon Ondoy. *Natural Disaster Research Report of the National Research Institute for Earth Science and Disaster Prevention*, No. 45, 75–80.

Yeung, Y. (2001) Coastal mega-cities in Asia: transformation, sustainability and management. *Ocean and Costal Management*, No. 44, 319–333.