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Urbanisation, Demographics and Adaptation to Climate Change in Semarang, Indonesia

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Acronyms and Abbreviations

ACCCRN	Asian Cities Climate Change Resilience Network
BAPPENAS	National Development Planning Agency
BKKBN	National Population and Family Planning Board
BNPB	National Agency for Disaster Management
BPS	Central Statistical Bureau

CCROM	Centre for Climate Risk and Opportunity Management
CEO	Care Environmental Organization
COP	Congress of the Parties
DFID	Department for International Development
DNPI	National Council on Climate Change
FPPI	Semarang Climate Change Forum
GCM	Global climate model
GDP	Gross domestic product
GHG	Greenhouse gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICCSR	Indonesia Climate Change Sectoral Roadmap
IPB	Bogor Agriculture Institute
IUCCE	Initiative for Urban Climate Change Environment
LECZ	Low elevation coastal zone
Kedung Sepur	Kendal-Demak-Ungaran-Salatiga–Semarang–Purwodadi
KLH	Ministry of Environment
KSN	National Strategic Area (Kawasan Strategis Nasional)
NGO	Nongovernmental organisation
PAKLIM	Policy Advice for Environment and Climate Change
RAN-API	National Action Plan Addressing Climate Change
RAN-GRK	National Action Plan on Greenhouse Gas (GHG) Reduction
RAN-MAPI	National Action Plan on Mitigation and Adaptation to Climate Change
SLR	Sea level rise
SMA	Semarang Metropolitan Area
STI	Secure tenure index
SST	Sea surface temperature
SAT	Surface air temperature
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund

Introduction

Addressing the impacts of climate change is a strategic issue that requires a comprehensive and sustainable approach. As a result of climate change, global temperatures are expected to continue to rise, resulting in sea level rise and an increase in the frequency of extreme weather events such as floods, droughts, landslides and storms. These hazards are expected to affect natural ecosystems, as well as human communities through their costly impacts on basic services, infrastructure, housing, economic livelihood and health.

Cities in Indonesia face unique challenges in the context of climate change because of the country’s geographic characteristics, as well as its rapidly growing economy. As an archipelagic nation, low-lying coastal areas and many small islands are vulnerable to the impacts of sea level rise. The country already suffers from drought, extreme temperature fluctuations, and land degradation and desertification, all of which are expected to worsen as a result of climate change.

Additionally, as an emerging economy, Indonesia is struggling to find the best way to balance national economic development with reductions in greenhouse gas (GHG) emissions and environmentally responsible development (Hayes, 2011). Unsustainable economic activities, land-use change and deforestation have resulted in Indonesia's position as one of the top three GHG emitters in the world (Sari *et al.*, 2007).

In addition to environmental changes, Indonesia has seen a steady increase in the portion of its population living in cities. About 50 per cent of the country's residents live in urban areas, a figure that is expected to increase to 65 per cent by 2025 (World Bank, 2013a; BAPPENAS, BPS, UNFPA, Population Statistics, 2005). This urban growth is occurring despite an overall decline in Indonesia's population growth rate (World Bank, 2012). It is estimated that approximately 40 per cent of this urban growth can be accounted for by migration and reclassification, as opposed to natural increases (Firman, 2004).

To the extent that these expanding cities are located in areas that are especially susceptible to the environmental hazards associated with climate change – as are the many coastal cities of Indonesia – cities are increasingly important sites of overlap between concentrated populations and exposure to environmental hazards. This makes urban areas important sites for examining vulnerability and fostering adaptive capacity.

Although Indonesia is undergoing a process of urbanisation, its rate of urban growth is more gradual than many other middle-income developing countries, which provides an opportunity for this growth to be managed in regard to its environmental impacts. To effectively manage urban development and increase resilience requires a comprehensive understanding of the links between local population dynamics and climate change (Schensul and Dodman, 2013; Hayes, 2011). This includes understanding the localised risks of exposure to particular environmental hazards, as well as the levels and drivers of vulnerability among the local population.

Responding to climate change therefore requires an in-depth analysis of the specific social, economic, political and geographic dynamics of each particular city and its interaction with environmental processes. As a result of its geographic, economic and demographic context, urban Indonesia provides an important site for examining urban vulnerability to climate change and understanding capacities for responding and adapting to this.

Vulnerability to climate change is described as the susceptibility of a system to climate change and its inability to cope with the consequences (IPCC, 2011). Vulnerability has three components: hazard exposure, sensitivity and adaptation capacity. The spatial relationship between population dynamics and climate change risk exposure and vulnerability is the main concern of this paper. Specifically, we use the city of Semarang in Indonesia as a case study to develop an understanding of variation in the geography of urban vulnerability to climate change.

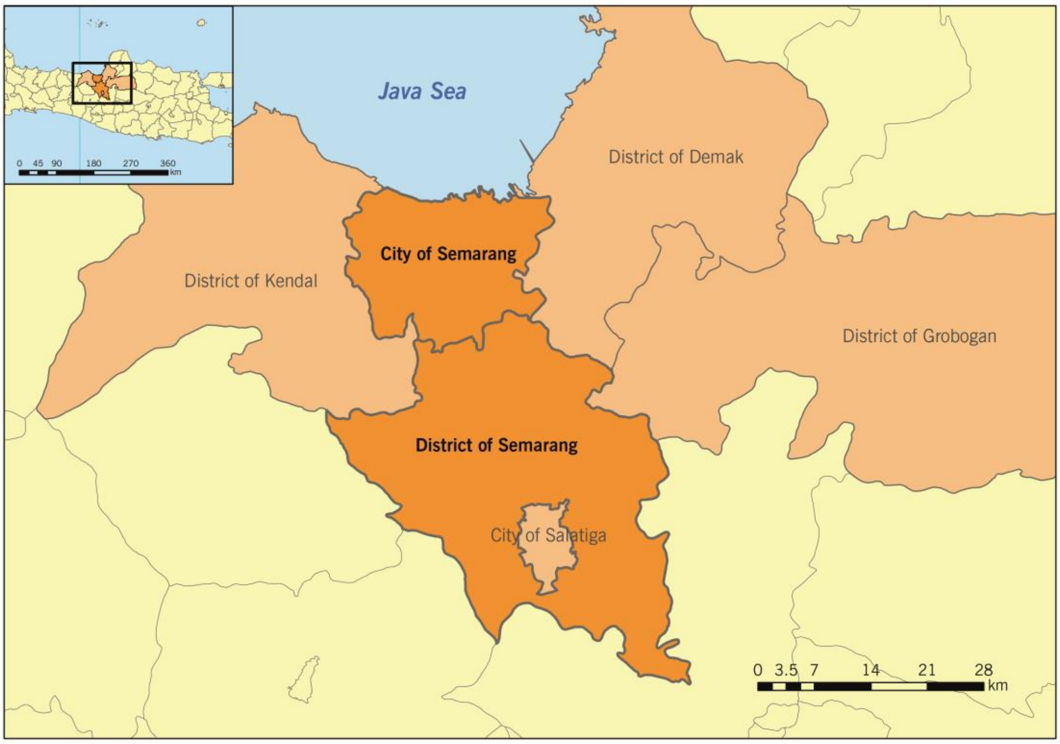
Using demographic and hazard risk data in conjunction with spatial analyses, we develop a framework for identifying the geographic distribution of potential vulnerabilities. This analysis allows for a community-level, contextualised understanding of vulnerability and can provide a foundation for more effectively fostering adaptive capacity. This localised understanding of needs enhances the capacity of communities to negotiate for resources, and also allows governments to better understand levels of need and more effectively direct resources at the most vulnerable communities and populations.

Although efforts to address climate change in Indonesia have mainly focused on the national level, hazard risks, vulnerability and the potential for adaptation and resilience are also urban governance and management issues. In this study, we base our emphasis on local efforts to assess and address climate change vulnerability in Semarang on the notion that governments must be well informed about local population dynamics to confront the impacts of climate change.

By studying local environmental and population dynamics in Semarang, and exploring the policy and governance context in which they play out, this study provides the opportunity to integrate appropriate adaptation and risk-management strategies into existing urban development and planning.

Semarang is major port city on the northern coast of Java Sea (Figure 1). As of 2010, the broader Semarang Metropolitan Area (SMA) had a population of almost 5.5 million residents, including the approximately 1.5 million people who live in Semarang City itself (BPS, 2010). The city is currently experiencing an annual population growth rate of 1.4 per cent whereas the SMA is growing at 0.7 per cent. As the population of Semarang continues to grow, so too does the risk for exposure to hazards associated with climate change.

Figure 1 Semarang Metropolitan Area (SMA)



Throughout this study, we use spatial and policy analyses to examine climate change hazard exposure, vulnerability and adaptation. The use of spatial analysis allows for the identification of those regions of Semarang that are the most vulnerable to the environmental hazards associated with climate change.

The hazard data is then mapped in conjunction with demographic information including population density, age, household characteristics and other social and demographic indicators to assess the relationships between community characteristics and vulnerability, as well as the potential for communities to adapt to the impacts of climate change.

The process of spatially linking hazard-exposure risk information to demographic data can provide information about who is most vulnerable and the types of interventions that will maximise the potential for adaptation (Schensul and Dodman, 2013). In addition to spatial analysis, key policies were examined to assess the extent to which national and local government efforts to address climate change take into account the important role that population dynamics play in shaping vulnerability.

This policy analysis was complemented by qualitative interviews with officials from local government, and nongovernmental organisations (NGOs) and community organisations that deal with climate change issues. These processes are laid out in the sections below. We begin by establishing a conceptual framework for understanding the relationship between urbanisation and climate change vulnerability. The subsequent section provides a brief overview of population dynamics in Indonesia.

We then discuss specific population dynamics in the case study area of Semarang and provide an overview of climate change vulnerability and potential for adaptation in Indonesia, and Semarang specifically. Policy responses to these dynamics are then analysed. Finally, we generalise conclusions from the analysis to consider potential responses to the impacts of climate change on these areas.

1 Urbanisation and Climate Vulnerability

More than one-third of the world's population currently lives in urban areas in low- and middle-income nations. These cities contain nearly three-quarters of the world's urban population and are expected to continue to grow rapidly over the coming decades. This process of urbanisation has important implications for climate change and vulnerability.

Urbanisation and the related concentration of population and economic activity can in some cases contribute to climate change (Romero-Lankao and Dodman, 2011). In many cities, particularly in low-income countries, population densities are especially high and create urban heat islands that magnify temperature changes associated with global climate change.

In low- and middle-income countries, in particular, rapid urbanisation has often expanded the demand for housing, infrastructure and services in cities beyond the available supply. This places significant pressure on existing resources, and potentially forces development into environmentally hazardous areas where construction often uses makeshift materials and techniques (UN Habitat, 2011; Davis, 2006).

Residents in these areas may therefore be subject to more frequent and severe hazards, and the impacts of these hazards on local housing and infrastructure are especially detrimental. To the extent that these areas develop without adequate infrastructure such as water, sanitation and drainage, residents are also vulnerable to negative health consequences (Romero-Lankao and Dodman, 2011; Satterthwaite *et al.*, 2007). The failure of urban areas to adapt change can be catastrophic for those populations that climate change affects directly and indirectly (ISET, 2009).

A World Bank study categorised these potential impacts along three dimensions: (i) Environmental – Changes in coastal and marine systems, forest cover and biodiversity; (ii) Economic – threats to water security, impacts on agriculture and fisheries, disruption of tourism, and reduced energy security – all of which could have negative impacts on gross domestic product (GDP); and (iii) Social – Population displacement, loss of livelihood, and increased health problems (Sinha *et al.*, 2009).

Although climate change can pose a significant challenge for cities around the world, by gaining a better understanding of local risks and drivers of vulnerability, urban stakeholders are better positioned to adapt to its consequences (Hallegatte and Corfee-Morlot, 2011). Urban areas cannot be overlooked as a key innovation arena for formulating policies, initiatives and activities aimed at reducing emissions and adapting to and mitigating the effects of climate change (Romero-Lankao, 2008).

Municipal governments generally have control over land-use planning and public transportation, which means that they are well positioned to play a role in fostering climate change adaptation (Dodman, 2009). Additionally, the concentration of people and industries in cities allows for concentrated innovation and economies of scale when it comes to addressing climate change. By recognising the challenges and opportunities related to urbanisation and climate change, cities can better position themselves to increase their capacity to cope with climate hazards and their impacts.

2 Population Dynamics in Indonesia

2.1 Indonesian population trends

Indonesia consists of 17,504 islands, bridges the continents of Asia and Australia and is intersected by the equator. The country reaches 3,977 miles from the Indian Ocean to the Pacific Ocean and comprises five main islands: Sumatra (with an area of 473,606 km^2); Java (132,107 km^2); Kalimantan (539,460 km^2); Sulawesi (189,216 km^2); and Papua (421,981 km^2).

In addition to its large geographic size, Indonesia is the world's fourth most populous country after China, India and the United States. In 2010, it had a population of 237.6 million people (BPS, 2010). Compared to the total population of 203.4 million in 2000, this represents an increase of approximately 33 million people in 10 years, constituting a growth rate of 1.49 per cent.

In terms of distribution, the population is heavily concentrated on Java, the most populous island in Indonesia, with approximately 60 per cent of the country's population. Despite being home to a majority of Indonesia's population, Java comprises only 7 per cent of the country's total area (UNDP, n.d.).

Table 1 Population of Indonesian islands, 2010

Island	**Total population**	**% of Indonesian population**	**Urban population**	**Rural population**	**Urban Pop. (%)**	**Rural Pop. (%)**
Sumatra	50,630,931	21.3	19,787,423	30,843,508	39.1	60.9
Java	136,610,590	57.5	79,948,347	56,662,243	58.5	41.5
Bali- Nusa Tenggara	13,074,796	5.5	5,126,415	7,948,381	39.2	60.8
Kalimantan	13,787,831	5.8	5,798,975	7,988,856	42.1	57.9
Sulawesi	17,371,782	7.3	5,842,957	11,528,825	33.6	66.4
Maluku Papua	6,165,396	2.6	1,813,901	4,351,495	29.4	70.6
Indonesia	**237,641,326**	**100**	**118,318,017**	**119,323,309**	**49.8**	**50.2**

Source: Directorate-General of Spatial Planning based on Central Statistical Bureau (BPS) Population Census, Ministry of Public Works, 2012b

2.2 Urbanisation in Indonesia

During the past three decades, Indonesia has experienced substantial urbanisation. In 2010, 49.8 per cent of the population, more than 118 million people, lived in urban areas. This is in contrast to an urban population of 85 million in 2000, which constituted about 42 per cent of the Indonesian population. The National Development Planning Agency (BAPPENAS) (2005) estimates that by 2025, 65 per cent of the country's total population will live in urban areas. Much urban population growth in Indonesia is held to be the result of rural-urban migration patterns (Resosudarmo and Suryadarma, 2011).

Table 2 Urban and rural populations in Indonesia

Year	Urban population[1] (million)	Rural population (million)	Total population (million)	Population living in urban areas (%)	Annual urban growth rate (%)
1971	20.5	98.9	119.4	17.2	-
1980	32.8	114.1	146.9	22.4	6.67 (1971-80)
1990	55.5	123.8	179.3	30.9	6.92 (1980-90)
2000	85.8	117.7	203.5	42.2	5.46 (1990-2000)
2010	118.3	119.3	237.6	49.8	3.79 (2000-10)

Source: Central Statistical Bureau (BPS) cited in World Bank, 2012, p. 10

2.3 The City as Administrative Region

The definition of urban area varies from country to country. Therefore, it is difficult to conduct international comparisons concerning levels of urbanisation. In the case of Indonesia, the 2004 Law on Local Governance refers to three administrative categories of urban areas. These are:

1) Urban areas as autonomous regions known as city governments
2) Urban areas as part of district government boundaries
3) Urban areas as part of two or more administrative boundaries.

In terms of these categories of administrative regions, Indonesia has 34 provinces, 94 autonomous city governments and 399 district governments. Table 3 shows the number of autonomous cities (those that fall into category 1 above) and their classification in terms of population. Of the autonomous cities, the largest – those with a population of greater than 1 million people – are classified as metropolitan cities. This includes Semarang City, which has a population of approximately 1.5 million people.

[1] The definition of urban areas used by the Central Statistical Bureau (BPS) relies on three main indicators namely: population density of 5,000 people or more per km^2; 25 per cent or less of households working in the agricultural sector; and access to eight or more types of urban facilities (Firman, 2004).

Table 3 Autonomous cities in Indonesia

City size classification[2]	Number of cities	Area (km^2)	Total population (2010)	Population living in autonomous cities (%)
Metropolitan cities	11	3109	28,356,337	54.28
Large cities	16	4401	11,367,533	21.76
Medium cities	56	14,691	11,770.504	22.53
Small cities	11	12,339	745,581	1.43
Total	**94**	**34,541**	**52,239,955**	**100.00**

Source: National Development Planning Agency (BAPPENAS), 2010

2.4 Semarang Metropolitan Area (SMA)

Indonesia's 2030 National Spatial Plan identified National Strategic Areas (KSN) based on criteria related to defence and security, economic growth, social and cultural role, natural-resource management and environmental carrying capacity. One such area is the Semarang Metropolitan Area (SMA), also known as Kedung Sepur (Kendal-Demak-Ungaran-Salatiga–Semarang–Purwodadi). The SMA consists of six districts/cities, which include: Kendal District, Demak District, Semarang City, Semarang District, Grobogan District, and Salatiga City (see Figure 1).

In terms of population distribution, almost one-third of Kedung Sepur's population lives within Semarang City, which is currently experiencing an annual growth rate of approximately 1.4 per cent. It is predicted that by 2030, the population of the larger SMA will have reached 7.156 million inhabitants, with about 36 per cent living in the city of Semarang (Ministry of Public Works, 2012).

Despite this growth throughout the region, the rate of population growth in Semarang City has been higher than the surrounding areas (the growth rate for the whole SMA is about 0.7 per cent). This indicates its importance in attracting migrants from surrounding areas, as well as its status as the region's core city.

Semarang is also noted to be particularly vulnerable to hazards related to climate change because of its low coastal position, sea-water incursion, subsidence, landslides and cyclones. This combination of demographic and environmental characteristics makes the SMA a particularly important site for examining local vulnerabilities and adaptability to climate change.

[2] These classifications are derived by BPS based on population size and are as follows: metropolitan city (population greater than 1 million), large city (population between 500,000 and 1 million), medium city (population between 100,000 and 500,000) and small city (population below 100,000).

Table 4 Population of Kedung Sepur

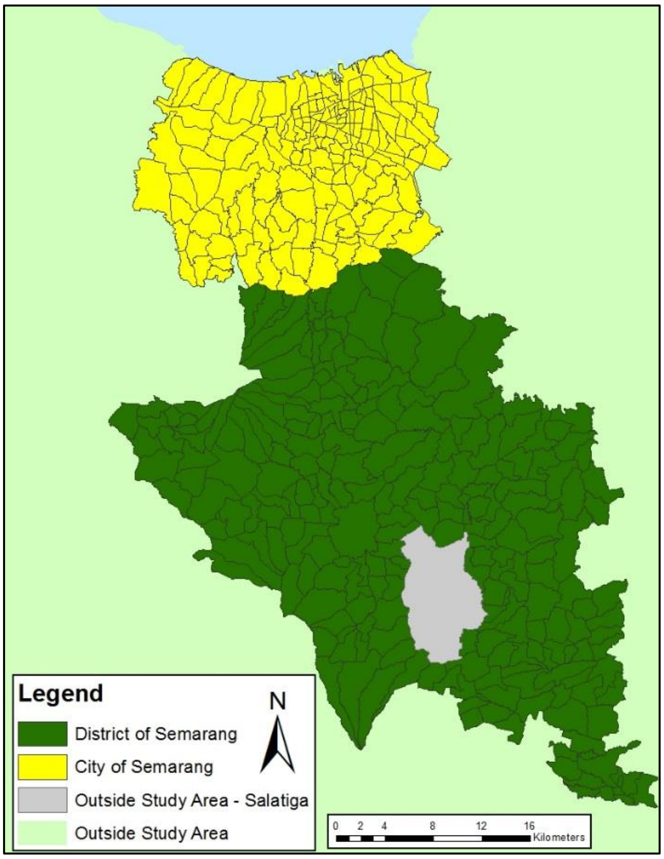
City/District	Population size			Population growth rate (%/year)	Projected population 2030
	2000	2005	2010		
Semarang City	1,309,667	1,419,478	1,553,778	1.4	2,569,986
Semarang District	831,262	896,048	993,772	1.2	1,285,836
Salatiga City	144,796	166,740	171,067	1.7	1,259,290
Kendal District	878,095	905,803	900,611	0.3	821,023
Demak District	980,218	1,036,521	1,058,938	0.8	977,159
Grobogan District	806,588	831,460	808,402	0.02	242,842
Kedung Sepur Area	**4,950,626**	**5,256,050**	**5,426,568**	**0.7**	**7,156,136**

Source: Technical Report of SMA, Ministry of Public Works, 2012

2.5 Demographic characteristics of the Semarang Metropolitan Area (SMA)

In examining exposure to climate hazards, vulnerability and adaptation to climate change, our spatial analysis focuses specifically on Semarang City and Semarang District, directly south of the city, because these are among the largest and fastest growing districts in Kedung Sepur (Figure 2). These areas have a combined population of almost 2.5 million people, though Semarang City has the higher concentration of residents. Here, population densities reach more than 23,000 people per km^2.

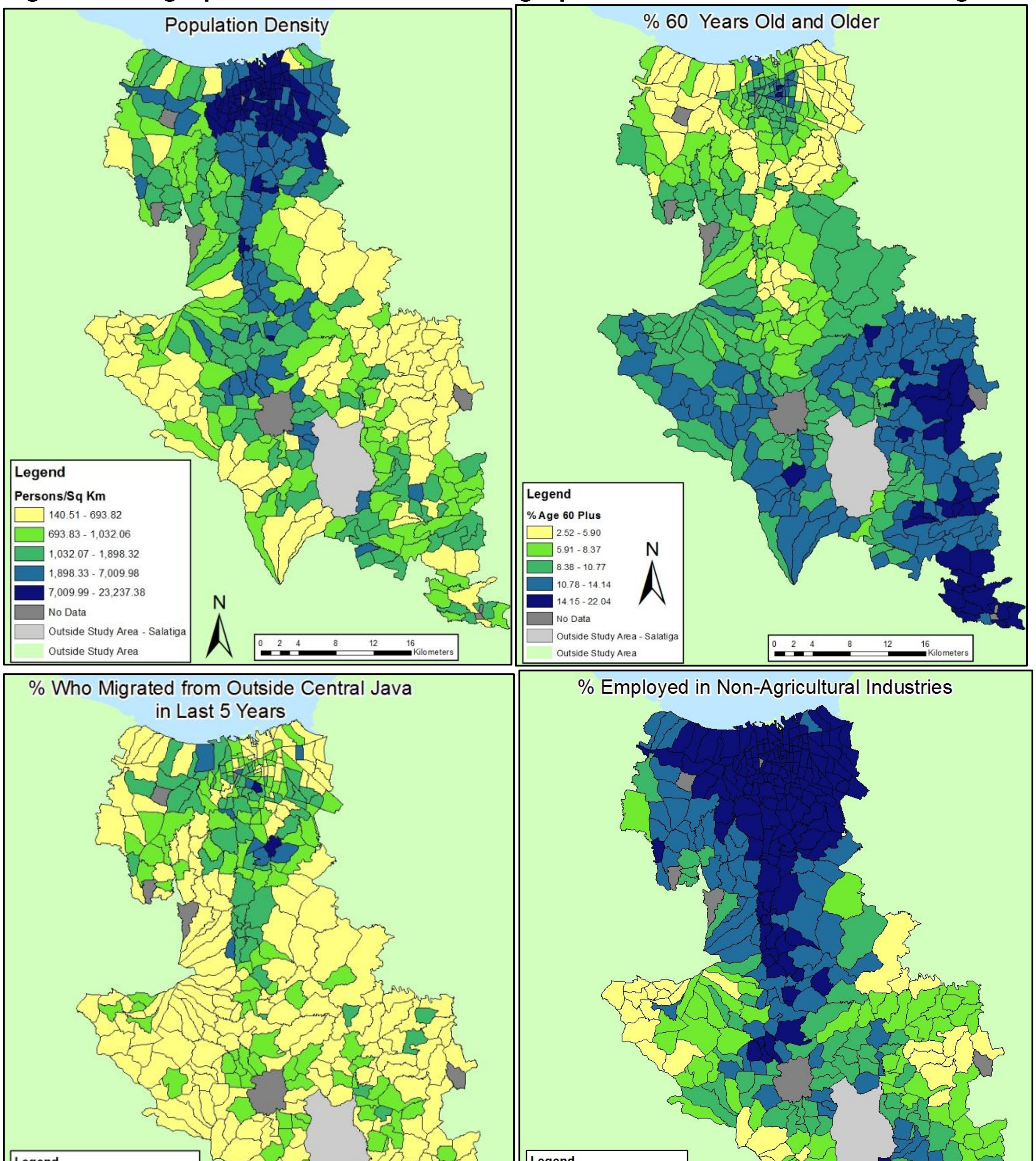
Figure 2 Districts within Semarang



Source: Central Statistical Bureau (BPS), 2010

Given the population growth rate, it is likely that these densities will continue to increase. Although the majority of the people in our study area live in Semarang City, about 1 million live in the more rural Semarang District that lies to the south of the city. Village-level population densities tend to be much lower here, as Figure 3 shows.

Figure 3 Geographic distribution of demographic characteristics in Semarang



Source: Central Statistical Bureau (BPS), 2010

The population of the Semarang study area is relatively young with 42.55 per cent of all residents under the age of 25 and a median age of 29 (BPS, 2010). Approximately 8 per cent of the region's population is over the age of 60. A higher proportion of these older residents live in villages in the more rural areas of southern Semarang District, where more than 10 per cent of residents are over the age of 60 compared to 6.85 per cent in Semarang City. A few villages within the city (village is the term used for the smallest administrative areas, whether rural or urban), however, have a relatively high percentage of older residents.

Examination of the geographic distribution of migration within Semarang is constrained by the census data. It is possible to examine the proportion of residents who migrated to Semarang from outside the province of Central Java, but there is no way to estimate the proportion of residents who migrated from within Central Java. In Semarang, recent migration from outside of Central Java is limited. Overall, only 1.74 per cent of residents report having lived outside of Central Java five years ago.

The migration that has occurred has been centred on the urban communities in the north of the region and those communities just south of the central city. In some of these areas, up to 20 per cent of residents lived outside Central Java five years ago. Data from the 2005 Intercensal Population Survey (Resosudarmo *et al.*, 2009) suggest that almost 27 per cent of residents of Semarang City are long-term migrants, and of these almost 22 per cent came to the city from rural areas. These dynamics suggest that a significant portion of migration in Semarang City consists of regional migration of residents to the municipality from nearby rural areas.

Although migration may place additional pressures on the existing environmental and infrastructural resources in the city, across Indonesia a majority of those migrating from rural to urban areas have experienced improved access to the types of basic services and infrastructure that reduce vulnerability to climate hazards (Akiyama and Larson, 2004). In Semarang, of those residents of working age, just over 57 per cent were working during the week prior to the 2010 census (BPS, 2010).

Of these, almost 83 per cent worked in non-agricultural industries. This reflects the role of the city as an important port and manufacturing centre. As is to be expected, those employed in these non-agricultural occupations are concentrated in the urbanised areas around the municipality of Semarang. As Figure 6 shows, in some of the communities in the urban areas of northern Semarang, almost 100 per cent of those who are employed work in non-agricultural industries. In the more rural areas to the south, agricultural employment is more prevalent.

3 Climate Change Impacts and Vulnerability in Indonesia

3.1 Climate change and its impacts in Indonesia

Climate change in Indonesia has been marked by an increase in surface air temperatures, precipitation change, sea surface temperature rise, sea level rise, and extreme climatic events. The country is especially vulnerable to the negative consequences of these hazards given its vast coastline, its already high susceptibility to natural disasters, and its agricultural production systems.

In recent years, Indonesia has experienced an increase in the frequency of severe climate-related hazards with floods and windstorms accounting for 70 per cent of these disasters; and droughts, landslides, forest fires, heat waves, storms and others climatic events accounting for the remaining 30 per cent (ISET, 2010). Between 2003 and 2005 alone, there were 1,429 disaster incidents in Indonesia, of which about 53 per cent were hydro-meteorological disasters (BAPPENAS and Bakornas PB, 2006).

Box 1 Climate change in Indonesia (ICCSR, 2010)

Increases in surface air temperature (SAT): A limited number of stations have collected SAT data over the past 100 years that show a temperature increase of approximately 0.5°C during the 20th century (ICCSR, 2010). Between 2020 and 2050, it is projected that average temperatures in Indonesia will increase between 0.8°C and 1°C relative to the baseline period of 1961 to 1990 (ICCSR, 2010).

Precipitation change: Projected precipitation patterns show significant temporal and spatial variations. In Indonesia, it is important to note that changes in rainfall trends vary not only by season but also from month to month. For example, in Jakarta rainfall in January was shown to have increased by around 100 mm in the period between 1955 and 1985 when compared to the period between 1885 and 1915 (ICCSR, 2010).

Sea surface temperature (SST): The average SST in Indonesian sea waters is projected to increase by as much as 0.65°C by 2030, 1.10°C by 2050, 1.70°C by 2080, and 2.15°C by 2100 (ICCSR, 2010). One of the immediate impacts of SST increase is the depletion and movement of fishing stocks away from Indonesian waters.

Sea level rise (SLR): SLR for Indonesia has been projected from observed satellite altimeter and tidal data, as well as from global climate model (GCM) output. An average SLR of 0.6 cm/year to 0.8 cm/year has been estimated from the output of four GCMs (ICCSR, 2010).

Climate-related risks vary across Indonesia, from east to west and from island to island. Important differences exist between regions in terms of geography, culture, environment, socio-economic conditions and political context. Over the past decade, a process of decentralisation has resulted in the transfer of responsibility and significant resources to local government, providing challenges and opportunities for responding to climate change. This variation in hazard exposure as well as social and political characteristics makes localised, place-based adaptation planning especially important to consider.

3.2 Climate change trends in Semarang City

The SMA faces a number of potential hazards related to climate change (Stinson and Taylor, 2010). Rising sea levels in the low-lying coastal areas pose a substantial threat of increased flooding. This risk is further magnified by changing weather patterns, which extend the length of the wet season and increase the intensity of the dry season, which results in more frequent droughts. Resulting changes in groundwater levels are likely to undermine the stability of land, potentially increasing the frequency of landslides.

Variation in exposure to these climate hazards, sensitivity to their impacts and the ability of residents to adapt to these challenges mean that climate change will affect segments of the city's population in different ways.

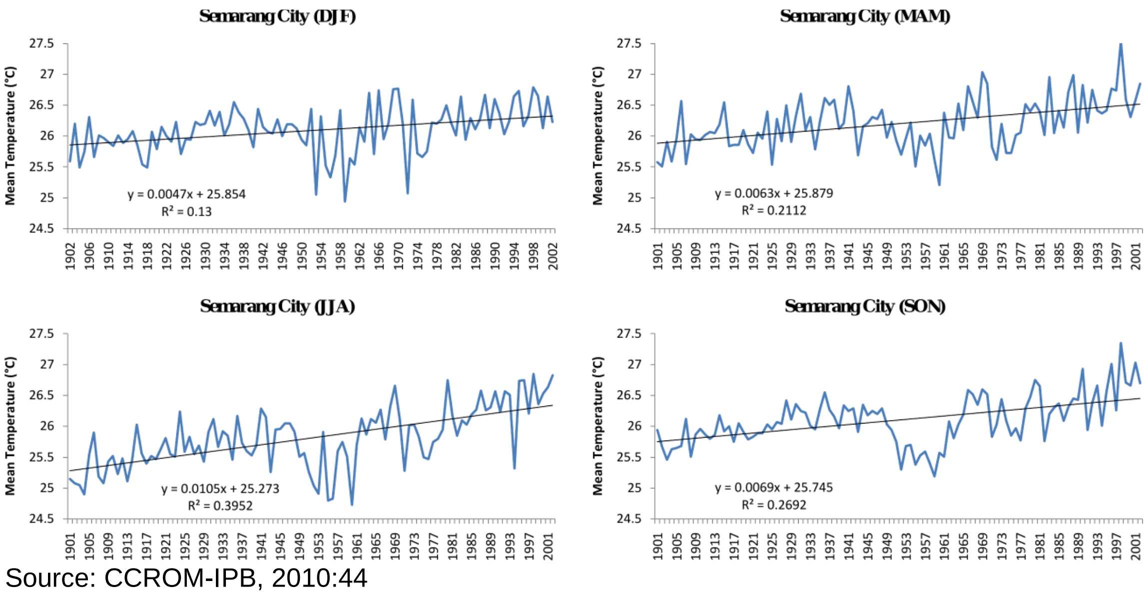
Limitations in climate data present an obstacle to obtaining a comprehensive understanding of climate variability and changing conditions in Semarang. A vulnerability study that the Centre for Climate Risk and Opportunity Management (CCROM) conducted found, however, that climate change is occurring in Semarang and has resulted in a change in temperature and rainfall trends (CCROM-IPB, 2010).

The most tangible evidence of this is the increase in monthly average surface temperatures over the past 100 years. In the CCROM study, temperature and rainfall trends in Semarang City were analysed based on data extracted from the Climate Research Unit (CRU) for the period between 1901 and 2002.

As can be seen in Figures 4 and 5, the data show significant changes in climate trends in Semarang. Figure 4 shows a significant increase in temperature over the past 100 years; Figure 5 indicates a significant temporal shift in rainfall at the beginning and end of the season, as well as a changing frequency of extreme conditions. In general, rainfall has increased in its intensity during the rainy season, whereas the number of rainy days has decreased during the dry season, potentially leading to more frequent drought.

In addition, between 1985 and 1998,[3] coastal areas in Semarang experienced rising sea levels (Semarang City Government, 2010), with an additional rise of between 0.4 m and 0.8 m projected over the next 100 years. This rate of sea level rise will expand the inundation area between 1.7 km and 3 km inland.

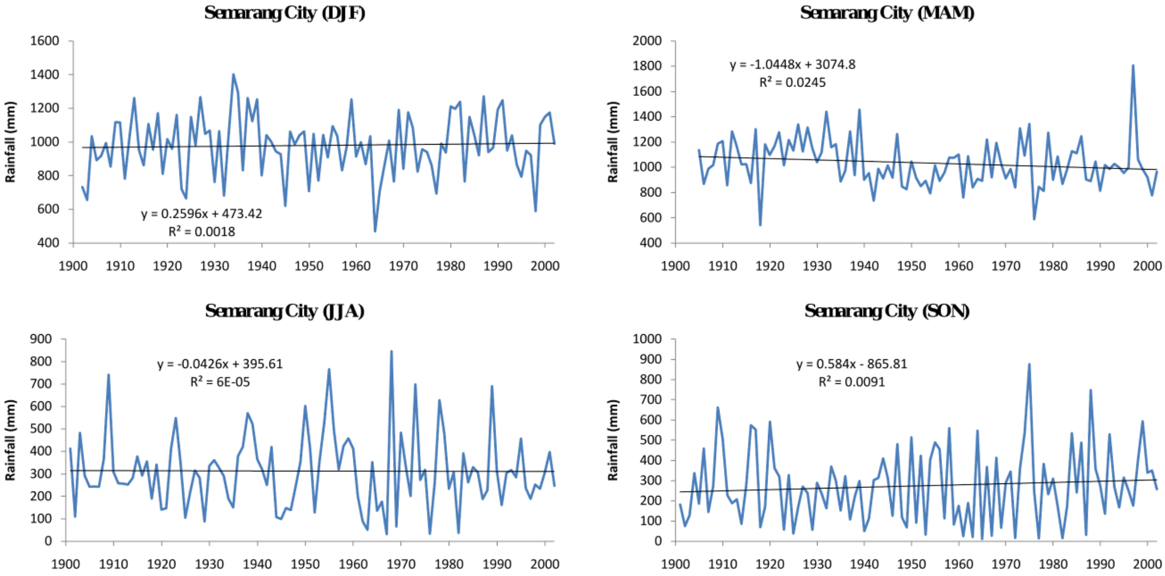
Figure 4 Average temperatures in Semarang City, 1902-2002
[abbreviations in brackets refer to months of the year]



Source: CCROM-IPB, 2010:44

[3] More recent measurements were deemed unreliable because of instrument failure.

Figure 5 Rainfall in Semarang City



Source: CCROM-IPB, 2010:42

3.3 Climate hazards and vulnerability in Semarang City

An Asian Cities Climate Change Resilience Network (ACCCRN) project in 2009 instituted a shared-learning dialogue in which city stakeholders tried to understand how changes in the climate shape vulnerability. The ACCCRN also supported a community-based assessment to identify the most vulnerable groups and the areas of Semarang most vulnerable to extreme climate events and climate change (Taylor, 2010). The areas of Semarang that were identified as particularly vulnerable were:

1. Lowland regions, which are exposed to coastal flooding and sea level rise
2. Settlement areas located in riverbeds, which are exposed to flooding
3. Hilly areas, which are exposed to high winds
4. Areas that are exposed to land movement and landslides
5. Neighbourhood residential areas on the city outskirts, which are far away from water sources
6. Nodes of movement and transportation (i.e. airports, seaports, train stations, terminals)
7. Functional central business districts (with an emphasis on the areas of trade and industry)
8. Historic areas and cultural assets (i.e. Old Town area of Semarang).

Furthermore, CCROM carried out a scientific vulnerability assessment (2010) to analyse the area's current and future vulnerability to climate change. The assessment found links between exposure to climate change hazards and demographic characteristics that may increase vulnerability. Table 5 summarises potential hazards, the areas and sectors most affected by these hazards, vulnerable groups and key issues that would exacerbate the hazards' impact.

Table 5 Summary of climate vulnerability in Semarang City

Climate hazard	**Tidal flooding**	**Coastal erosion**	**Drought**	**Landslide**
Vulnerable areas	Coastal areas and river banks: Tugu, Kemijen, Bandarharjo, Panggung Lor, Dadapsari, Gunungpati, Gayamsari, Genuk, Pedurungan	Coastal areas: Tapak	Sukorejo	Upper area of Semarang (hilly): Tandang and West Seamarang
Affected sectors	Fisheries and fishery ports; small industries; transportation; housing; tourism; agriculture; public service	Fisheries; energy delivery infrastructure (electricity towers); tourism; ecosystem (mangroves); coastal residences	Agriculture; health; industry; forestry; housing	Housing; transportation
Most vulnerable groups	Slum settlements; fishermen; women; entrepreneurs; farmers	Fishermen; those dependent on tourism	Poor residents; entrepreneurs; farmers	Poor residents
Key issues that worsen impact	Poor waste management; inadequate drainage; unemployment; insecure tenure; destructive fishing practices; salinisation; lack of clean water supply; lack of early warning system			

Source: ACCCRN, 2009; ISET, 2010; Bintari, 2012

Although previous studies are critical in examining vulnerability to climate change, the current work builds on their findings to create a comprehensive spatial vulnerability assessment of all of Semarang and highlights those areas with relatively high risk in conjunction with relatively high vulnerability. It does this by using geographic data to examine the spatial distribution of hazard exposure, as well as demographic and infrastructural factors that can influence vulnerability.

Understanding the spatial overlap between these dynamics allows us to identify areas that may be especially vulnerable and provides information about the factors shaping that vulnerability. It can therefore provide important information for determining where to target efforts at increasing adaptive capacity, and the types of resources that communities need to reduce vulnerability.

3.4 Spatial, social and demographic dimensions of climate vulnerability and adaptation in the Semarang Metropolitan Area

The purpose of this study is to examine the spatial correspondence between exposure to climate change hazards and the vulnerability of the population of Semarang to the impacts of these hazards. Additionally, we create a framework for identifying those communities with the highest levels of hazard risk and vulnerability and examining the contextual factors driving local vulnerability. To systematically analyse these dynamics, we proceed in three steps.

First, we examine the spatial distribution of risk of exposure to environmental hazards across the study area. We specifically look at exposure to flooding and landslide risk. We then categorise villages based on their average hazard risk, and examine the distribution of demographic and household characteristics within each level of risk. This analysis provides us with an assessment of whether households that have higher levels of vulnerability based on demographic and household characteristics are concentrated in areas with relatively high levels of hazard risk.

Second, we use census data to further assess levels of vulnerability specifically within those villages that have relatively high levels of risk for flooding and landslides. Finally, within those villages that are the most vulnerable, we analyse the factors that make them vulnerable. By identifying the sources of vulnerability in the most vulnerable areas of the city, we can provide information about how to best target resources at enhancing adaptive capacity.

In discussing the process of building a successful adaptation strategy, Hayes (2011:57) identifies four key steps that must be taken. First, the environmental hazards that are likely to affect a particular location must be identified. Second, the vulnerable populations in those areas must also be identified. It is then necessary to identify precisely what makes people in those areas vulnerable. Finally, policies need to be developed to enable the populations to adapt to the risks. Our analysis addresses steps one to three in this process, and thereby provides the information necessary for step four.

These analyses rely on data from the 2010 Indonesian census conducted by BPS,[4] the Indonesian census agency, and climate hazard risk data from the National Agency for Disaster Management (BNPB). The census data provide information about various demographic and household characteristics including age, access to household services, and education, among others.

These data were aggregated to the village level and linked with spatial data that outline the geographic boundaries of each village within the study area. Linking these census and geographic data allows the mapping of village-level information and examination of the spatial distributions of characteristics measured in the census.

The climate hazard risk data are derived from maps provided by BNPB and are used to understand the spatial distribution of risk for particular hazards, specifically flooding and landslide risk – both of which are likely to become more frequent and intense as a result of climate change (Stinson and Taylor, 2010). The maps provided by BNPB illustrate the level of risk for each hazard across Semarang by associating different colours with specific levels of risk.

Although these maps are useful for visualising variations in risk, they do not allow us to calculate levels of risk within particular village boundaries, which is necessary for our study. To perform this calculation, we visually evaluated the colour scales for different

[4] Of the 406 villages in the study area, eight were missing census data that could be linked to the map shapefiles. These villages were therefore left out of the analysis.

risk levels. We then drew boundaries around areas of similar risk using ArcGIS, and assigned a value to each area based on the BNBP colour scale.

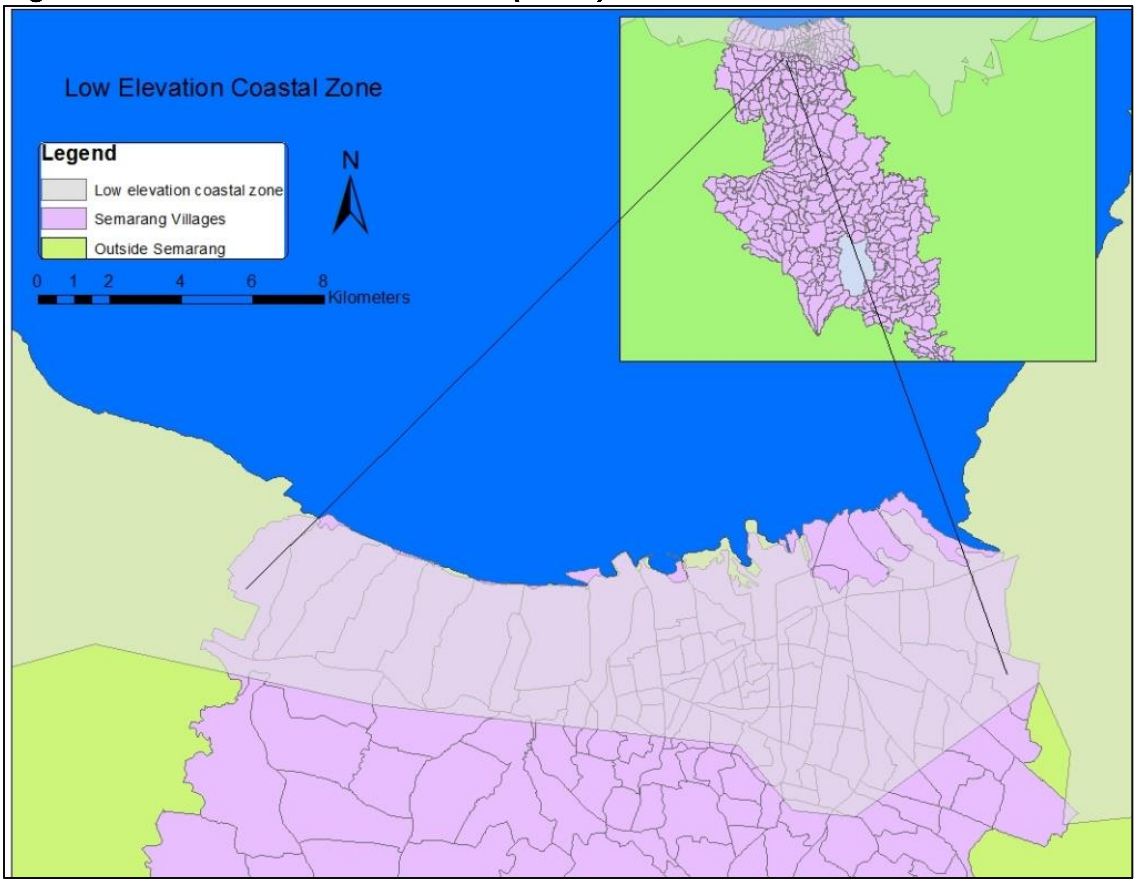
Risks are assigned with values from 1 to 7, with 1 representing the lowest level of risk and 7 the highest. This process was performed for the flooding and landslide maps. Each of these hazard maps was then overlaid on the boundaries of the villages within Semarang and an average level of exposure risk calculated for each village.

3.5 Village hazard exposure risk

3.5.1 Flood risk

The low elevation of much of Semarang and its coastal location make much of the region particularly susceptible to flooding associated with rising sea levels and changing climate patterns. As Figure 6 shows, a large portion of the Semarang municipality falls within the low elevation coastal zone (LECZ), defined here as those areas with an elevation less than 10 m above sea level. In Semarang, almost 840,000 people live within the LECZ, and communities within this area have an average population density of 10,201 people per km^2.

Figure 6 Low elevation coastal zone (LECZ)

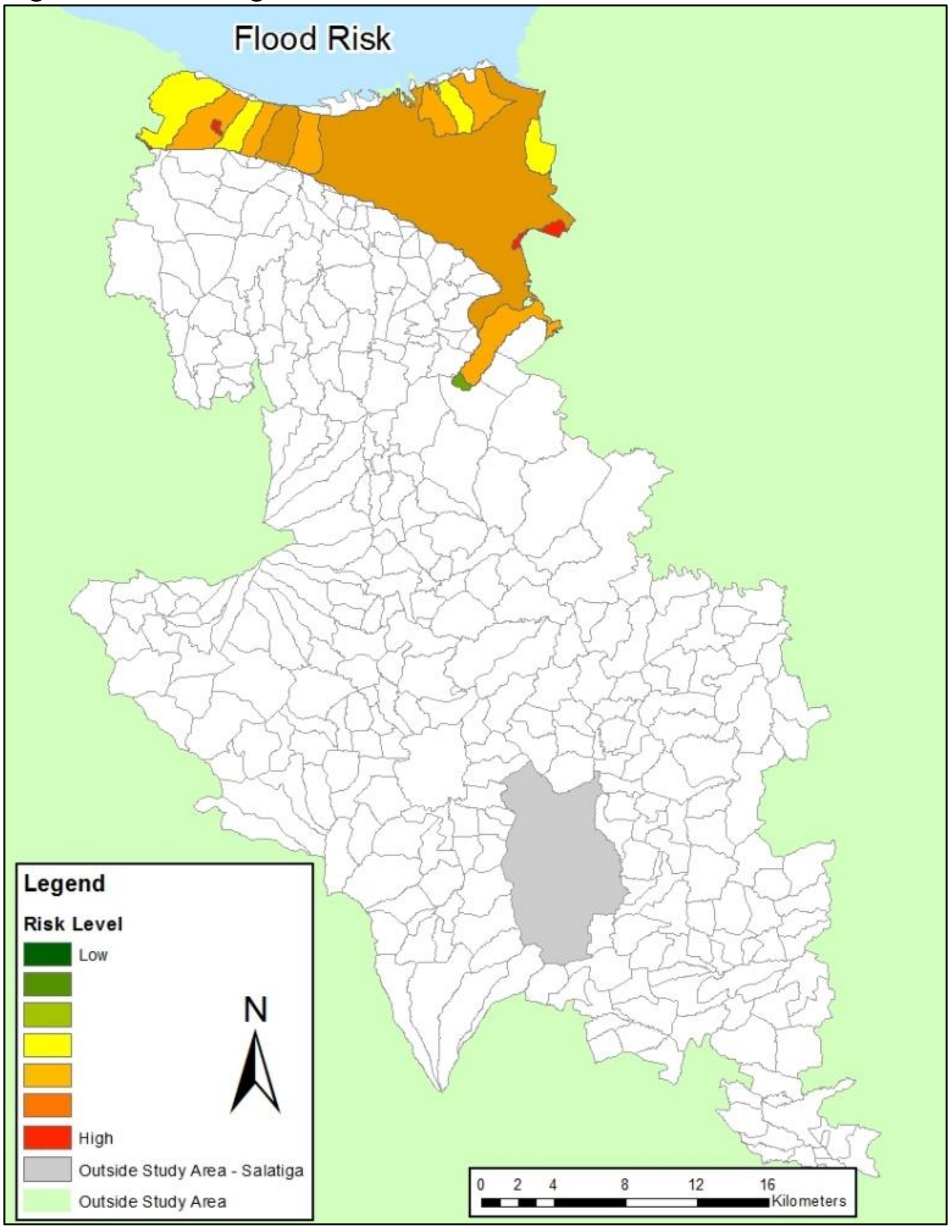


Source: McGranahan, Balk and Anderson, 2007

This is in comparison to a population density of 3973 people per km^2 for Semarang City and 3883 people per km^2 for the entire Semarang study area. The flood risk map in

Figure 7 shows that communities within the LECZ are at particularly high risk from flooding. This high risk, coupled with a high population density, implies that a significant portion of the region's population is sensitive to the impacts of flooding and sea level rise.

Figure 7 Semarang flood risk



Source: National Agency for Disaster Management (BNPB), n.d.

As noted previously, based on BNPB data, levels of hazard risk were mapped across the study area. Given that the risk-level boundaries do not correspond to village boundaries, an average hazard exposure risk was calculated for each village based on the overlap of the geography of hazard risk zones and village boundaries for each type of hazard (flooding and landslide).

Our first objective, as outlined above, was to examine the geographic distribution of hazard exposure risk. To compare hazard risks with various demographic and household characteristics that have the potential to shape vulnerability, we categorised villages according to their average hazard risk value (low, low-medium, medium, medium-high and high risk), based on quintiles modified to ensure that villages of the same risk level were in the same category.

Within each flood risk category, we then aggregated the demographic and household characteristics of all households or individuals (depending on the variable). This allowed for the examination of demographic and household characteristics among villages that shared a similar risk of hazard exposure. Tables 6-8 examine the relationships between demographic and household characteristics and risk for flooding. Table 9 examines the relationships between demographic and household characteristics and risk from landslides.

The risk categories are not necessarily comparable across hazards. If a village falls into the medium-high flooding risk and category (4) and the high risk category for landslide risk (5), it does not necessarily imply that that village is at greater risk for landslides than flooding. It simply means that of all of the villages in the study area, that village is in the fourth quintile in terms of risk for flooding and the highest (fifth) quintile for risk from landslide.

These risk categories were examined in conjunction with a number of demographic and household characteristics. These characteristics were chosen because they are potentially important in shaping levels of vulnerability for each specific risk; therefore, the characteristics associated with flood risk may not be reported for landslide risk because they were not considered to be as relevant as for flooding.

Additionally, it should be noted that the analysis was somewhat constrained by the available data sources. Where possible, we used the most reliable indicators of potential vulnerability, but sometimes we had to use adjusted measures. Also, whereas previous research suggested that particular characteristics shape levels of vulnerability, additional fieldwork is necessary to identify the exact processes and mechanisms by which those characteristics translate to vulnerability in Semarang.

3.5.2 Flood risk and earthen floors

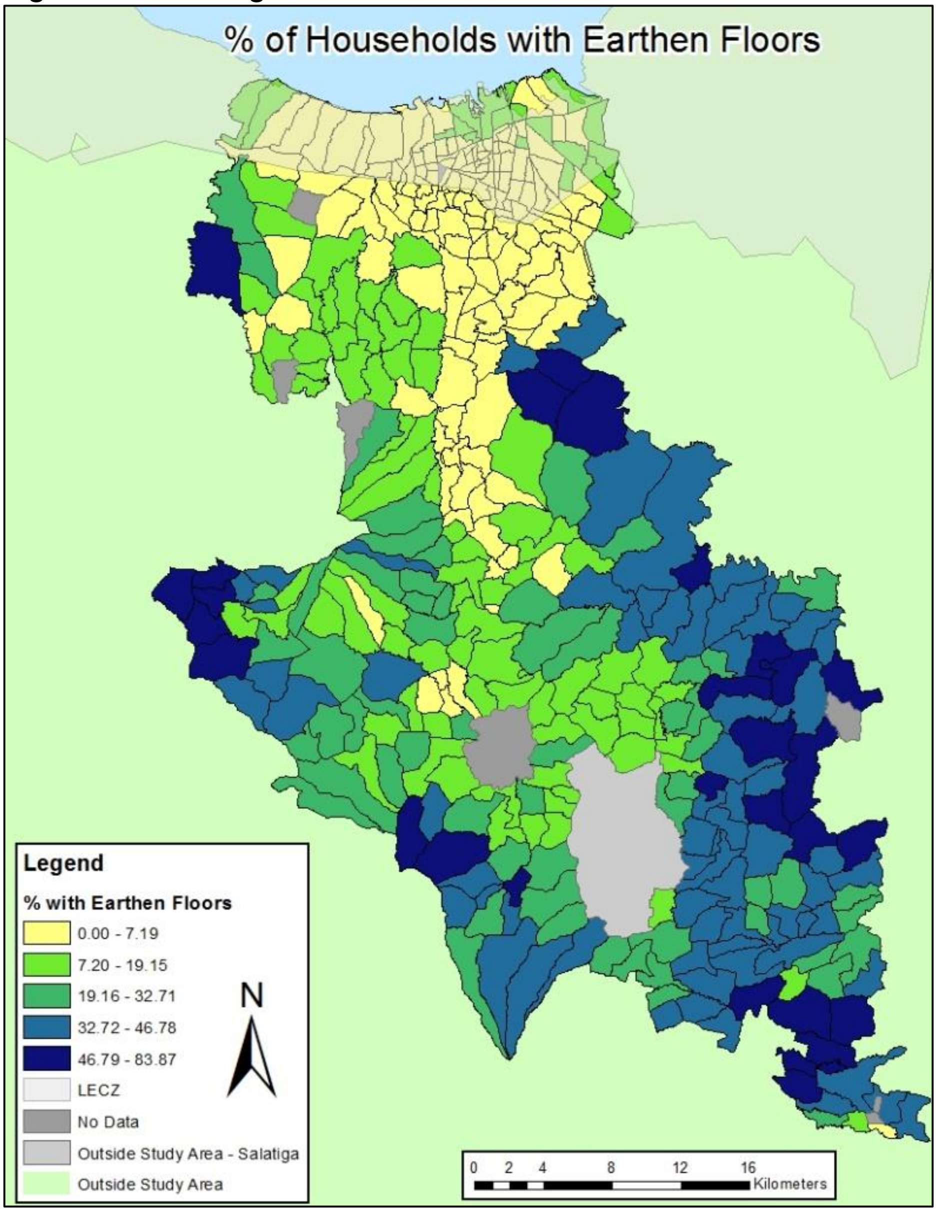
In the Indonesian census, there is no direct measure of the permanency of dwellings, therefore, dwellings with earthen floors are used as a proxy. These structures are less likely to sustain the damage associated with flooding compared to more permanent structures or elevated dwellings (Taylor, 2010). Throughout Semarang, 12.05 per cent of all households have earthen floors. As Table 6 shows, within the highest flood risk areas, a relatively low percentage of households have earthen floors: the highest flood risk areas are on the coast where the population is most urban (see Figure 8).

Table 6 Earthen floors and flood risk

Flood risk category	Number of households in risk category	Households in risk category with earthen floors (%)
1 - Low	357,923	18.04
2 - Med.-low	61,165	7.21
3 - Med.	69,452	6.44
4 - Med.-high	147,173	2.31
5 - High	4994	6.73

Source: Central Statistical Bureau (BPS), 2010

Figure 8 Percentage of households with earthen floors



Source: Central Statistical Bureau (BPS), 2010

3.5.3 Flood risk and piped water

Table 7 uses the same methodology to examine the relationship between flood risk and the percentage of the population with access to piped water. Within the SMA, 32.94 per cent of residents have access to piped water either inside or outside their house. Piped water is less likely than other sources to be contaminated during flooding, which ensures a more stable and sanitary water supply (Charles *et al.*, 2009).

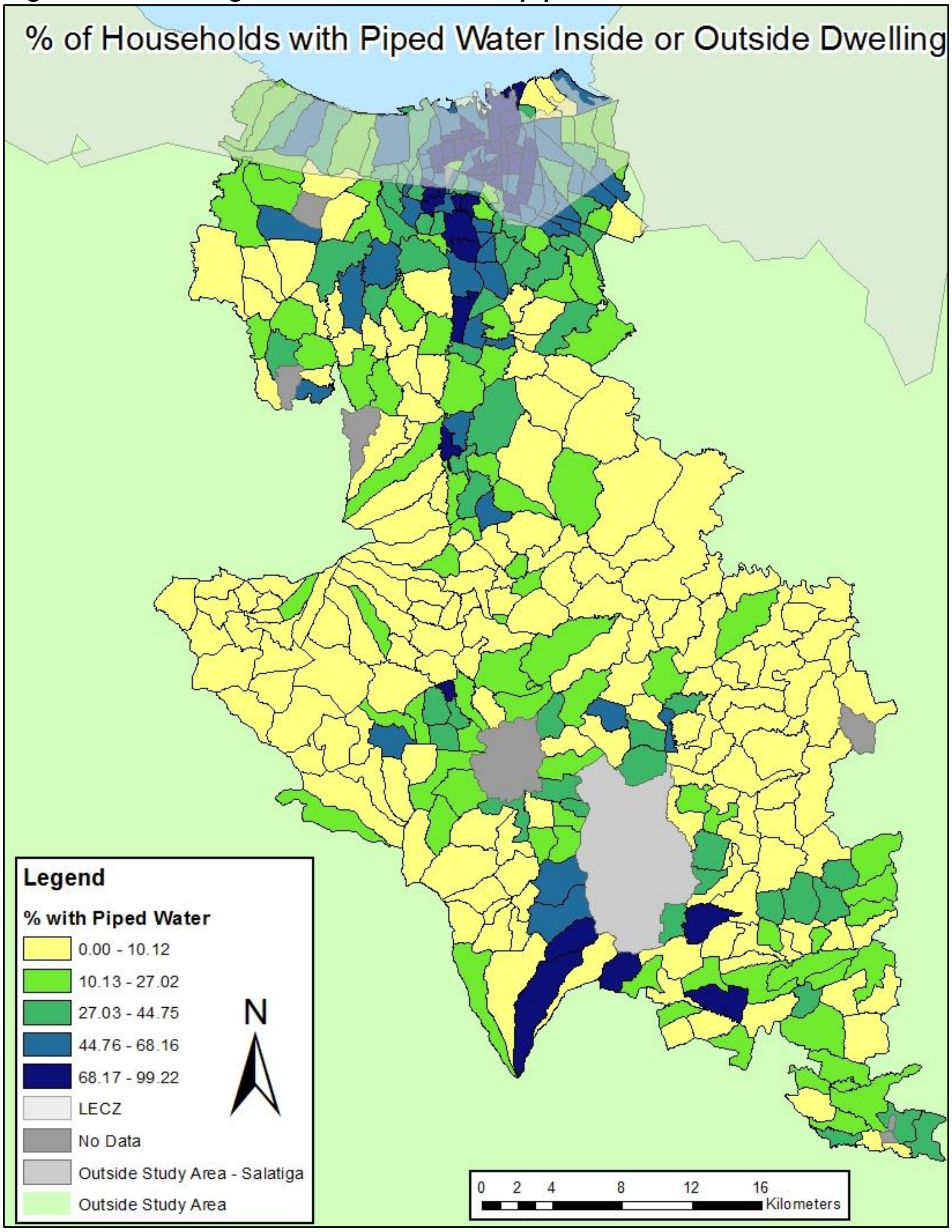
In Semarang, households exposed to medium and medium-high levels of flood risk are more likely to have access to piped water. However, only about 33 per cent of households in villages at the greatest risk for flooding have access. This is likely to be because of the substantial variation in access to piped water within those areas of the LECZ, as Figure 9 shows.

Table 7 Piped water and flood risk

Flood risk category	Number of households in risk category	Households in risk category with piped water (%)
1 - Low	357,923	19.40
2 - Med.-low	61,165	35.41
3 - Med.	69,452	47.44
4 - Med.-high	147,173	57.99
5 - High	4994	32.78
Overall % of households with piped water in study area		**32.94**

Source: Central Statistical Bureau (BPS), 2010

Figure 9 Percentage of households with piped water



Source: Central Statistical Bureau (BPS), 2010

3.5.4 Flood risk and improved toilets

Finally, in the event of significant flooding, those households without access to improved toilets[5] are more likely to be exposed to health hazards associated with a lack of human waste disposal. In Semarang, 76.92 per cent of households have access to improved

[5] Households with improved toilets are defined as those with private toilets that have some type of disposal system. In the census, this includes those connected to a septic tank; and those not connected to a septic tank, which are likely to be connected to sewers.

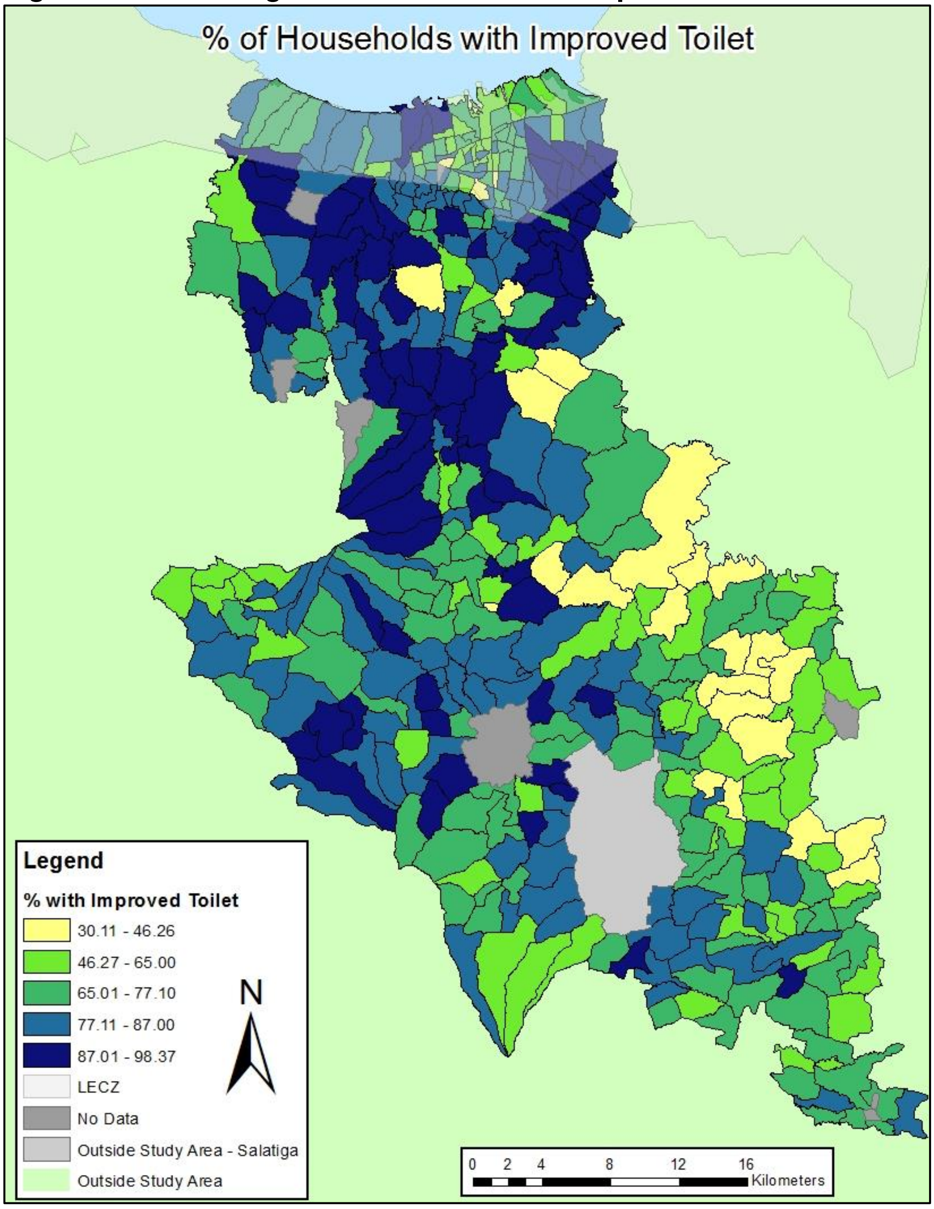
toilets. As Table 8 shows, access tends to be relatively high across all flood risk categories, but is greatest in the areas of highest risk. Figure 10, however, shows that despite the high level of access in high risk areas, in some LECZ communities the percentage of households with access to improved toilets is still less than 46 per cent.

Table 8 Improved toilets and flood risk

Flood risk category	**Number of households in risk category**	**Households in risk category with improved toilets (%)**
1 - Low	357,923	74.92
2 - Med.-low	61,165	83.90
3 - Med.	69,452	78.30
4 - Med.-high	147,173	77.84
5 - High	4994	87.10
Overall % of households with improved toilets in study area		**76.92**

Source: Central Statistical Bureau (BPS), 2010

Figure 10 Percentage of households with improved toilets



Source: Central Statistical Bureau (BPS), 2010

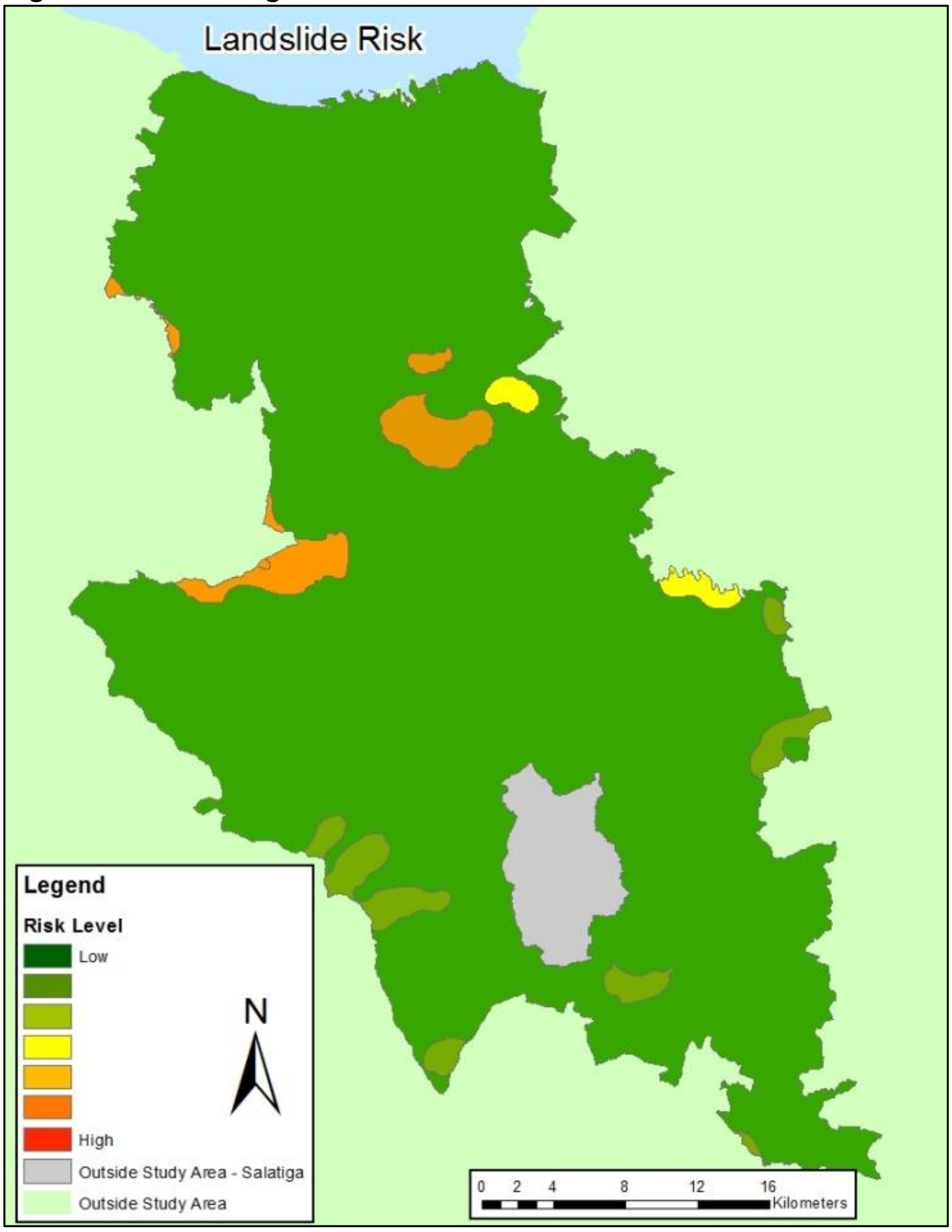
3.5.5 Landslide risk

To calculate landslide risk, we replicated the methodology described above for categorising flood risk and assessing the distribution of various demographic and household characteristics within those categories. The nature of risks associated with landslides is likely to be different to those associated with flooding. Therefore, of the previous variables examined in relation to flooding, only household construction was examined in relation to landslide risk.

Changes in the intensity and frequency of rainfall, as well as the increasingly dramatic temperature fluctuations associated with climate change, are likely to have significant impacts on groundwater levels. These changes in groundwater levels will have subsequent impacts on land stability and may increase the frequency of landslides (Dehn *et al.*, 2000). In some of the areas of Semarang, where communities are situated on or near steep slopes, increased landslide frequency could pose a substantial threat.

Figure 11 illustrates the distribution of landslide risk throughout Semarang. For the majority of the metropolitan area, the risk landslides pose is relatively low. In some of the more mountainous regions of central Semarang, however, the risk of landslides is significant.

Figure 11 Semarang landslide risk



Source: National Agency for Disaster Management (BNPB), n.d.

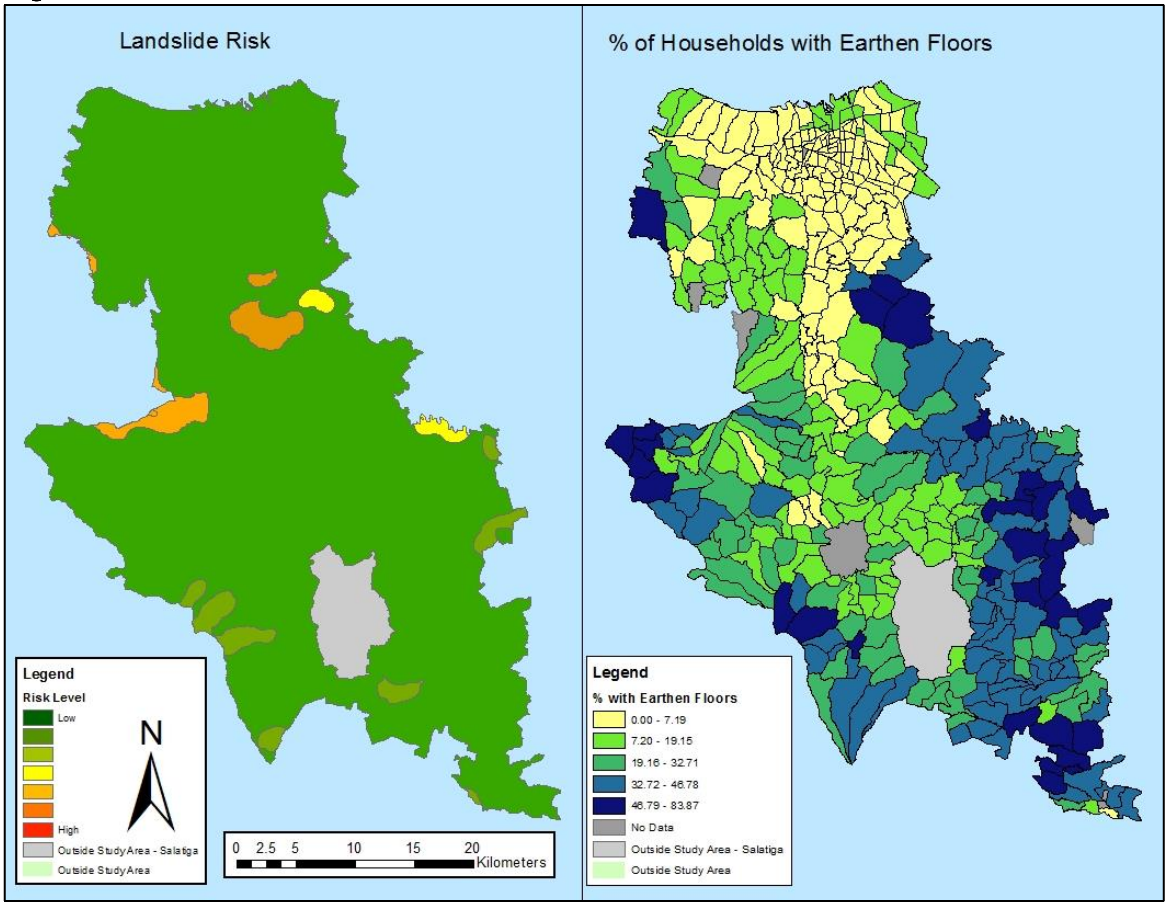
Housing built from impermanent materials is likely to be particularly vulnerable to landslides (Taylor, 2010). As noted previously, because of data limitations, earthen floors were used as a substitute for impermanent dwellings. Table 9 shows that those in the middle risk categories are most likely to have earthen floors. More than 18 per cent of those residing in high risk areas, however, also live in dwellings with earthen floors. As Figure 12 shows, the high levels of risk and moderate portion of homes with earthen floors in the central portion of the study area largely drive these dynamics.

Table 9 Earthen floors and landslide risk

Landslide risk category	Number of Households in risk category	Households in risk category with earthen floors
1 - Low	566,345	10.23
2 - Med.-low	17,985	31.16
3 - Med.	17,104	24.63
4 - Med.-high	18,577	30.30
5 - High	20,696	18.30
Overall % of households with earthen floors in study area		**12.05**

Source: Central Statistical Bureau (BPS), 2010

Figure 12 Landslide risk and earthen floors



Source: National Agency for Disaster Management (BNPB), n.d.; Central Statistical Bureau (BPS), 2010

Mapping the distribution of hazard risk provides an important starting point for assessing climate change vulnerability in Semarang. This exercise highlights that the risk of hazard exposure varies significantly across the urban area. Additionally, the correlation between levels of hazard exposure and potential indicators of vulnerability reinforces the importance of understanding local contexts when making assumptions about vulnerability.

Often, the generalisation is made that in cities of low- and middle-income countries, the poorest urban residents live in impermanent structures, with limited services in those areas that have the highest exposure to environmental hazards. Evidence from Semarang suggests that this is not necessarily the case. In Semarang, those areas with the highest risk of flooding and landslides do not necessarily correlate to areas with high concentrations of impermanent dwellings or lack of services. In fact, high risk areas actually have relatively low concentrations of households with these characteristics.

3.6 Vulnerability assessment in medium to high hazard risk villages

3.6.1 Demographic and housing characteristics in the medium to high hazard risk villages

The previous analysis provides a broad overview of hazard risk across Semarang. Developing a comprehensive response to climate change vulnerability, however, requires more than examining the geography of hazard risk. It also requires a closer examination of what vulnerability looks like in those areas that have the highest risk for particular hazards.

The second phase of our analysis provides an in-depth assessment of types of vulnerability in those villages in Semarang that have medium to high levels of risk for climate hazards. We classified villages according the risk for exposure to climate hazards using the same methodology described for the previous tables. The results below focus only on those villages that were in categories of medium, medium-high, and high risk.

Within these medium to high risk villages, Tables 10 and 11 examine demographic and household characteristics that may contribute to vulnerability, including the percentage of female-headed households within a risk category. It has been argued that women tend to face greater constraints in climate change adaptation than men (Hayes, 2011; Taylor, 2010).

This can be attributed to the assumed domestic role of women, which implies lower levels of educational attainment and lower labour force participation. Therefore, they may lack the information, skills and economic means necessary to adapt to climate hazards.

Given these dynamics, female-headed households are likely to be constrained in their adaptive capacity. Table 10 shows that among the risk categories for flooding and landslides, the portion of female headed households tends to range between 10 per cent and 15 per cent. For the study area as a whole, almost 17 per cent of all households are female headed. However, in the medium-high flood risk category, 21.9 per cent of all households are headed by women.

Age also plays an important role in shaping vulnerability. When a large portion of the population is economically inactive, because they are either too young or too old, local development can be limited and the availability of economic resources for adaptation may be constrained (Hayes, 2011). We use the dependency ratio to measure the portion of a village population that consists of children under 15 and adults over 60. This index is calculated as:

$$\text{Dependency ratio} = \frac{(number\ of\ population\ aged\ 0-14 + those\ 60\ and\ over)}{number\ of\ population\ aged\ 15-59} \times 100$$

Table 10 shows that the dependency ratio is substantially higher for households facing landslide risk than those facing flooding risk. In each case, however, the dependency ratio is lowest in the highest risk category.

Table 10 also includes information about migration in relation to hazard risk. Migration can be an adaptive strategy in itself. There is evidence that as climate change begins to affect sending communities, many migrants choose to relocate, often to urban areas (Hayes, 2011). On arriving in their new communities, migration is likely to have substantial impacts on the ability of individuals and communities to adapt to the impacts of climate change. This is partly because new arrivals may have fewer housing opportunities and are forced to live in precarious housing in high risk areas (Taylor, 2010).

Additionally, recent migrants may be less resilient in the face of these climate hazards, because their shorter time in the community is often associated with limited social integration and restricted knowledge of the specific risks the community faces. Given that informal social safety nets are an important mechanism for adapting to hazards (Taylor, 2010), new migrants without established social networks are less likely to adapt to the challenges associated with climate change.

As described earlier, data limitations restricted our measurement of migration to those who lived outside of Central Java five years ago. In Semarang, this migrant population tends to be relatively low at only 1.74 per cent of the total population. In general, the percentage of migrants in the medium to high risk categories is even lower. Again, the medium-high flood risk category is an exception to this trend, with a substantially higher percentage of migrants at 2.3 per cent.

Generally, areas with higher flood risk categories tend to have a higher percentage of migrants than landslide categories. This is likely to be because the flood risk area includes Semarang City, which has received more migrants than other parts of the SMA.

Access to schools and hospitals also plays a very important role in shaping vulnerability to climate change hazards. Adapting to the consequences of climate change requires incorporating information about hazards and planning for potential risks (Taylor, 2010).

Education provides an institutional environment for accessing information about the risks associated with climate change, participating in the training necessary for adjusting to these risks, and acquiring job skills that can enable individuals to be better positioned to adapt to changing employment structures associated with the impacts of climate change. Furthermore, climate change can have significant impacts on health. For example, rates of communicable diseases tend to increase when there are severe weather events (Hayes, 2011).

Given the importance of access to education and healthcare in the context of environmental hazards, Table 10 includes information about the number of schools and hospitals that are located in villages in the medium to highest risk categories for each hazard. No data on the capacity of these facilities were available, so school coverage could not be determined. Vital to consider in adaptation planning, however, are infrastructure and services located in flood or landslide risk areas, which are also highly vulnerable.

Population density is also examined across risk categories and hazards. It has been widely argued that high population density in areas exposed to hazards is closely associated with increased vulnerability because of problematic escape routes and the high number of people exposed to those hazards (Yusuf and Francisco, 2009; Brooks *et al.*, 2005; Sullivan and Meigh, 2005). Again, the medium-high flood risk category tends to be the most vulnerable because it has the highest population density of all risk levels across hazards.

Landslide risk is concentrated outside of the more populated parts of Semarang, which means that population densities tend to be much lower than for the flood risk categories. Among the landslide risk categories, however, population density is highest in high risk category, illustrating a potential correspondence between hazard risk and vulnerability.

Table 10 Characteristics of individual vulnerability in flood and landslide risk levels

Vulnerability indicators	Flood risk			Landslide risk		
	Med.	**Med.-high**	**High**	**Med.**	**Med.-high**	**High**
Number of villages	25	63	2	14	16	16
Total population	270,087	554,465	19,858	65,683	69,698	78,375
Population density (per km^2)	8162.3	12,189.9	5336.2	917.8	797.1	1227.8
Total female-headed households	10,119	28,428	570	2468	2151	2095
Female-headed households (%)	15.4	21.9	11.6	14.7	12.1	10.5
Total children aged 0-9	45,890	82,332	3135	10,792	12,266	14,418
Children aged 0-9 (%)	15.8	13.3	16.0	16.3	16.5	17.6
Total adolescents aged 10-14	22,103	40,565	1650	5408	5968	6329
Adolescents aged 10-14 (%)	7.9	7.0	8.4	8.2	8.4	8.1
Total aged 60+	16,033	44,596	1015	6971	5988	5996
Aged 60+ (%)	6.4	9.1	5.0	11.9	10.4	8.8
Average dependency ratio	44.5	43.4	41.9	59.9	57.2	54.5
Total migrants	3542	10,801	341	369	875	1109
Migrants (%)	1.7	2.3	1.7	0.7	0.7	1.1
No. of schools	35	163	10	54	43	26
No. of children aged 0-14/school	1942.7	754	479	300	424	797
No. of hospitals	5	22	2	6	1	5
No. of people/hospital	54,017.4	25,203	9929	10,947.2	69,698	15,675

Note: We evaluated the sum of numbers and the average proportion value for the three flood levels and landslide levels.

Table 10 focuses on the relationships between demographic characteristics and hazard risk. Table 11 highlights a range of highly important housing conditions, together with a composite of these conditions used to measure slums called the secure tenure index (STI). The STI provides a measure of general vulnerability based on five specific factors: access to water; permanency of dwellings; regulatory compliance of housing; connection to a sewer; and connection to electricity (Herr and Karl, 2002).

STI ranges from 0-100, with a higher value indicating lower vulnerability. The census does not include a measure of the regulatory compliance of housing, so this factor was not included; the measure we used is therefore referred to as an adjusted STI.[6]

Table 11 shows that those villages that are at medium to high risk for flooding tend to have higher STIs than those villages in comparable landslide risk categories. This is unsurprising given that landslide areas are more rural, but STI varies substantially within urban areas as well. The table also includes information about the distribution of various household characteristics that may shape vulnerability.

As described previously, piped water is less likely than other sources to be contaminated, ensuring households a more stable and sanitary water supply in the event of extreme weather. Also, households with an earthen floor are used as an indicator of the permanency of the dwelling and its ability to withstand extreme weather events.

In the event of extreme weather, access to improved toilets can increase sanitation and reduce the spread of disease. The use of charcoal or wood for cooking can increase vulnerability to the extent that climate change speeds deforestation and reduces the availability of these items for those households that depend on them (Guzman, Schensul and Zhang, 2013).

Table 11 shows the relationships between these household variables and flood and landslide risk. For each of these items, households in landslide risk areas tend to be more vulnerable than those in flood risk areas.

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[6] A similar adjusted STI has been show in other instances to operate well as a proxy of the full STI (Schensul *et al.*, 2013). Principal component analysis (PCA) is conducted to obtain the component score coefficient of each variable. The adjusted STI is the normalised component score scaled from 0 to 100, indicating low to high economic status of the household. The adjusted STI is calculated as:

$$\mathrm{STI} = \frac{\begin{array}{c}(Proportion\ of\ households\ with\ access\ to\ electricity \times component\ score\ coefficient\ + \\ proportion\ of\ households\ with\ improved\ toilets \times component\ score\ coefficient\ + \\ proportion\ of\ household\ with\ perment\ stucture \times component\ score\ coefficient\ + \\ proportion\ of\ household\ with\ access\ to\ piped\ water \times component\ score\ coefficient)\end{array}}{Sum\ of\ component\ score\ coefficients} \times 100$$

Table 11 Characteristics of household vulnerability in flood and landslide risk level categories

Risk category	Flood risk			Landslide risk		
	Med.	**Med.-high**	**High**	**Med.**	**Med.-high**	**High**
Number of villages	25	63	2	14	16	16
Total households	69,452	147,173	4994	17,104	18,577	20,696
Total households with earthen floor	4473	3397	336	4213	5629	3788
% households with earthen floor	6.5	2.0	8.4	28.4	39.7	25.6
Total households with charcoal/wood for cooking	1968	2634	222	10,120	9178	7701
Households with charcoal/wood for cooking (%)	3.3	1.5	5.1	66.6	65.6	51.1
Total households without bottled/piped water	17,167	21,835	1674	14,572	15,153	14,009
Households without bottled/piped water (%)	28.8	10.9	43.4	83.2	92.3	79.7
Total households without an improved toilet	15,064	32,609	644	3582	4057	3869
Households without an improved toilet (%)	22.6	25.4	13.5	24.7	27.2	26.1
Total households without a phone	7433	13,703	455	4255	4100	3938
Households without a phone	10.8	9.4	9.8	27.0	28.1	25.3
Total households without Internet	52,913	101,995	3540	14,441	15,571	16,423
Households without Internet (%)	76.5	68.6	75.8	86.6	89.0	84.1
Average STI	84.4	90.6	81.5	60.5	53.4	62.2

3.6.2 Flood risk vulnerability assessment at the village level

The final step in our analysis aimed to provide a more in-depth examination of those villages that had medium to high levels of hazard risk, as well as high levels of vulnerability based on three of the measures presented above – specifically population density, dependency ratio, and STI. Each of these measures represents vulnerability and highlights a separate set of factors that drive that vulnerability.

Figures 13-15 display the spatial distribution of these indexes at the village level in relation to flood risk. Population densities tend to be relatively high in villages in the medium to high flood risk areas. With a few exceptions, however, villages within these flood risk categories also have lower dependency ratios. These maps also reveal that villages with a low STI generally tend to fall outside of the areas with medium to high flood risk.

There are a few locations that have both high exposure to hazards, and high levels of vulnerability based on STI. The information about the spatial distribution of all of these vulnerabilities is overlaid on the location of flood risk in Figure 16. This map illustrates the distribution of vulnerable villages and the factors that shape that vulnerability. By providing information about the source of vulnerability in conjunction with the geography of flood risk, this analysis can enable resources to be targeted more effectively and address specific local needs.

Figure 13 Population density (people per km^2) in villages with medium to high flood risk

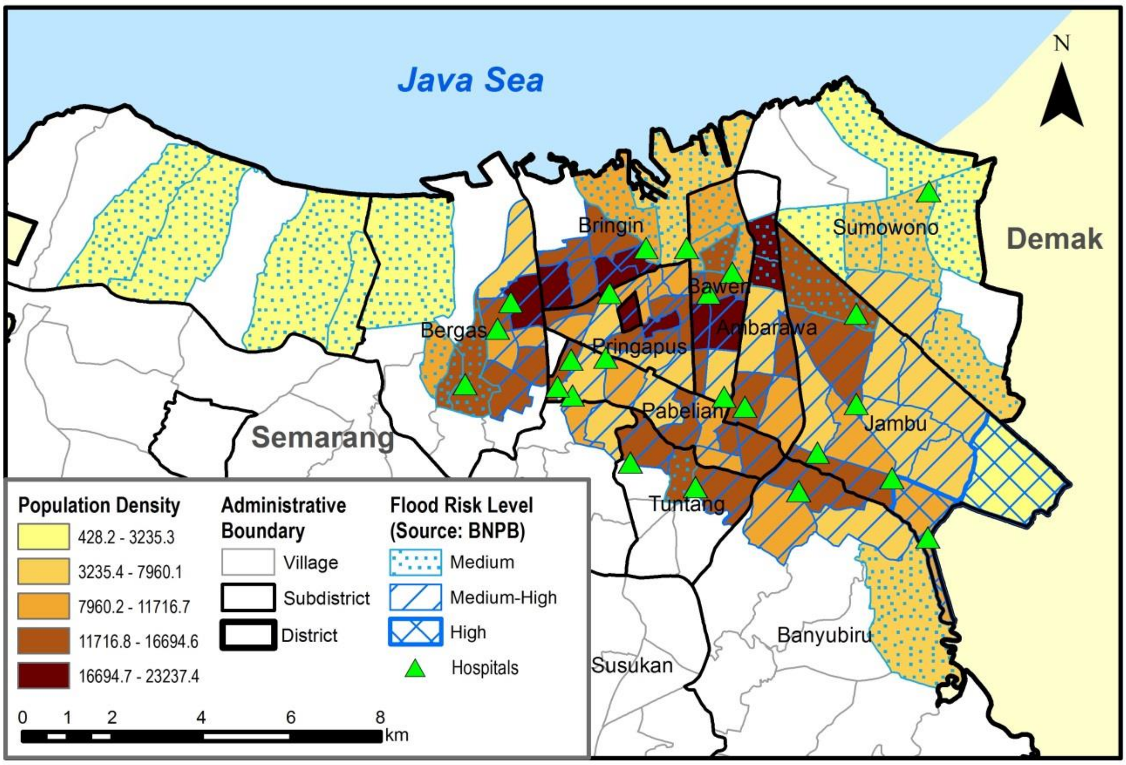

Figure 14 Dependency ratio in villages with medium to high flood risk

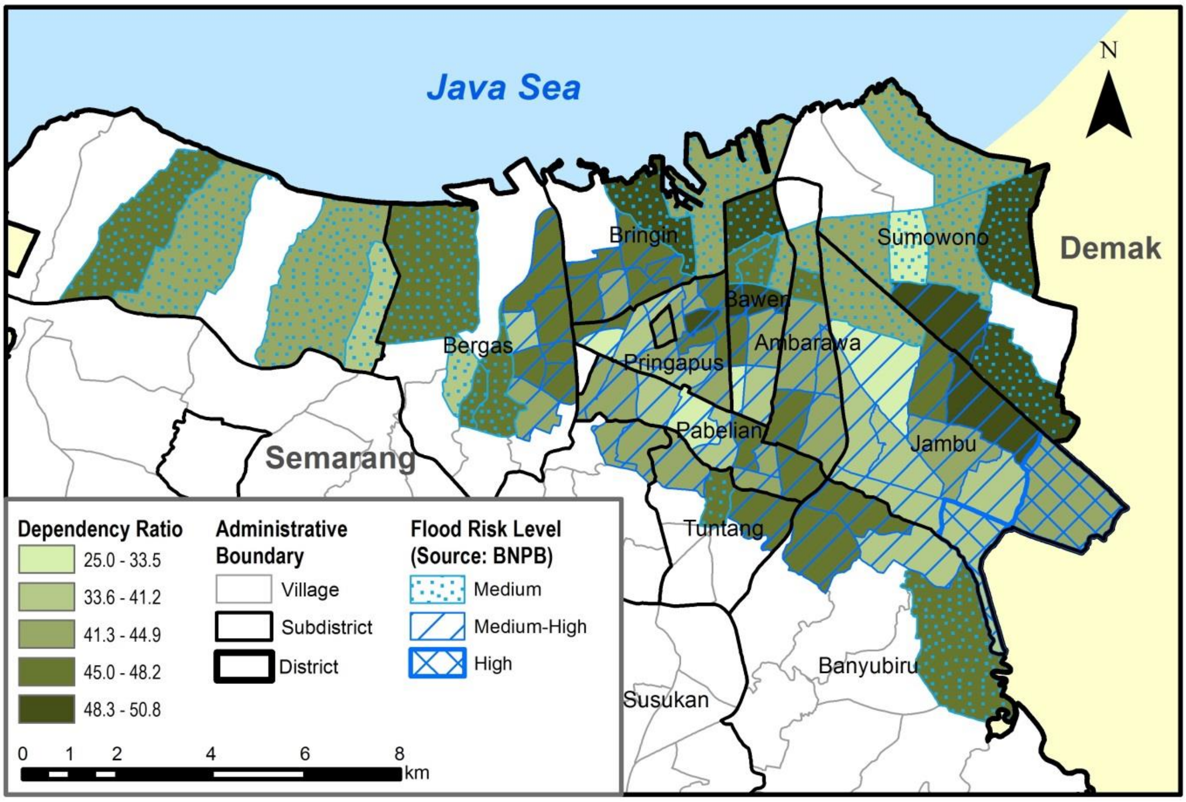

Figure 15 STI in villages with medium to high flood risk

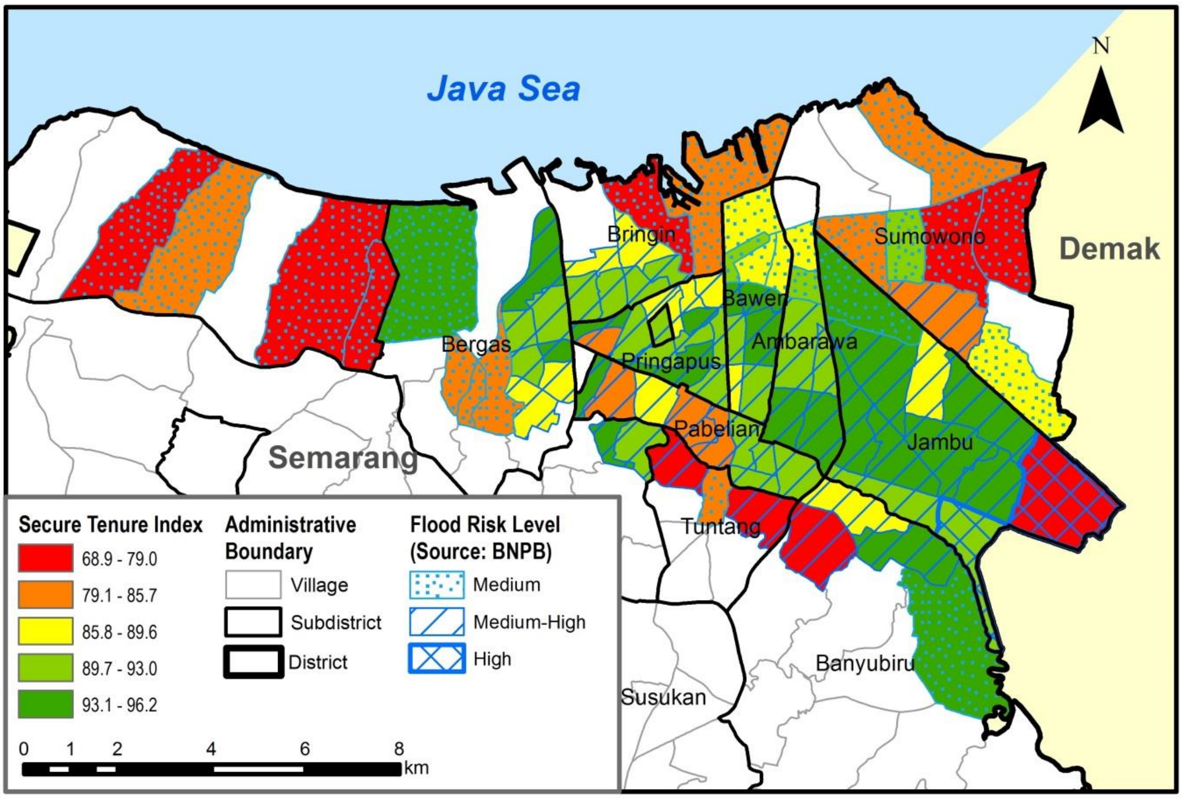

Figure 16 Vulnerable villages with medium to high flood risk

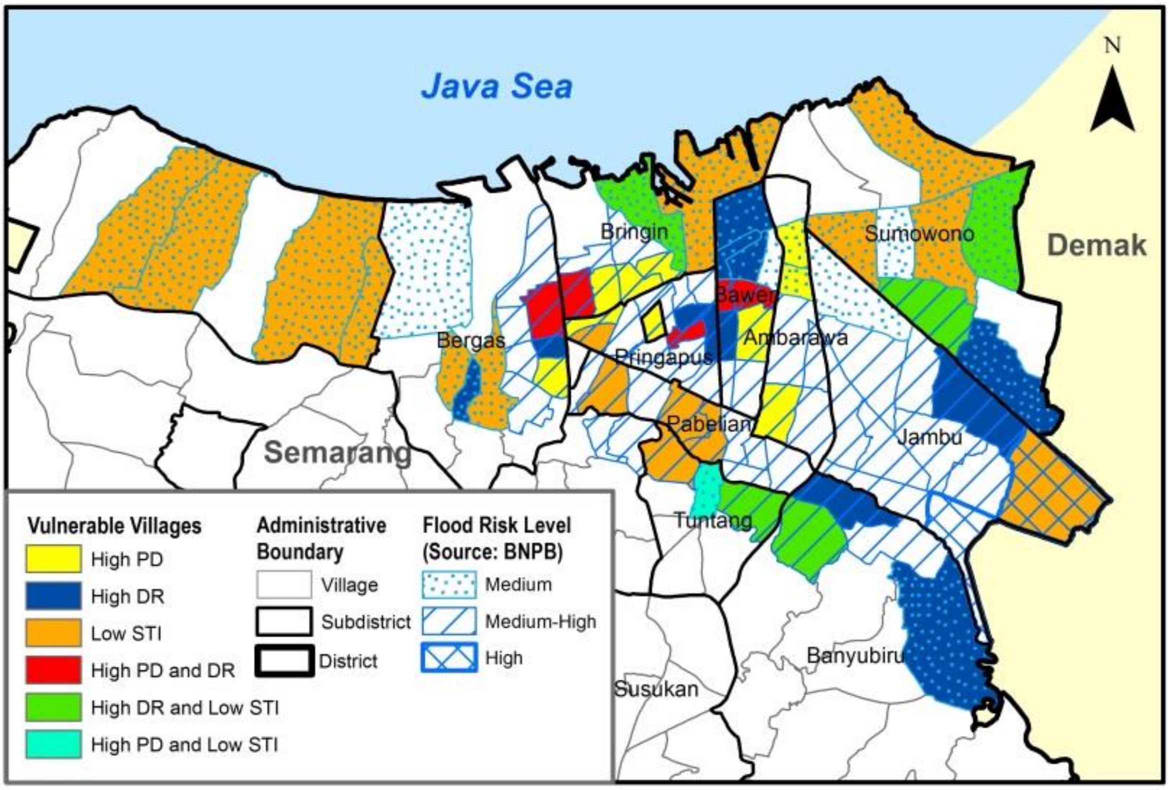

Table 12 provides a list of the most vulnerable villages for each of the vulnerability measures. A total of 90 villages fall into one of the medium to high flood risk areas (categories 3-5). Of these, 49 are identified as vulnerable according to at least one of the three indicators above. Table 12 aggregates this information and creates a classification scheme for highlighting vulnerable villages. This table includes the 22 highest ranked[7] villages on each indicator of vulnerability.

This classification breaks down as follows: 11 villages are identified as vulnerable because of high population density; 12 because of their high dependency ratio; 16 because of their low STI; 5 because of their high population density and high dependency ratio; and 5 because of their high dependency ratio and low STI. Only 1 village, Candi, is vulnerable based on its high population density and low STI.

[7] This represents those villages that fall within the highest quartile rank.

Table 12 Rank of villages vulnerable to flood risk by secure tenure index (STI), dependency ratio and population density

Rank	Population density threshold: >14940/ km^2	Risk level	STI threshold: <85.34	Risk level	Dependency ratio threshold: >47.41%	Risk level
1	Gabahan	Med.-high	Banjardowo	Low	Mangkang Wetan	Low
2	Bulu Lor	Med.-high	Penggaron Kidul	High	Kebonagung	Med.-high
3	Dadapsari	Med.-high	Jerakah	Low	Bugangan	Med.-high
4	Sawahbesar	Med.	Tugurejo	Low	Tlogomulyo	Med.-high
5	Lempongsari	Med.-high	Genuksari	Low	Bandarharjo	Low
6	Rejosari	Med.-high	Tandang	Med.-high	Kemijen	Low
7	Sarirejo	Med.-high	Bandarharjo	Low	Kranggan	Med.-high
8	Kaligawe	Med	Tegalsari	Med.-high	Bangetayu Kulon	Med.-high
9	Krobokan	Med.-high	Jomblang	Med.-high	Banjardowo	Low
10	Purwosari	Med.-high	Mangkang Wetan	Low	Sendangmulyo	Low
11	Candi	Med	Gisikdrono	Low	Tandang	Med.-high
12	Lamper Lor	Med.-high	Muktiharjo Lor	Low	Gabahan	Med.-high
13	Bugangan	Med.-high	Candi	Low	Krobokan	Med.-high
14	Kebonagung	Med.-high	Kalibanteng Kulon	Low	Kalibanteng Kidul	Low
15	Plombokan	Med.-high	Randusari	Med.-high	Jomblang	Med.-high
16	Bojongsalaman	Med.-high	Trimulyo	Low	Sendangguwo	Med.-high
17	Pandean Lamper	Med.-high	Wonodri	Med.-high	Sarirejo	Med.-high
18	Karang Ayu	Med.-high	Bangetayu Kulon	Med.-high	Cabean	Med.-high
19	Kuningan	Med.-high	Randu Garut	Low	Mlatibaru	Low
20	Pendrikan Lor	Med.-high	Pendrikan Kidul	Med.-high	Rejomulyo	Low
21	Karangturi	Med.-high	TanJung Mas	Low	Jagalan	Med.-high
22	Jagalan	Med.-high	Pleburan	Med.-high	Bulu Lor	Med.-high

3.6.3 Landslide risk vulnerability assessment at village level

We replicated the flood risk and vulnerability analyses for landslide risk. Forty-six villages are located in the medium to high categories of landslide risk. As previously, we analysed the three main indexes of vulnerability for each of these villages.

Figures 17-19 show the results. These maps reveal that villages with the highest risk for landslides are in the southeast part of the LECZ. Many of these villages are vulnerable based on high population densities and high dependency ratios.

Villages with a low STI tend to be distributed around the edges of the study area, whereas those with a high dependency ratio are mostly located on the eastern edge. Villages with the highest population density are located towards the centre.

These maps also overlay vulnerability indexes on the landslide risk levels, which shows that most villages with a low STI are located in the medium flood risk category. One village in the lowest STI category, however, is located is highest flood risk category. This village may be particularly vulnerable because of a low STI in conjunction with high landslide risk.

As for flood risk, the most vulnerable villages based on each index are listed in Table 13, which shows the 12[8] most vulnerable villages for each indicator. The STI values are much lower for villages at risk from landslides than for those in the flood risk area – the 12 villages all have an STI value below 49.3. Five of the 12 villages with the highest population density are located in areas in the highest landslide risk category.

Of those with the lowest STI, only 3 are located in areas with the highest risk, and only 2 of the villages with the highest dependency ratio fall into the highest landslide risk category. Some 5 villages are listed in the most vulnerable villages for STI and dependency ratio.

The 12 villages with the highest population density are less likely to be listed as vulnerable by the other two indexes. Figure 20 shows the locations of the 12 villages and highlights the factors influencing their vulnerability.

[8] This represents those villages that fall within the highest quartile rank.

Figure 17 Population density (people per km2) in villages with medium to high landslide risk

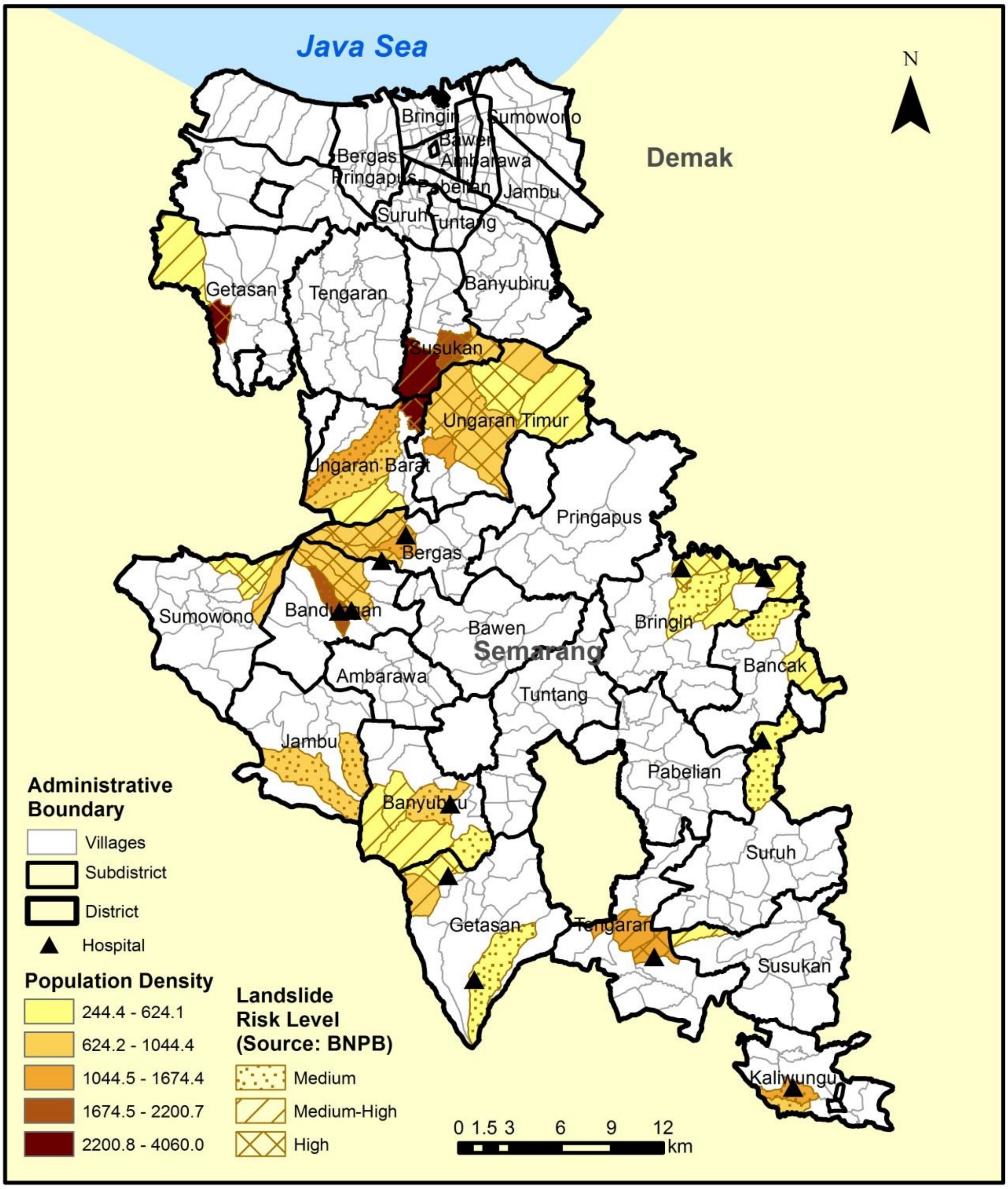

Figure 18 Dependency ratio in villages with medium to high landslide risk

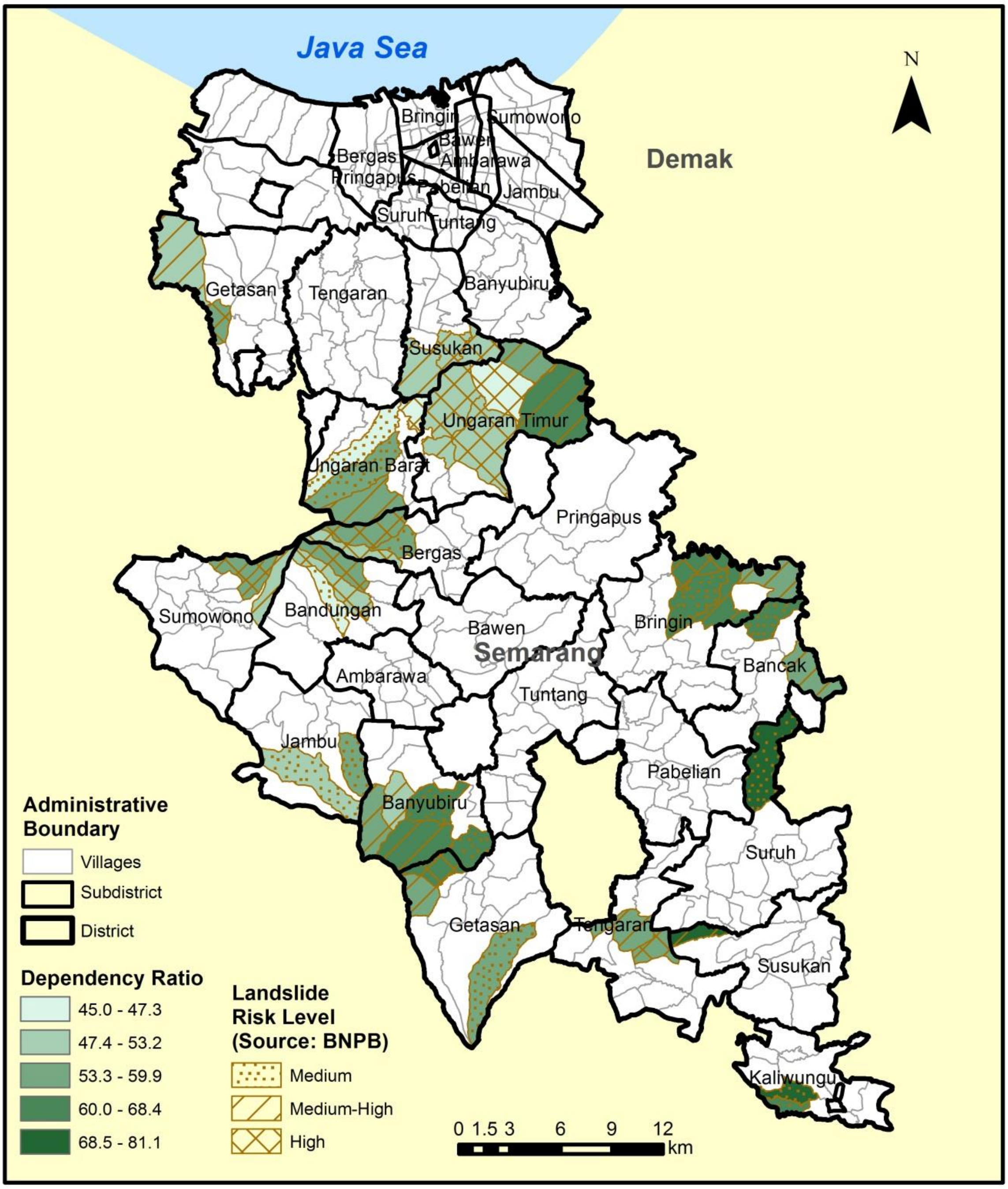

Figure 19 STI in villages with medium to high landslide risk

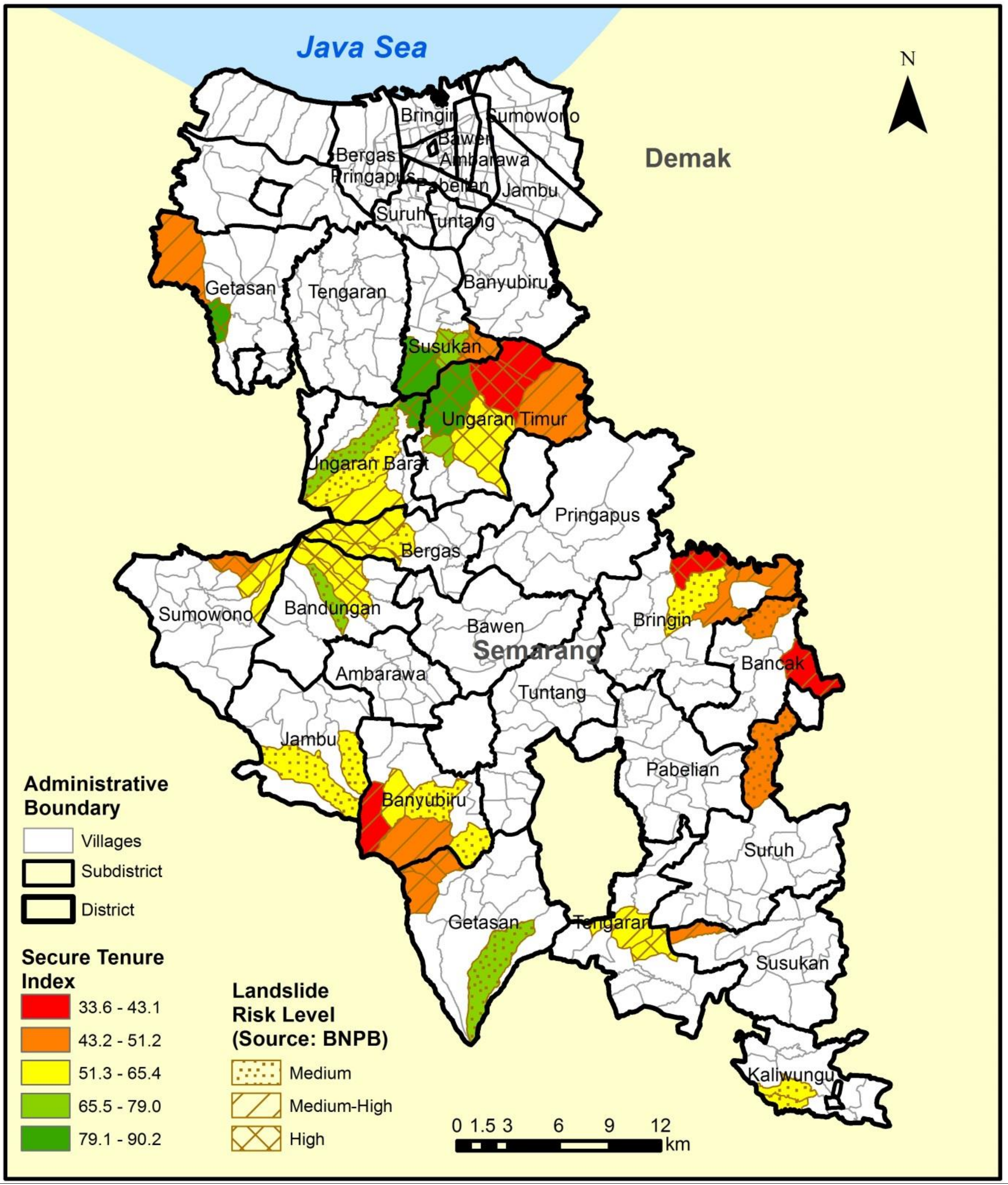

Figure 20 Vulnerable villages with medium to high landslide risk

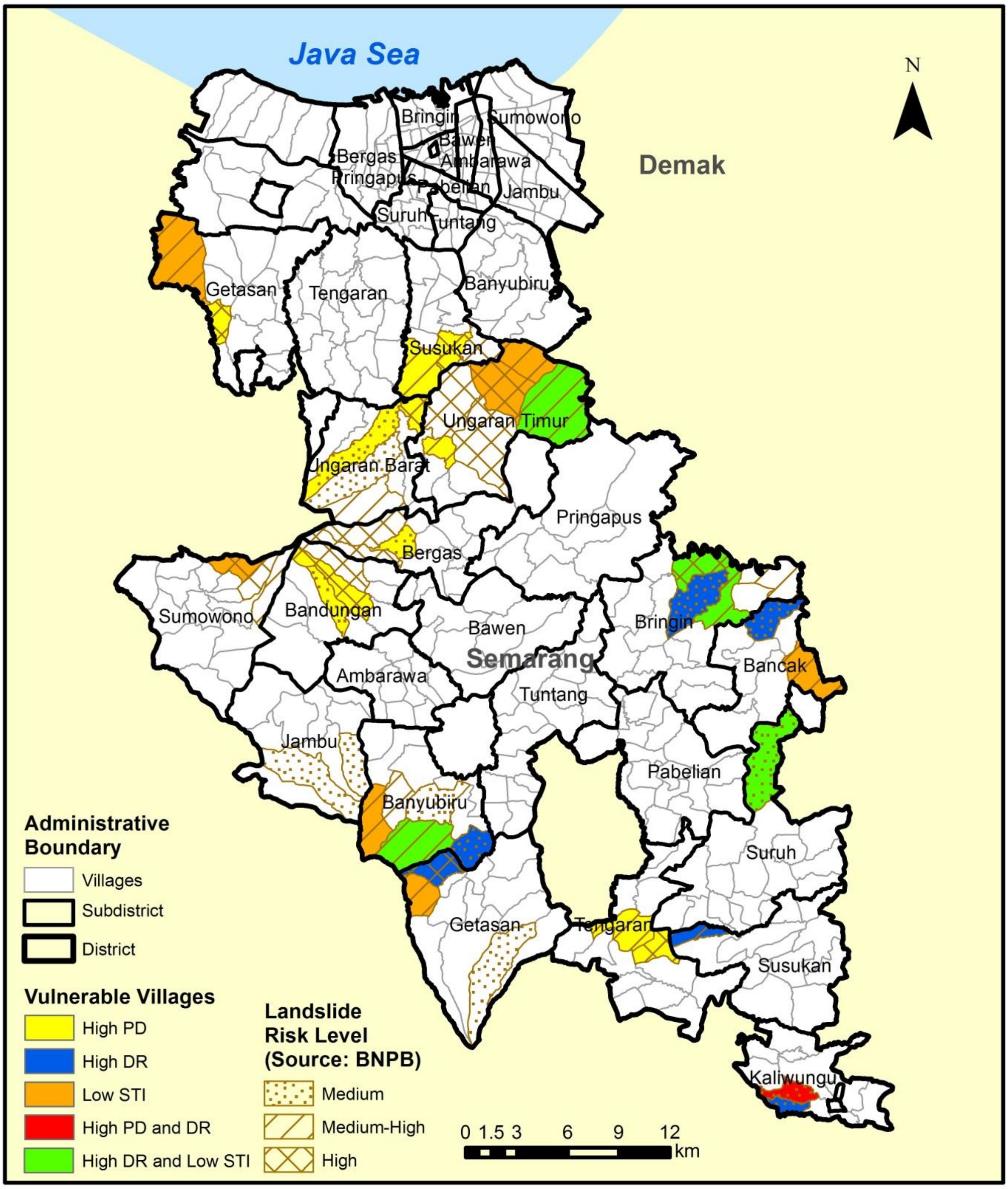

Table 13 Rank of vulnerable villages to landslide risk by STI, dependency ratio and population density

Rank	STI threshold: <49.30	Risk level	Dependency ratio threshold: >61.10%	Risk level	Population density threshold : >1044/km^2	Risk level
1	Plumutan	Med. -high	Kemetul	Med. -high	Jatisari	High
2	Kalikayen	Med. -high	Mukiran	Low	Bandarjo	High
3	Mluweh	High	Dadapayam	Low	Pudakpayung	Med.-high
4	Kalikurmo	High	Siwal	Low	Gedawang	High
5	Wirogomo	Med. -high	Gogodalem	Low	Bandungan	Low
6	Dadapayam	Low	Nogosaren	High	Kalirejo	Med.-high
7	Kemawi	High	Gedong	Low	Pagersari	Low
8	Wonoplumbon	Med. -high	Boto	Low	Karangduren	Med.-high
9	Kawengen	Med. -high	Kawengen	Med. -high	Lerep	Low
10	Tolokan	Med. -high	Wiru	Med. -high	Cukil	High
11	Sepakung	Med. -high	Sepakung	Med. -high	Mukiran	Low
12	Wiru	Med. -high	Kalikurmo	High	Duren	High

The above analysis highlights the existence of multiple geographies of vulnerability within Semarang. In the same city, the distribution of risk and the distribution of vulnerability overlap in a variety of combinations. This implies that policies and efforts that aim to address climate change vulnerability require flexibility, as well as a recognition of the important and varied roles that demographic and household characteristics play in shaping that vulnerability.

4 Policy Responses Regarding Climate Change Adaptation

The findings above suggest that significant portions of the population of Semarang are vulnerable to the consequences of climate change and may lack the resources to adapt to its impacts. Moreover, the factors that shape vulnerability show significant variation across the metropolitan area as a result of exposure to hazards, access to infrastructure and community characteristics.

Increasing adaptive capacity requires taking into account this localised variation and co-ordinating the efforts of various stakeholders, including various levels of government and agencies within them, as well as NGOs and community groups. In examining how to better address vulnerabilities and increase adaptive capacity, it is necessary first to understand the efforts that are currently underway.

4.1 National policies on climate change adaptation in Indonesia

Although many of the dynamics of vulnerability highlighted above are dependent on local contexts, the national government will still need to play a significant role in increasing adaptive capacity. Climate change has become a major issue of concern for the government of Indonesia.

The government recognises that climate change mitigation and adaptation efforts should be undertaken in a systematic and integrated manner. As a result, policy documents to guide the efforts have been developed by relevant ministries. Text Box 2 shows a summary of major national-level policy initiatives related to climate change adaptation.

Box 2 Policy documents on climate change mitigation and adaptation in Indonesia

- **National Action Plan for Mitigation and Adaptation to Climate Change (RAN-MAPI)**. The Ministry of Environment prepared this plan in November 2007. It served as the initial guidance and multi-sectoral co-ordination effort to address mitigation and adaptation to climate change.

- **National Development Planning: Indonesian Responses to Climate Change**. This 'yellow book' was prepared by the National Development Planning Agency (BAPPENAS) in December 2007 and was revised in July 2008. It was intended to reinforce the RPJMN (National Medium-Term Development Plan) 2004-2009 and provide inputs for the preparation of RPJMN 2010-2014 in the context of creating a more integrated approach to addressing climate change.

- **Indonesia Climate Change Sectoral Roadmap (ICCSR)**. BAPPENAS published this document in March 2010. It includes nine sectoral strategies on mitigation and adaptation (namely, forestry, energy, industry, transportation, waste, agriculture, marine and fisheries, water resources, and health) to deal with climate changes challenge until 2030.

- **Indonesia Climate Change Adaptation Strategy**. BAPPENAS prepared this document in November 2011 as a national progress report for the UNFCCC Congress of the Parties (COP17) in Durban, South Africa in 2011. It contains a general adaptation strategy on four related sectors (marine and fisheries, agriculture, health, water resource and disaster management) and policy recommendations to further develop a national action plan on climate change adaptation.

- **National Action Plan on Greenhouse Gas (GHG) Reduction (RAN-GRK), the Presidential Decree No. 61, 2011**. The RAN-GRK is an action plan document to implement various activities that directly and indirectly reduce GHG emissions to national targets of 26 per cent through the nation's own efforts or 41 per cent with international aid by 2020. The action plan was formulated for five major sectors, including agriculture, forestry and peat, energy and transportation industries, and waste management.

- **The draft National Action Plan Addressing Climate Change (RAN-API), 2012**. BAPPENAS and line ministries/institutions are currently formulating this action plan to foster the harmonisation and operationalisation of available policy documents related to climate change adaptation.

These policies show a significant effort to create an integrated approach to addressing climate change issues in Indonesia, but have generally focused on the needs of specific sectors. Rather than examining the spatial distribution of population dynamics in relation to hazard risks, most policy documents have addressed climate change adaptation according to the needs of agriculture, marine and fisheries, health, water resources, disaster response and other individual sectors.

Although it is important to recognise the impact climate change will have on these specific areas, failure to also examine the ways that demographic characteristics shape vulnerability and adaptation limits the ability of these policies to formulate more integrated and effective responses to climate change.

In national-level policy, addressing contextually specific local needs, such as those associated with climate change vulnerability, can be a significant challenge. In Indonesia, government policy has recently shifted towards recognising that many of these issues are dependent on local contexts, and acknowledge the unique role of cities in relation to climate change.

This has been reflected in policy documents such as the formulation of the draft National Action Plan Addressing Climate Change (RAN-API) in 2012, which identified urban regions as a category of special areas in the context of adaptation to climate change in coastal areas and small islands. The document highlighted the fact that addressing climate change in urban areas requires integration between stakeholders at various scales.

In addition, the National Development Planning Agency (BAPPENAS)'s National Urban Development Team has developed a National Urban Strategy and Policy (KSPN) as guidance for stakeholders in urban development. The KSPN supports cities' efforts to improve environmental quality and their capacity to cope with disaster events and adapt to climate change.

Although these initiatives provide the basis for more localised efforts to enhance adaptive capacity, they do not fully address the importance of population dynamics in climate change adaptation planning and policy. The Indonesian government, however, is increasingly aware that programmes and activities on adaptation must take into account efforts to target the most vulnerable population groups.

These population dynamics are not yet integrated into the draft RAN-API, but the need to address population and gender issues in the final version has been raised during the formulation process. UN Women has prepared a policy paper on incorporating gender issues into climate change adaptation efforts, and encouraged adjustments to new and existing legal and policy documents and practices.

Indonesia's National Population and Family Planning Board (BKBBN) is also conducting research on the relationship between population growth and climate change, and recognises that increased total population will affect demands for food, energy and health support.

4.2 Local policies and stakeholders in Semarang

The importance of national as well as local factors in understanding vulnerability means that various levels of government must co-ordinate efforts to build adaptive capacity. Local government plays an especially important role in addressing climate change issues within the city; and the provincial government is critical in fostering vertical co-ordination between local authorities and the central government.

The issue of co-ordination across levels of government is one of the main challenges in planning and implementing climate change adaptation policies in Indonesia. This is largely because of the decentralised political structure and system of governance. The implementation of adaptation policies does not depend on only one ministry/government agency, but involves various sectors across all levels of government, the private sector, and the public at large.

The challenges associated with this co-ordination can be seen in attempts to address the climate consequences of the high number of commuters in Semarang. The Provincial Government of Central Java has attempted to facilitate co-operation with the local government of Semarang to address this issue. But interviews with local stakeholders, as well as existing literature, indicate that despite strong economic linkages, co-operation with the local government in the SMA remains very limited in terms of planning and development around these issues.

This is a result of the lack of an integrated program as well as a limited budget available for strengthening co-ordination. Co-ordination between levels of government is further hindered because climate change issues are not necessarily perceived as problems of the greater Kedung Sepur region, but rather as Semarang's problems, which should be address by Semarang City itself.

Co-ordination is necessary not only across levels of government but also between governments and other stakeholders. Within Semarang City, a number of NGOs have worked with the municipal government on projects intended to foster adaptive capacity and address climate change vulnerabilities. These include the Asian Cities Climate Change Resilience Network funded by Rockefeller Foundation (2009-13), which assists the city government in conducting vulnerability assessments and formulating a climate resilience strategy.

ACCCRN has also assisted the local government in implementing pilot projects to strengthen city resilience, such as the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)' Policy Advice for Environment and Climate Change (PAKLIM) project, which assists the Semarang City government in integrating mitigation and adaptation strategies on climate change. Table 18 shows a more extensive list of the various stakeholders in climate change policy in Semarang.

To strengthen the capacity of local stakeholders and improve co-ordination around climate change issues within Semarang City, the City Team for Climate Change issues was established in 2010. The team integrates actors from the city government, NGOs, universities and the private sector.

The local government is represented by a local planning board, the Environmental Protection Agency (BLH), fire and rescue, the health agency, and the mineral and energy agency. Nongovernmental interests are represented by Bintari (a local NGO), Care Environmental Organization (CEO), Semarang Climate Change Forum (Forum Peduli Perubahan Iklim Semarang–FPPI), Universitas Negeri Semarang (UNES), the University of Sugiyapranata and Diponegoro University (UNDIP), also in Semarang.

The City Team is responsible for managing and co-ordinating climate change-related activities. Discussion with local stakeholders and community leaders suggests that the team has resulted in broader communication, which has led to more integrated policy development and programmes to address climate change hazards. Stakeholders suggested that the number of climate programmes and initiatives has also increased. Stakeholders in Semarang have also formed the Initiative for Urban Climate Change Environment (IUCCE).

IUCCE evolved from discussion among local participants in the City Team and aims to reduce communication barriers among stakeholders. Individuals in this group represent their own concerns regarding climate change rather than the interests of any specific institutions. The City Team and IUCCE could provide a useful arena for sharing information between existing stakeholders about the nature of climate change vulnerability and the way in which it is distributed geographically across the city.

Table 14 Stakeholder involvement in climate change policy in Semarang

Stakeholder	Roles, tasks and responsibilities	Potential contributions to climate change mitigation and adaptation
Local government		
Bappeda (Regional Development Planning Agency)	▪ Develop and implement local government policy, especially in relation to local government planning. ▪ Engage in policy formulation, co-ordination of development planning, monitoring and other tasks and responsibilities related to planning.	▪ Formulate overall development programmes. ▪ Incorporate programmes from local government agencies into integrated local government development programmes.
Environmental Protection Agency (BLH)	▪ Develop and implement local government policies and programmes on environmental issues. ▪ Includes: arranging and implementing local government policies in the environmental sector through technical formulation, support and	▪ Formulate sound environmental programmes to improve environmental conditions. ▪ Monitor community and industrial activities that potentially harm the environment.

	monitoring; technological development; other tasks and responsibilities related to environmental issues.	▪ Seek out and support environmentally friendly technology.
Health agency	▪ Develop and implement local government policies and programs related to health issues. ▪ Includes: implementing local government action in the health sector through technical formulation; support and monitoring of technological developments; and other tasks and responsibilities related to health issues, such as preventing diseases and promoting community development on health issues.	▪ Disseminate and campaign for community health. ▪ Engage in prevention and treatment activities for the public. ▪ Formulate programs that aim to provide better healthcare access to city residents as well as raise public awareness about health issues.
Water management/ Energy and mineral agency	▪ Develop and implement local government policies and programmes related to water management issues. ▪ Includes: formulating technical functions, providing public services, monitoring and other activities in engineering, water resources, energy and geology; as well as equipment and pump water management.	▪ Formulate programs aimed at monitoring the use of groundwater and other water resources.
Fire rescue	▪ Develop and implement local government policies and programmes related to disaster management. ▪ Includes: formulating technical functions; providing public services, monitoring, technical engineering, other tasks related to disaster management.	▪ Formulate and implement disaster management programs to increase community awareness.
NGOs		
Bintari (Yayasan Bina Karta Lestari)	▪ Aims to protect and support environmentally sustainable development, especially in waste management, clean water, environmental education, land conservation, and environmental tourism.	▪ Waste management ▪ Environmental education partnerships ▪ Coastal management and

		mangrove planting
Care Environmental Organization (CEO)	▪ Disseminates climate change information.	▪ Conducts Climate Smart Leaders programme for sharing climate change information.
Semarang Climate Change Forum (Forum Peduli Perubahan Iklim Semarang–FPPI)	▪ Engages with diverse stakeholders including local government, community members, environmentalists, private sector actors, and media to foster collaboration on issues of climate change and environmental management.	▪ Involvement in environmental management and protection activities including watershed, flood, and landslide management.
Universities		
Universitas Negeri Semarang (UNES)	▪ Provides programme input to increase community capacity to adapt to climate change. ▪ Builds partnerships with local government to analyse climate change hazards.	▪ Conducts studies and provides recommendations to the government to formulate climate change programmes.
University of Sugiyapranata, Lembaga Manusia dan Bangunan	▪ Provides programme input to increase community capacity to adapt to climate change. ▪ Builds partnerships with local government to analyse climate change hazards.	▪ Conducts studies and provides recommendations to the government to formulate climate change programmes.
Urban and Spatial Planning, Diponegoro University	▪ Provides programme input to increase community capacity to adapt to climate change. ▪ Builds partnerships with local government to analyse climate change hazards.	▪ Conducts studies and provides recommendations to the government to formulate climate change programmes. ▪ Conducts urban studies and provides recommendations for local government.
Private sector actors		
PT Aqua Farm	▪ Aqua-farming production.	▪ Uses environmentally

	▪ Conducts programs aimed at fostering corporate responsibility in terms of social and environmental protection.	friendly technology Works either independently or in co-operation with the government to improve the environment and strengthen community understandings of climate change hazards.
PT Djarum Peduli Lingkungan	▪ Conducts programmes aimed at fostering corporate responsibility in terms of social and environmental protection.	▪ Engages in campaigns for environmental improvements including river improvement, planting and others. ▪ Conducts several environmental improvement activities in conjunction with the local government.

The ability of groups throughout the city to co-ordinate action and represent a variety of interests offers significant promise for the type of adaptation approach necessary for addressing the different sources and profiles of community vulnerability across Semarang. In fact, well-co-ordinated adaptation efforts have already begun to have an impact in two villages – Tugurejo and TanJung Mas – that our analysis identified as vulnerable.

Tugurejo and TanJung Mas are considered potentially vulnerable to the impacts of climate change given their low STI and medium levels of risk for flood and drought, as Table 15 shows. They are located in the northern part of the study area facing the Java Sea, with Tugurejo located slightly west of TanJung Mas (Figure 16). As Table 15 shows, the two villages have very similar population structures, but their housing conditions are quite different.

In Tugurejo, a higher proportion of households use charcoal or wood for cooking and lack piped water. In TanJung Mas, a higher proportion of households lack an improved toilet and have an earthen floor. Tugurejo faces a medium-high risk for drought, and a lack of piped water may exacerbate vulnerability to the impacts of droughts. Efforts to address the vulnerability of these villages have had significant impacts.

Table 15 Vulnerability in Tugurejo and TanJung Mas villages

Climate change risks	**Tugurejo village**	**TanJung Mas village**
Low elevation coastal zone (LECZ)	Within	Within
Flood risk level	Medium	Medium
Drought level	Med.-high	Medium
Landslide risk level	Low	Low
Population indicators		
Total population	6590	27,801
Population density	1085.0	7743.2
Female-headed households (%)	13.6	16.1
Children aged 0-9 (%)	15.0	14.8
Population aged 10-14 (%)	8.5	8.0
Population aged 60+ (%)	5.4	6.1
Population who have never/not yet attended school (%)	3.8	3.6
Population currently attending school (%)	25.0	22.7
Population no longer attending school (%)	71.2	73.8
Population who have completed junior high (%)	61.1	55.3
Migrants (%)	0.6	0.6
Dependency ratio	42.2	42.7
Household indicators		
Total households	1689	7233
Households with earthen floor (%)	3.6	8.5
Households with charcoal/wood for cooking (%)	3.0	0.7
Households without bottled/piped water (%)	69.4	9.8
Households without an improved toilet (%)	13.6	41.0
Households without a phone (%)	7.9	16.0
Households without Internet (%)	73.2	81.9
STI	75.4	85.3

In 2010, ACCCRN initiated a pilot project to plant mangroves and construct breakwaters to reduce the local impacts of climate change in Tugurejo. More than 20,000 mangrove seeds have been planted, and 120 metres of breakwater have been constructed from used tyres in the coastal areas of Tugurejo. This project has increased attention on climate change impacts, and improved the local community's capacity to organise through community groups, co-operate with city stakeholders, and sustain mangrove conservation.

Subsequently, the community developed mangrove nurseries and promotes eco-tourism through the Mangrove Education Center in Tapak (see Text Box 3). The local community group has also provided scholarships to send its members to school (MercyCorps, 2013). These outcomes suggest a great deal of promise for addressing the vulnerabilities of villages such as Tugurejo.

In the face of sea level rise, housing in low-lying coastal areas is especially vulnerable to flooding. In TanJung Mas, 79 per cent of homes have been raised above ground level. Additionally, many other coastal communities are taking action to widen and deepen channel embankments to reduce flood potential. Coastal areas are also being used for fish ponds and planted with mangroves. This planting contributes to the livelihood of farmers and enhances fishing activities. In addition, mangroves serve as a carbon sink that can reduce global warming.

As these projects illustrate, social relationships and kinship networks among communities are an especially important factor in adapting to climate change hazards in vulnerable areas. For example, during floods residents often meet with family members, neighbours and friends in their community to discuss efforts to mitigate and alleviate the impacts of the disaster.

If the residents cannot find a solution on their own, the next step is to conduct a village-level gathering to decide on a course of action. If problems cannot be resolved, they are then handed over to local governments at either the village or district level. When there is cohesive community action, residents are better able to work together to address the impacts of large-scale disasters, and to protect, care for, and preserve the existing environment to mitigate the impacts of future disasters.

The availability of resources can at times constrain individual and community-based efforts at adaptation. To adapt to increased risk of flooding, many communities have put early flood warning systems in place. In some areas, however, their impact is limited by the availability of effective communication tools and boats during flooding.

As a consequence, when a flood occurred in 2011 communities along the Beringin river experienced significant devastation, with 10 people killed and many homes and material possessions lost. In response, the local government and ACCCRN are working to support more effective early warning systems.

The cases described above highlight the importance of a community-level analysis of vulnerability; and of supplementing hazard, demographic and infrastructure data with fieldwork or additional data collection that explores the added social dimensions of vulnerability and adaptation that are not collected in currently available secondary data sources.

Box 3 Mangroves for Life

In the coastal region of KelurahanTugu, KecamatanTapak in Semarang, the majority of residents are fishermen whose livelihoods are likely to be significantly affected by climate change. In this region, climate change is predicted to significantly increase the occurrence of floods and storm surges. It will also make it more difficult to predict sea levels, and to know when to put fish into fishponds.

To adapt to the potential consequences of climate change, a number of initiatives have been implemented. Since 2000, the community has planted mangroves to minimise the impact of storm surges. Local NGO Bintari has been working with the community to provide knowledge on managing climate change processes. This initiative aims not only to minimise the impact of climate hazards, but also to increase community income by creating other income-generating activities.

Interviews with a local leader indicate that these efforts have made a significant contribution in reducing the impacts of climate change. Community and NGO projects have ensured that storm surges cannot reach the established community areas and that they have a minimal impact on fishponds.

Moreover, the initiative has provided a greater opportunity for the community to conduct alternative income-generating activities, such as selling mangroves and conducting mangrove tourism through the Mangrove Education Center. Groups of people regularly come to the area to learn about and enjoy the mangroves.

It was also noted that the initiative has increased social capital within the community. Specifically, a formalised community association was established to manage the new initiatives. A young local leader commented that 40 per cent of income from eco-tourism will be allocated to operational expenses. An additional 20 per cent will be used for management and 30 per cent will be used for social activities.

The community has also established a strong ethos of preserving the mangroves and reached a collective agreement to prohibit destruction of the mangroves. This initiative has not only increased community awareness in Tapak, but also among other stakeholders and communities from other areas of Semarang and beyond.

5 Conclusion

Addressing the impacts of climate change is a critically important challenge for urban areas around the world. Central to this is the ability to develop initiatives that increase the adaptive capacity of the most vulnerable residents. This requires a thorough understanding of local population dynamics and their relationship to climate risk.

As the hub of social and economic activity in Central Java Province, Semarang faces many climate change-related challenges, as well as opportunities to lead local efforts to address vulnerability and adapt to climate change impacts.

Historically, the city has faced hazards such as drought, land subsidence, landslides and floods, which are likely to be magnified and become more frequent as a result of climate change. Within Semarang, our demographic and spatial analysis allows for an understanding of the spatial distribution of these climate hazards along with the vulnerabilities communities face in confronting these challenges.

A number of key findings stand out. Within our study area, many of the high-risk areas also have high population densities, which increases their overall vulnerability to temperature changes, water supply issues and health problems. In many ways, however, those areas with the highest risk also have the lowest vulnerability, with relatively high adjusted STI values and low dependency ratios.

Substantial variation in the levels of vulnerability remains, though, as well as the sources of vulnerability within Semarang. The spatial analyses developed in this study show that by examining the distribution of hazard risk in relation to various types of vulnerability, it is possible to more effectively target policies and initiatives to reduce the impacts of climate change.

Climate change policy must recognise the ways that population dynamics mitigate or heighten vulnerability and influence the capacity of communities to adapt to hazards. To be most effective, programmes should specifically target those communities that face significant risk and also have demographic characteristics that may make them particularly vulnerable. As noted previously, the specific characteristics that constitute vulnerability are likely to vary based on the type of hazard a community faces.

To respond to this variation, policies must be flexible or be developed closely with local communities and officials. Information regarding the sources of vulnerability for specific communities, as well as the geographic distribution of vulnerability, provides a framework for a more comprehensive understanding of how to effectively target resources at increasing adaptive capacity.

Although understanding population dynamics is critical for developing effective policy, integrated demographic information has not yet served as a foundation for approaching climate issues in Indonesia. Rather, the discussion of population dynamics has generally been absent from policy. At the national level, the response to climate change has instead been divided primarily along the needs of specific sectors.

Increasingly, though, policies that are currently being developed recognise that urban areas and specific population groups face unique challenges in confronting the impacts of climate change, and may require more tailored policies and programmes to meet their needs. By developing tools for assessing these demographic components of vulnerability in conjunction with policy shifts, there is an opportunity for one to inform the other and to address vulnerability more effectively.

A number of potential avenues exist to move this line of research forward in Indonesia and elsewhere. First, the analysis conducted for Semarang highlights local processes of vulnerability. Although some of the findings may be specific to Semarang, the methodology used can be applied across Indonesia.

The 2010 census covered the entire country at the village level and the data are available for analysis. The census-based vulnerability assessment approach can therefore be applied to other villages, municipalities or regions at relatively low cost and with limited additional expense of time. BNPB already has the hazard data for the whole of Indonesia.

Care will need to be taken in making comparisons between rural and urban areas, and districts and regions within the country, but as a component of understanding local vulnerability and adaptive capacity, this approach should have significant value.

Besides flood risk vulnerability analysis, this study also shows which villages are most at risk from landslides. Future studies could examine and map the vulnerability of villages for other climate change risks, or for disaster risk reduction. In addition, this approach could be adjusted to apply to a broader array of development questions; for example, proximity to services, efforts to reduce poverty and inequality, and other kinds of environmental degradation questions.

The dynamics of demographic characteristics mean that census data used in the study may differ from the current situation on the ground. Further aggregate analysis at the village level may not capture the full range of vulnerable individuals and households, either, because they are hidden in summary statistics, or because the most vulnerable populations may have disproportionately avoided being counted in the census.

Census-based vulnerability assessments should be complemented with links to local government and nongovernmental stakeholders, as well as community members, to evaluate the results and link the assessments with adaptation planning.

The analyses provided here develop a methodological approach for understanding climate change vulnerability, and provide a foundation for Semarang City and the national government to target initiatives at maximising resilience to climate risk. By understanding the spatial relationships between vulnerability to hazards and the potential for local populations to adapt, future policies and initiatives can be developed in a more targeted and efficient manner.

By disseminating this information throughout the networks of actors that deal with climate issues in Semarang, this analysis can provide a common starting point to take action to increase local adaptation to hazards through an integrated response.

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