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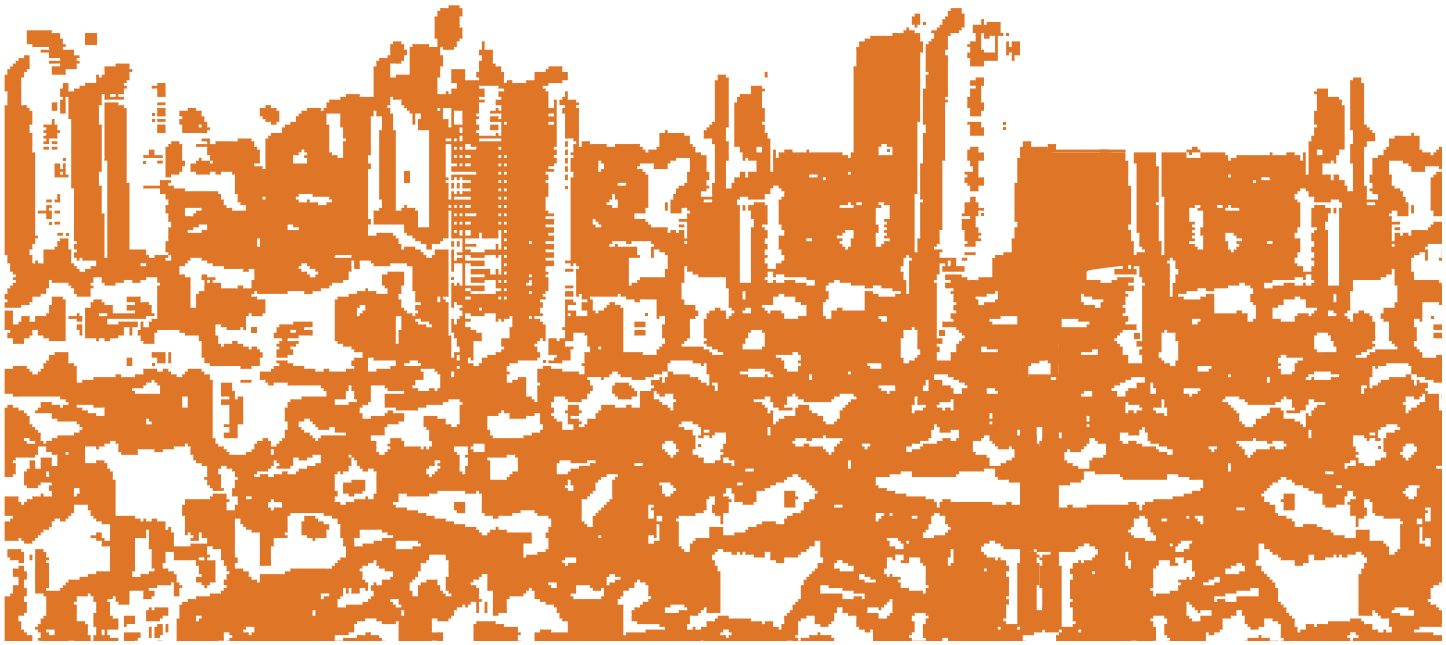
Climate change, floods and homes

A social networks approach to understanding location preferences in Indonesia

BY MUSTIKA ANGGRAENI, ISMU RINI DWI ARI AND ENDRATNO BUDI SANTOSA



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Contents

About the authors **2**

List of figures **5**

Acronyms **6**

Abstract **7**

1 Introduction **8**

2 Conceptual framework **10**

2.1 Climate change in Indonesia 10

2.2 Home location preferences 11

2.3 Vulnerability 11

2.4 Background: housing in Bojonegoro Regency 12

2.5 Climate change adaptation 15

2.6 Community decision-making systems 15

3 Research methods **17**

3.1 Research questions and objectives 17

3.2 Methods 17

3.3 Surveys 18

3.4 Sample and sampling system 19

4 Characteristics of the study area **21**

4.1 Flooding and its impacts 21

4.2 Settlement characteristics 25

4.3 Demographics in the research locations 27

4.4 Exposure to flooding and adaptation mechanisms 30

5 Factors influencing settlement location choices **31**

5.1 High-vulnerability communities 33

5.2 Medium-vulnerability communities 34

5.3 Low-vulnerability communities 35

5.4 Combined results for the communities 36

5.5 Structural equation models: discussion 37

6 Community social structures **39**

6.1 Community group profiles 39

6.2 Community group membership 41

6.3 Typology of social structures 43

7 Conclusion **53**

7.1 Recommendations 56

References **57**

Appendix 1. Household survey: structural equation models **60**

Appendix 2. Calculations for social network analysis **65**

List of figures

Figure 1. Spatial distribution of vulnerable areas 12

Figure 2. Flood-prone areas in the Bojonegoro Regency 13

Figure 3. Summary of the research scheme 16

Figure 4. Research framework design 18

Figure 5. Flooding disaster frequency, Bojonegoro regency 21

Figure 6. Photos of Banjarjo during flooding 22

Figure 7. Water height in metres, 2010–2013 24

Figure 8. Photos showing how close the Bengawan Solo River is to houses 26

Figure 9. Area flooded during March 2010 26

Figure 10. Education levels for heads of households 28

Figure 11. Income levels per household (IDR) 30

Figure 12. Path model for high-vulnerability communities 33

Figure 13. Path model for medium-vulnerability communities 34

Figure 14. Path model for low-vulnerability communities 35

Figure 15. Path model for the combined communities 36

Figure 16. Settlement elements with the strongest influence by category of vulnerability 54

Table 1. Flood history of Bengawan Solo River in Bojonegoro 14

Table 2. High-vulnerability communities 19

Table 3. Medium-vulnerability communities 20

Table 4. Low-vulnerability communities 20

Table 5. Flooding pattern, Bojonegoro 23

Table 6. Age of heads of household by area vulnerability category 27

Table 7. Heads of household: occupations 29

Table 8. SEM independent variables 32

Table 9. Summary of community group types 40

Table 10. Multiple memberships in the high-vulnerability communities 41

Table 11. Multiple memberships in the medium-vulnerability communities 42

Table 12. Multiple memberships in the low-vulnerability communities 43

Table 13. Density level for the communities at all three levels of vulnerability 45

Table 14. Centrality for high-vulnerability communities 47

Table 15. Centrality for medium-vulnerability communities 49

Table 16. Centrality for low-vulnerability communities 50

Table 17. Rate of participation of the communities in each category of vulnerability 52

Acronyms

Arisan	A community savings and credit group at RT or RW level
BKM	Badan Keswadayaan Masyarakat (community self-reliance agency for urban civil society)
BPBD	Badan Penanggulangan Bencana Daerah (Regional Disaster Management Agency)
Jamaah Tahlil	Islamic group
Karang taruna	A youth organisation
Kelompok Tani	Farmer groups
NU	Nahdatul Ulama (a traditionalist Sunni Islam group in Indonesia)
Petok D	Certificate of ownership issued by the local tax office
PKK	Pembinaan Kesejahteraan Keluarga (Family Welfare Movement), a women's neighbourhood group
PNPM	Program Nasional Pemberdayaan Masyarakat (National Programme of Community Empowerment)
Remaja Masjid	Islamic youth group
RT	Rukun tetangga (small neighbourhood association)
RW	Rukun warga (groups of RTs/neighbourhood associations)
SHM	Sertifikat hak milik (certificate of ownership issued by the National Land Agency)
Siskamling	Sistem keamanan lingkungan (neighbourhood watch system)

Abstract

Cities face mounting challenges from climate change. In Indonesia rising temperatures, changing rainfall patterns, higher sea levels, and more frequent and severe extreme events such as droughts and floods threaten to overwhelm settlements, urban infrastructure, services and management systems. This working paper focuses on the Bengawan Solo River Side Buffer of Bojonegoro Regency in East Java. The area has high frequency floods and the Bojonegoro Regency have built a levee for flood protection. However, about 1,300 families from 1,100 households have chosen to locate their homes outside the protected area, and this continues to happen from generation to generation. Using structural equation modelling (SEM) and social network analysis (SNA), this paper seeks to investigate the typology of social structures to examine why these populations are choosing to remain in at-risk areas.

The structural equation model shows that for all of the communities (low, medium and high vulnerability) their greatest fear is not only flooding but consequential land losses due to torrential water when the upstream dam is opened. The communities' priority is managing their inherited lands sustainably rather than their homes. The emotional needs and community groups are significant sub-variables for each of the three categories of vulnerable community in the research area.

The social network analysis shows that the low-vulnerability communities can better mobilise their local and extra-local resources to live in flood-prone areas than residents in high- and medium vulnerability communities. They have stronger networks of interpersonal relationships that is stimulated by some prominent residents, and also face the least flood risk. In line with Putnam (2000) and Leenders (2002), the findings of this study suggest that the choice of residents to remain in flood-prone areas is determined by the strength of their social network, and that is influenced by prominent residents who are influenced by overall community resilience to flood disaster.

1 Introduction

Most coastal and river-oriented cities in Asia including Indonesia are threatened by climate change. This is indicated by the high frequency of hazards from climatic events, such as flooding, intensified storms, rising sea levels and storm surges, which in turn may result in large losses of life and infrastructure, as well as damage to national and regional economies (Fuchs, 2010). Bojonegoro is a river-oriented regency in East Java, Indonesia, threatened by climate change. The Bengawan Solo river basin sub-system, in Bojonegoro Regency, sees relatively high flooding frequency. In 2010 there were 16 flooding events, (Widayanti *et al.*, 2012). The real threat of climate change is felt by society as routine floods occur every rainy season. In recent years, the community has perceived these impacts increasing in intensity and frequency. Changes in rainfall patterns such as a delayed rainy season which ends earlier may be attributed to climate change (Naylor *et al*., 2007). While the rainy season is shorter, the intensity is greater, affecting areas such as river-based Bojonegoro. This threatens the settlements outside of the area protected by the levee.

Built in the 1970s by the government, the levee along the river protects the city from floods. However, as urbanisation advanced in the 1970s and 80s, especially in Bojonegoro, people decided to open the levee to access and live along the riverside buffer outside of the protected area. Now the area has developed into a settlement with 1,100 houses and about 1,300 families living in the flood-prone areas.

The density of the settlement has increased over the past 10 years. It is equipped with infrastructure such as streets, electricity, water and public services such as health and education – some provided independently by the community and some by the government. The Bojonegoro spatial planning document 2011–2031 describes this area as vulnerable, and as such it needs to be highly controlled (Bojonegoro Planning and Development Department, 2011). However, law enforcement in the regency is weak and the planning document has not been well implemented. To address this problem, the government needs to understand why inhabitants in flood-prone areas choose to remain and face such hazards.

One possible reason is the existence of social ties among individuals that might influence them to stay. A collective spirit might enable inhabitants to live with these circumstances for long periods. In the rainy season, they voluntarily work together to prevent and protect their environment from floods. Additionally, some residents have adapted their homes into low-rise houses in response to flooding, and their neighbours may have copied them. These circumstances might illustrate that decision-making processes related to home locations are representative of (i) human behaviour embedded in networks of interpersonal relationships (Wasserman and Faust, 1994) and (ii) that the choices made by individuals are determined by influential others as well as in reaction to the constraints and opportunities imposed by the social system (Leenders, 2002). For that reason, the hypothesis of this study is that a household with stronger community ties may be influenced to remain in a flood-prone area.

Many government policies and programmes are not implemented successfully. This might be due to the inappropriate formulation of policy and planning programmes that are not based on needs and sociocultural considerations. Therefore, it is necessary to dig deeper to reveal how the home location preferences of the inhabitants in the research area were formed.

Previous research in Bojonegoro Regency, especially in Bojonegoro District (a sub-district) focused on flooding problems (Ratna *et al*., 2011). It studied the influence of development of land-use patterns on the peak discharge of the water runoff to the river, emphasising that there is a correlation between land-use changes and the peak discharge of the water runoff. This study builds on this to focus on the social aspects of home location preferences.

Some studies have highlighted that it is important to study social vulnerability in relation to climate change, because social aspects are largely underemphasised in assessments of the impacts of climate change and climate extremes (Adger, 1999). Vulnerability is defined in Adger's research as the exposure of individuals or collective groups to livelihood stresses as a result of the impacts of environmental change. It is constituted by individual and collective aspects which can be disaggregated, but are linked through the political economy of markets and institutions. Adger (2003) developed the social aspect more profoundly by closely relating social collective action to climate change adaptation. Future changes in the climate pose significant challenges for society, not least how best to adapt to observed and potential future impacts of these changes to which the world is already committed. Adaptation is a dynamic social process: the ability of societies to adapt is determined, in part, by their ability to act collectively. In this study, the goal is to enrich knowledge relating to the decision-making processes used by residents who remain in the flood-prone area of Bojonegoro District.

Based on identification of the problem and the previous research, there are three main research objectives:

(1) Identify factors influencing why inhabitants have chosen to live in the flood-prone area or remain on site,

(2) Investigate the home decision-making models of the inhabitants, and

(3) Investigate the social structure of the community.

2 Conceptual framework

2.1 Climate change in Indonesia

Indonesia is world's fourth most populous nation and a significant emitter of greenhouse gases (GHG) due to deforestation and land-use change (Bradley, 2005). Indonesia consists of nearly two million square kilometres of land, most of which is covered by forests.

Impacts of climate change are already evident in Indonesia and will likely worsen due to further human-induced climate change. Rising concentrations of GHG will continue to raise the surface and ocean temperatures, change precipitation patterns, increase sea levels, and cause various other impacts from more frequent forest fires to increased health risks. Climate change will also continue to affect 'natural' climate variability, such as El Niño, and may lead to more frequent and more intense weather events (Diposaptono *et al*., 2009).

In certain areas of Indonesia, it is projected that rainfall will increase and may occur in fewer, more intense events which could lead to flooding. The Indonesian government estimates that losses will amount to Rp 4.1 trillion (US$ 450 million) (WHO, 2007). These types of trends (drying in parts and flooding in some areas), combined with an overall shift of the seasonality and timing of rainfall will lead to unpredictable and uncertain water availability and consequently an uncertain ability to produce agricultural goods and therefore lead to economic instability. Climate change-induced food production losses could drastically increase the number of undernourished people and hinder progress against poverty and food insecurity.

Global sea-level rise is currently increasing at about 2mm per year and is projected to accelerate to a rate of about 5mm per year over the next century (Cruz *et al.*, 2007). A change of this magnitude will undoubtedly result in significant losses of Indonesia's 80,000km of coastline, affecting thousands of islands and associated marine resources.

Climate change is a challenge for urban areas and inhabitants. The impact of climate change in Indonesia will mean that cities will have warmer temperatures and more frequent hot days and nights; fewer cold days and nights; increased frequency of wind/waves; increased frequency of heavy rainfall in some regions; increased drought-affected areas; an increase in intense tropical storm activity; and an increased incidence of high sea-level rise extremes (Surmaini and Susanti, 2009). The impact of flooding in some cities is also coupled with the problem of deficits in basic infrastructure for inhabitants. Climate change can also affect water availability, physical infrastructure, transportation, supply and demand of goods and services, energy provision and industrial production. These effects could disrupt local economic potential. Some residents may lose assets and livelihoods. The impact of climate change is felt in cities around coastal areas, watersheds or areas that have a lower elevation.

Bojonegoro Regency, located 110km from the capital city Surabaya of East Java Province, covers an area of over 230,000ha, with a population of over 1.47 million inhabitants (Statistics of Bojonegoro Regency, 2013). The Bojonegoro topography shows that 18 per cent of the area along the Solo River watershed is a lowland area. The city centre is spread across the low-elevated area with a population density of 3,871 inhabitants/km^2 (ibid). The main urban activities are commercial, public facilities, household industries, and residential settlements. The main risk faced by the city is regular flooding as the city centre is in the watershed area, reaching a peak of 17 flood events in 2007. As the city's commercial core is floodprone, this has significant implications for infrastructure and settlements.

2.2 Home location preferences

As many Indonesian cities have historically developed along rivers, riverbank settlements are common. However, as settlements grow, this has implications for environmental sustainability, particularly due to the river acting as a buffer area. Many of the riverbank settlements are informal with high density, houses in poor condition, and irregular, unplanned form (Kusno, 2000).

Predominantly many settlers have built houses without regard to prevailing regulations. Vacant land is used to establish security posts, cemeteries and landfills. Land between roads and homes is used for selling groceries, keeping cattle, and for the development of additional informal settlements. This is typical in the study area, although with some unique attributes.

Theoretically, residential location preferences are influenced by: (a) opinions on the current conditions of a settlement (b) the attractiveness of a settlement, (c) ideal conditions of a settlement, and (d) a comfortable settlement environment (Sinulingga, 1999). Choice of residence is not only determined by the condition of the residential dwelling. The surrounding residential neighbourhood also has a big influence. According to Turner (1976), those with high incomes will consider the environment as a determinant, while those with lower incomes have less choice in determining the location of their dwelling.

According to Amos Rapoport (1977: 81) people will adjust their preferences when selecting a residential environment. This means understanding the characteristics of people and the environment. If the person has the opportunity to make a choice, this opens up options regarding the preferred physical and social environment. Where people do not have a choice of preferred environment, this can affect people's livelihood and lifestyle options. Preferences affected by lifestyle cover four areas: consumption, social prestige, community and family (Moore in Rapoport, 1977).

Residents living on the Bengawan Solo riverbank outside of the flood protection area are there either because it is their preferred location, or because they did not have any choice. This decision needs to be explored because theoretically, safety would be a consideration in decisions relating to residential location. However if residents are exposed to frequent flooding in their location, one must examine whether this is because they have no choice over whether or not to relocate, or because community ties mean that the benefits of remaining outweigh the risks.

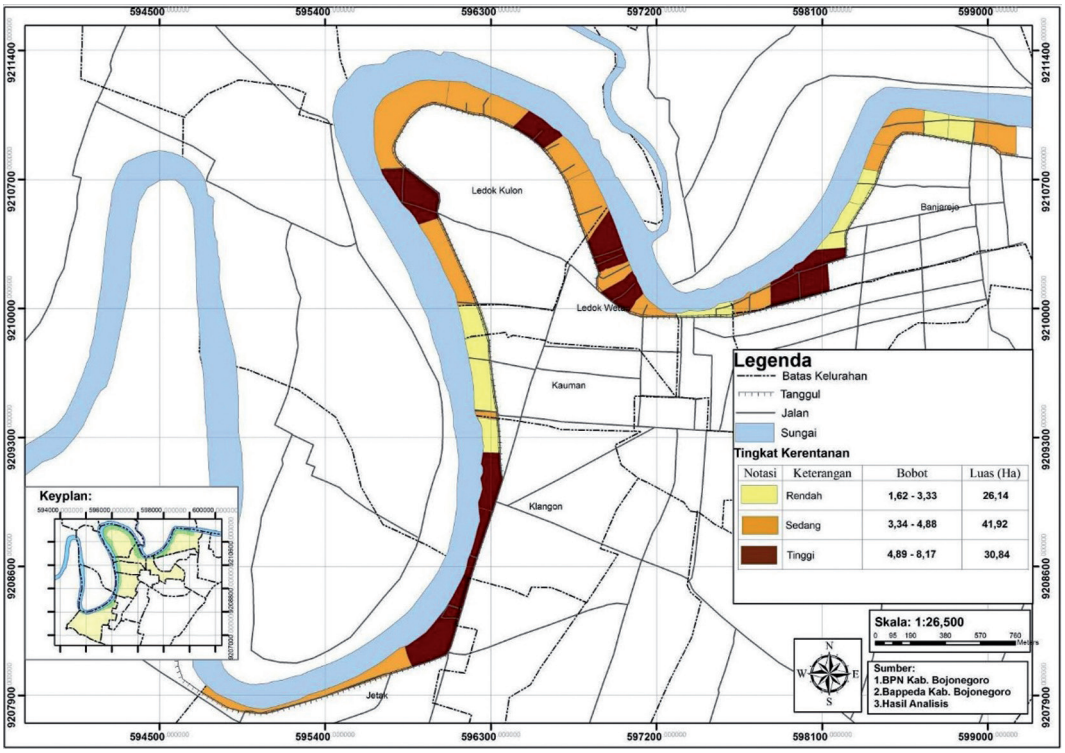
2.3 Vulnerability

From a previous study, the Bengawan Solo riverbank settlement compound was identified as a vulnerable area by **physical**, **economical**, **infrastructural** and **social** indices (Widayanti *et al*., 2012). As defined by the IPCC, vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes, and it is a function of exposure, sensitivity, and adaptive capacity (IPCC, 2007). The impact of climate change will depend in part on the nature, rate and severity of the change in climate, as well as the social, economic, governance and other forces that determine who and what are exposed to climate hazards, their sensitivities and their capacities. For some, the impacts may be beneficial. But predominantly harmful impacts are expected, particularly in the developing world (IPCC, 2001)

The Bengawan Solo riverbank settlement is an informal settlement that is considered vulnerable because its location is highly exposed to flood hazards (Figure 1) and because of the high density of houses. The area is also the city centre with a lot of important infrastructure, making the area more vulnerable.

Previous research (Widayanti *et al*., 2012) in Jetak, Klangon, Ledok Wetan, Ledok Kulon and Banjarjo sub-districts shows that 12 hamlets are areas with high vulnerability, from social (population density, building density, age group, health and education levels), economic (income and unemployment levels), physical (geology, topography, erosion, and flood hazard frequency) and infrastructure (public and transportation facilities) indices. Other areas with moderate vulnerabilities are 12 hamlets in Jetak, Kauman, Ledok Wetan, Ledok Kulon and Banjarjo sub-districts. Areas with low vulnerability are 9 hamlets in Klangon Kauman and Banjarjo sub-districts (Widayanti *et al*., 2012).

Figure 1. Spatial distribution of vulnerable areas



Source: Widayanti *et al*., 2012

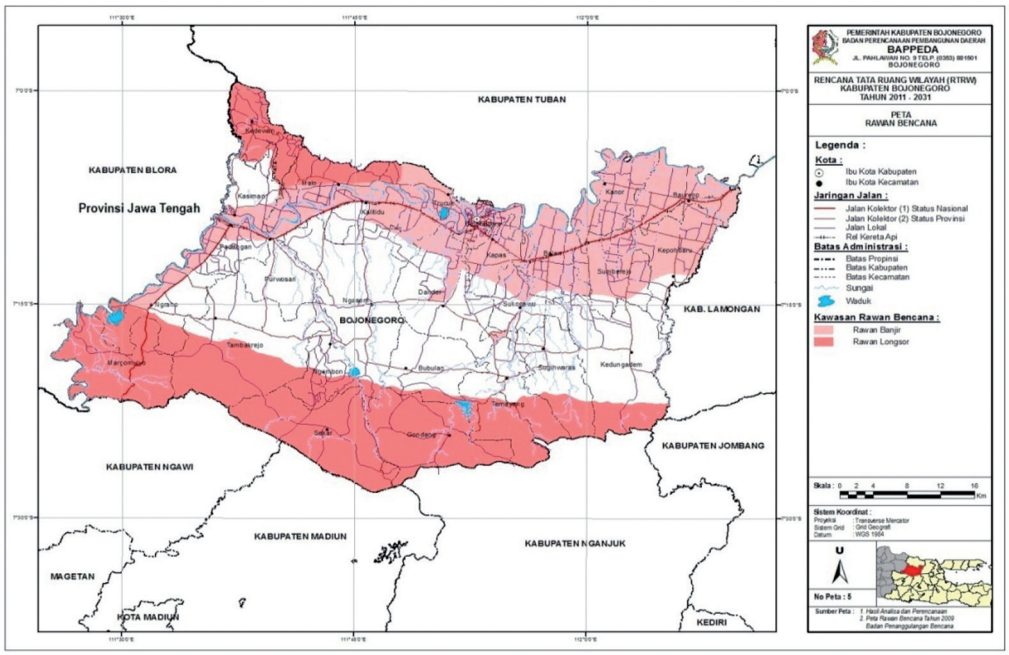
2.4 Background: housing in Bojonegoro Regency

Regarding exposure to hazards, the Bojonegoro study area is never free of natural disasters that occur throughout the year. The topography draining the Bengawan Solo River divides the northern and southern parts of the district. The northern region of Bojonegoro is low lying, exposing it to floodwater from the Solo River from upstream rivers in Central Java (Figure 2).

Meanwhile, the southern part is flat terrain with many tributaries that flow into the Solo River. Damage to forests in the highlands of southern Bojonegoro causes flashfloods that strike agricultural and residential areas around the tributaries to the river upstream. Stream flashfloods cause landslides and erosion hazards, washing away soil and silting up creeks on the spur of the Solo River during times of rainfall maximum.

When the Bengawan Solo River flooded in late December 2007 to early January 2008, it was the most severe flood on record, drowning Bojonegoro City. The Bengawan Solo levee was breached in several places along the river and stagnant water covered almost the entire surface area of the northern lowlands for more than two weeks. Local residents now dread the floods recurring every year.

Figure 2. Flood-prone areas in the Bojonegoro Regency



Source: Bojonegoro Planning and Development Department (2011).

The population in the district generally been settled for generations, especially in Banjarjo, Bojonegoro, Ledok Wetan, Ledok Kulon, Kauman, Jetak and Klangon sub-districts. Most residents have lived there for 21–40 years. The first recorded intensive flood event happened in 1966, with more flood events in the settlements around the riverbanks during 1994–2002.

Table 1. Flood history of Bengawan Solo River in Bojonegoro

Date	Incident	Location	Details
1868	Flooding	Upstream region of the Solo River	
1966	Flooding	Solo, Ngawi, Bojonegoro, Lamongan	168 people killed, 182,000 houses damaged, 142,000 hectares agricultural land in 93 districts flooded, damage to infrastructure including 42 bridges, 19 irrigation channels, 5km railroads, and 3.8km embankment
1982	Flooding	Bojonegoro	129 villages in 13 districts, 7,298 houses and 917,376 hectares of land flooded
1991	Flooding	Bojonegoro, Tuban, and Lamongan	27,000 hectares of agricultural land, plantations and settlements flooded
1996	Flooding	Bojonegoro, Tuban, Lamongan and Gresik	Loss of Rp. 13.29 billion, floods covering 220 villages in 36 districts with an area of 15,000 hectares
1998	Flooding	Blora, Bojonegoro, Tuban and Lamongan	Floods inundate thousands of homes
2005	Flooding	Bojonegoro	13 districts flooded
2006	Flooding	Bojonegoro	71 villages in 15 districts flooded
2007	Flooding	Bojonegoro	10,253 houses and 4,600 hectares of agricultural land and plantations flooded

Sources: Tjahjono (2008) and interview, 2013.

Bengawan Solo River crosses the district of Bojonegoro, flowing from west to east with a curve to the south and north of the river 150–170m wide. It has a depth of 7m. Tributaries located in this region are the Kedungbajul sub-watershed with an extensive catchment area of 77.23km^2, which flows south to north (Ratna, 2011).

The study area is located on the banks of the Solo River which has a discharge between 1,450–1,800m^3/second. With a large flow of water and downstream of the Solo River, the study area is greatly influenced by rainfall and upstream conditions. The increased flooding intensity in the Bengawan Solo catchment area is mainly caused by a combination of land-use changes and climate change, especially rainfall, increasing the vulnerability of the area. This combination has been confirmed in various scenarios using a hydrologic modeling system (HEC-HMS) model of the area (Martawati, 2010).

Rainfall and high water flow in the study area can cause flooding. Critical watershed conditions and the proximity of the settlements to the river buffer are parallel causes making the areas more prone to catastrophic flooding.

2.5 Climate change adaptation

Adaptation is defined as the adjustment in natural or human systems in response to actual or climatic stimuli or their effects that will occur to reduce the possibility of harm or exploit beneficial opportunities (IPCC, 2007). Adger and Vincent (2005) define 'adaptive capacity' as the adaptation space within which decision-makers in any system (regardless of location or state of development) might find feasible options but it does not guarantee which adaptations are actually attempted or which, in the end, will be successful (however measured). Clearly, it is not the potential adaptive capacity but what actions are really taken that influence a system's vulnerability and ultimately experienced impacts.

Future flood damages will depend heavily on settlement patterns, land-use decisions, the quality of flood forecasting, warning and response systems, and the value of structures and other property located in vulnerable areas. Flood losses are related to exposure, which is related to population and wealth, while adding precipitation increases the rate of loss. A number of studies have been carried out examining climate change and its potential flood damage impacts. For example a study in Boston found that by 2100 the number of properties damaged and the total cost of flood damage would double without adaptation investments, relative to the condition without climate change, including flood-related transportation delays. The conclusion of this study was that the economic magnitude of flood damage is adequately high to justify greater spending on adaptation strategies such as universal flood-proofing for all floodplains (IPCC, 2007).

For many people around the world, particularly in developing countries, the dangers associated with flooding are serious. Houses can be destroyed instantly as a result of heavy rain and flooding, particularly those types of homes found in informal settlements. Adapting homes to cope with flooding, either by retrofitting or by taking into consideration flooding in constructing new homes seems vital. Possible solutions to constructing new homes include locating them on higher ground, away from flood plains, and using materials which can withstand heavy rainfall.

Adaptation approaches implemented in Bojonegoro currently are reactive, and focus more on disaster management, like in Jakarta or lowland areas in Indonesia, rather than on efforts to specifically prepare for and reduce the impact of climate change. While the government has put in place early warning systems and risk reduction programmes to cope with disaster, these efforts are more reactive rather than proactive and in particular, city-level governments need to make an effort adapt cities to climate change (Firman *et al.*, 2011).

However, residents can also take their own measures to adapt to floods. For example, while the government has built a levee along the riverbank to protect the city from floods 1,100 people still live outside the protected area. These residents are familiar with floods and have their own mechanisms and habits to cope with the hazards, such as keeping an elevated storage area in their houses to keep belongings dry; and relocating to the top of the embankment during heavy rains. These are examples of coping measures, rather than preventative adaptation measures.

2.6 Community decision-making systems

Indonesian society in general still is based on *guyub*[1] and upholds a culture of mutual cooperation and mutual support, both as a value and as part of the nation's attitude. For Indonesians, mutual cooperation is not only significant as a form of behaviour, but also as a moral value. This means that mutual aid has always been the benchmark of good behaviour.

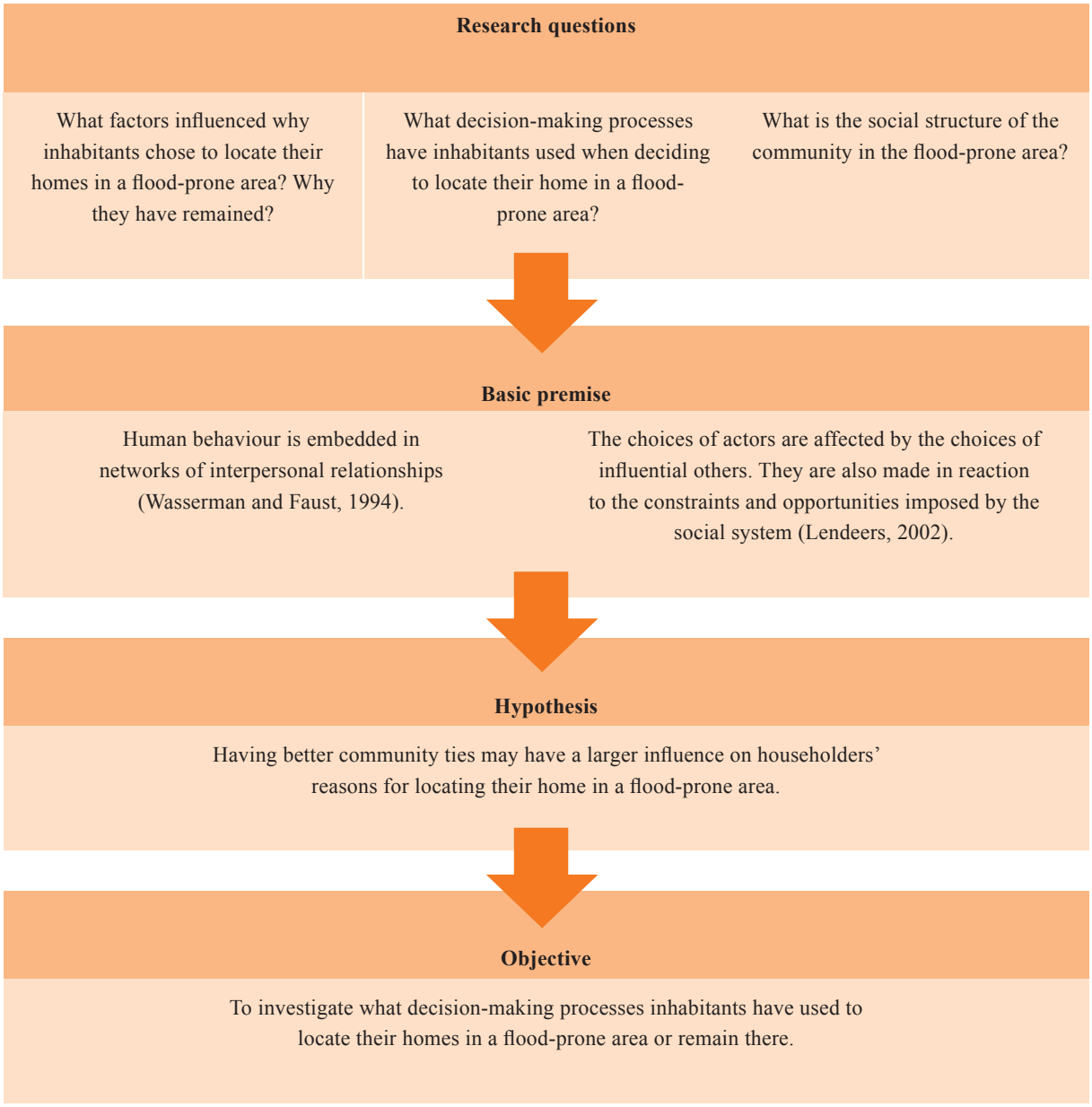
Applying mutual cooperation in Indonesia is dynamic. Mutual aid has been used by all levels of society, from bureaucrats and government leaders to farm workers, business leaders, organisations, sub-district administrators, RTs and RWs to night patrols in villages. In urban areas, however, mutual cooperation is declining, due to the busy nature of urban life. Conversely in rural, suburban areas, there are still many examples of mutual cooperation, for both public and private interests.

1 'Guyub' is harmonious behaviour within society or groups where social ties are based on strong personal ties.

The village democratic culture of Indonesia is based on the communal ownership of land, where every member of the public feels obliged to act by mutual consent, while participating in community activities. The democratic culture is also reflected in people's everyday lives, based on the principles of kinship and mutual cooperation. In principle, this requires an attitude which prioritises the common good and social obligations rather than individual interests. The inclusion of any individual in the achievement of a decision by mutual agreement reflects the maintenance of social relationships and a fundamentally democratic culture.

Residential preferences are often influenced by things outside of the settlement's environmental conditions. Tirtosudarmo in Koestoer (2001: 99–100) stated that: 'In Indonesia, the importance of family relationship patterns reflects the local culture. A case study in East Java declared in relation to migration, that family ties, friends, and family have an influence in facilitating and encouraging migrants in the city when determining their residence.'

Figure 3. Summary of the research scheme



3 Research methods

3.1 Research questions and objectives

Previous research in the city of Bojonegoro by Widayanti *et al*. (2012) concentrated on the problem of flooding in the study area. Ratna (2011) found a relationship between changes in land use and the discharge of water runoff. Widayanti *et al.* (2012) measured the vulnerability of Bojonegoro City and formulated relocation as an alternative solution. This study builds upon the previous studies and concentrates on the social aspects in settlement location decisions.

Adger (2003) revealed that social considerations and collective action can be associated with adaptation to climate change. Adaptation is a dynamic social process: the ability of the community is determined in part of their ability to act together. In this study, social vulnerability and social action are considered together.

3.2 Methods

Figure 3 outlines the three objectives to this study. The methodology used for the formulation of the first and second objectives is structural equation modeling (SEM), a statistical data collection method that allows the identification of the relationship between one or more independent variables and the dependent variable to be tested. SEM will describe a model for the decision-making processes of residents living in flood-prone areas in the city of Bojonegoro using the five indicators of Ekistics Theory formulated by Doxiadis in 1970. This theory of Doxiadis applies to the science of human settlements, and provides a framework explaining the 'container' of settlement elements, using the variables of nature, shell and network, and the 'content' of settlement elements using the variables of man and society (Doxiadis, 1970).

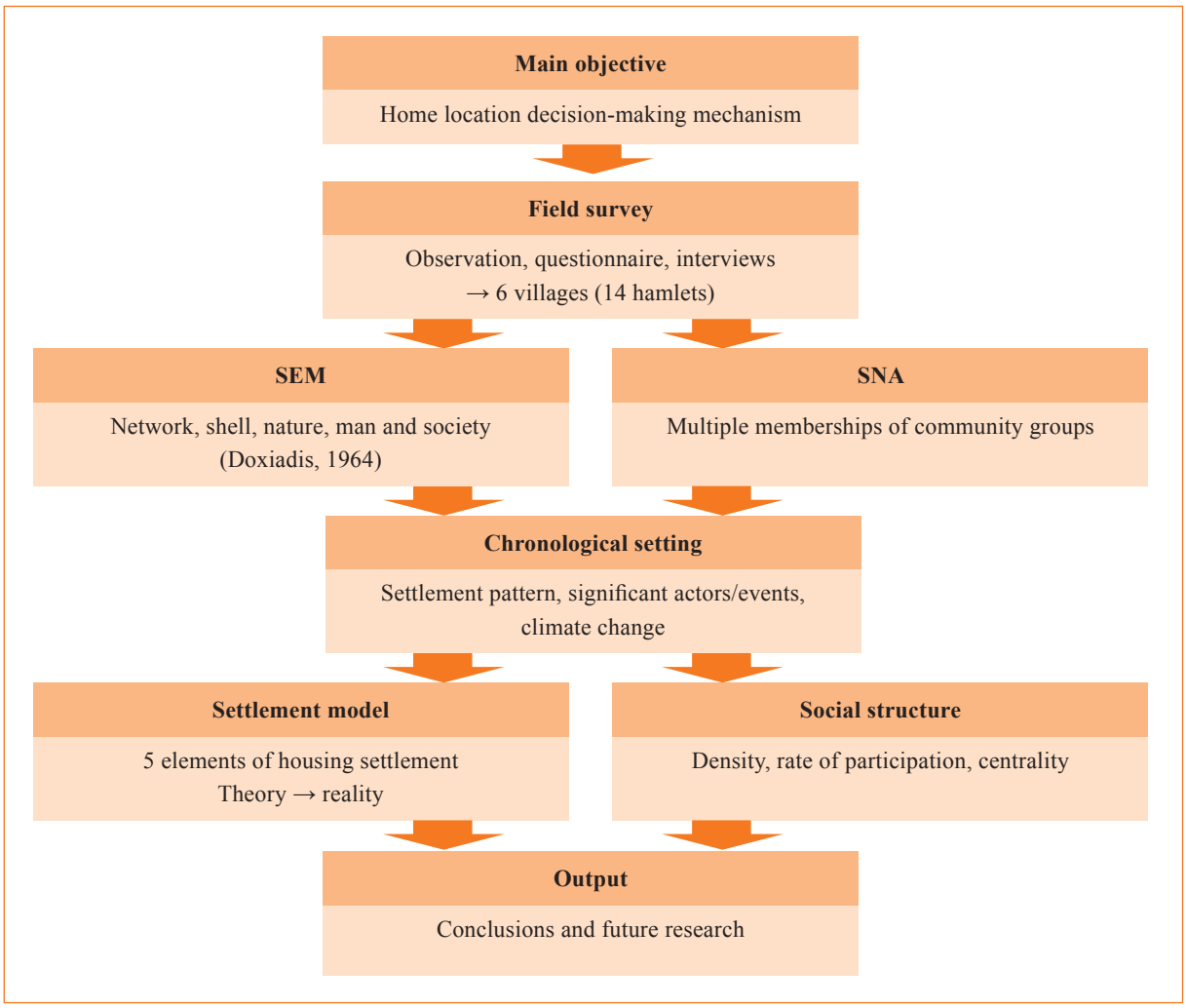
Much of the discussion of settlement elements – especially around elements supplied by the Indonesian government – considers only the 'container' of the settlement, such as the building construction, access, facilities and the power network. It therefore ignores the 'content': man and society. This study therefore seeks to examine whether all settlement elements play a role in influencing the formation of settlements in flood-prone areas. It also examines whether and how the 'content' variable, especially social structure, affects the decision-making processes relating to locating homes in flood-prone areas. Each of the five variables is measured by a series of indicators which are used to carry out the analysis.

In addition to SEM, social network analysis (SNA) will identify the social structure of those who have decided to settle in flood-prone areas Bojonegoro City. This study uses relational or affiliation data that is formed between individuals within membership organisations in the community, based on the results of previous research by Ari *et al.* (2013). This study examined public participation in water management in Singosari, Malang and identified a social structure at two household types in the three hamlets. In SNA, the variables used are: networks (including community organisations), social structure and the closeness of social relationships through three-centrality indices (ibid). This study focuses upon relationships between actors across multiple memberships of the present community groups. The relational data is composed into an affiliation 'actors-by-actors' matrix that it is categorised as a one-mode network (Wasserman and Faust, 1994).

Referring to Ari *et al*. (2014), in order to scrutinise the social structure of the community, this research has applied the SNA approach using software UCINET 6 for Windows version 6.523. Three measurements have been computed to uncover the typology of the social structure the three categories of vulnerable community in the research area covering density, centrality and rate of participation (ibid) (see Section 3.3 and Appendix 2 for details).

The rate of participation is identified by looking at rates of membership in various community groups within each hamlet, ranging from low to high. A high rate of participation illustrates that the majority of actors participate in more than half of all community groups, implying that community members are more likely to know one another and hence the flow of information among community members might be easier to disseminate than in communities with low rates of participation. The research framework can be seen in Figure 4.

Figure 4. Research framework design



3.3 Surveys

The field surveys for this study were divided into three stages:

a. The first survey consisted of observations to identify and understand conditions in the study area. Observations were also carried out during the week-long field survey to obtain attribute data, including a profile of the study area and location mapping studies. The first survey included interviews with heads of Klangon, Ledok Kulon, Ledok Wetan,

Banjarjo, Kauman and Jetak sub-districts, and related government institutions such as public works, development planning, disaster mitigation and environmental boards to gain an overview of the flood problem and the settlements.

b. The second survey was conducted over a week to establish a model to answer the second research question using the structural equation model (SEM) questionaire for 300 samples for three different levels of vulnerablity (low, middle and high vulnerability).

c. The third survey was conducted over a week to identify existing community organisations in the study area by using social network analysis (SNA) to determine the identity, leaders and members of each existing community organisation. The SNA survey was conducted in areas of high, medium and low vulnerability.

3.4 Sample and sampling system

Research was conducted in six villages consisting of 1,100 houses. Based on the results of a previous study, these villages were selected to represent three levels of vulnerability to climate change: low, medium and high (Widayanti *et al*., 2012). The variables used to identify the level of vulnerability are physical, social, economic and insfrastructure (ibid).

In this study, the respondents were residents living in the surrounding area and outside of the flood protection zone. The sampling approach used was random sampling. All respondents were heads of households, whether husband or wife, and able to describe their decision to settle. Using the approach of Slovin[2] with a degree of error of 5 per cent, the number of samples taken in this study was 300 households.

The residents live in six villages, divided into 15 hamlets and 33 sub-hamlets, as listed in the Tables 2, 3 and 4 below, which are ranked according to level of vulnerability.

Table 2. High-vulnerability communities

Village	Hamlet	Sub-hamlet	No of respondents
Banjarjo	RW1	RT3	12
Jetak	RW1	RT1	10
		RT2	9
		RT3	6
Klangon	RW2	RT8	7
Ledok Kulon	RW3	RT5	10
	RW4	RT2	14
		RT3	6
Ledok Wetan	RW1	RT2	17
		RT4	6
		RT6	16
		RT7	6
Total number of respondents			119

2 Slovins's formula is used to calculate an appropriate sample size from a population.

Table 3. Medium-vulnerability communities

Village	Hamlet	Sub-hamlet	No of respondents
Banjarjo	RW1	RT6	16
		RT7	7
Jetak	RW1	RT4	7
		RT5	7
Kauman	RW1	RT11	18
Ledok Kulon	RW1	RT1	7
	RW2	RT5	7
	RW3	RT1	7
		RT2	11
	RW4	RT4	8
Ledok Wetan	RW1	RT1	6
		RT3	11
Total number of respondents			112

Table 4. Low-vulnerability communities

Village	Hamlet	Sub-hamlet	No of respondents
Banjarjo	RW1	RT1	7
		RT2	9
		RT5	11
	RW2	RT9	8
	RW3	RT22	6
		RT23	5
Kauman	RW2	RT10	13
Klangon	RW1	RT1	6
Ledok Wetan	RW2	RT10	7
Total number of respondents			72

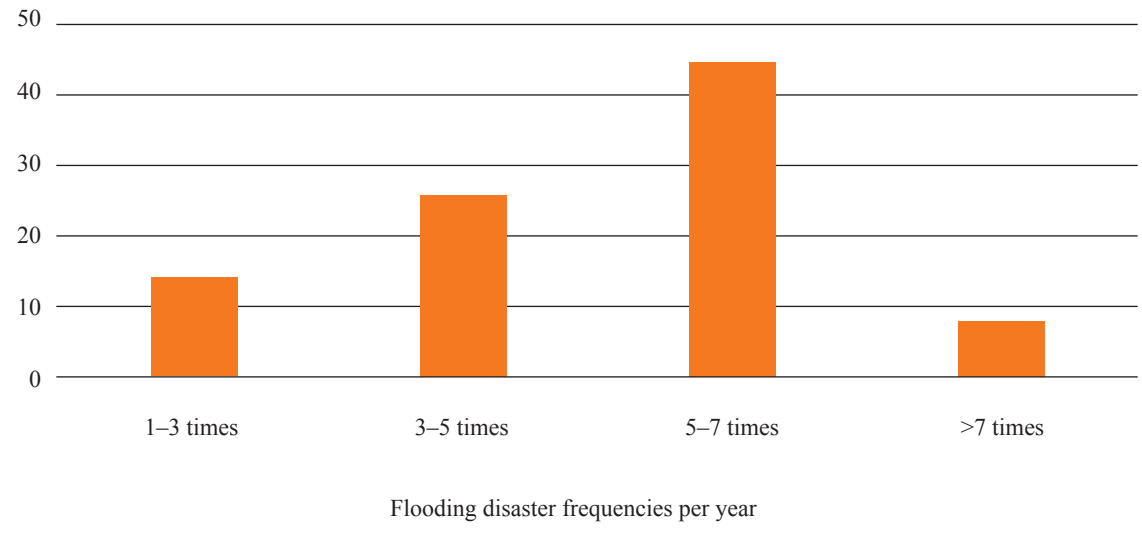
4 Characteristics of the study area

4.1 Flooding and its impacts

The six villages in the study area are located on the banks of the Solo River in the district of Bojonegoro: Banjarjo, Ledok Wetan, Ledok Kulon, Kauman, Jetak and Klangon.

Flood-prone areas are identified as those experiencing frequent and/or having a high potential for natural disasters such as flooding (see also Figure 5). Most areas in Bojonegoro are located in the Solo River watershed, which is a flood-prone area. Flooding is mostly caused by Bengawan Solo River basin overflow: the higher the intensity of the overflow, the more flooding there is downstream. The districts with the highest potential for flooding are Padangan, Kalitidu, Malo, Trucuk, Bojonegoro, Sumberejo, Kanor and Baureno.

Figure 5. Flooding disaster frequency, Bojonegoro regency



Source: Bengawan Solo Water Resources Management Boards, 2013.

The majority of riparian areas in the Solo River District in Bojonegoro prone to flooding are flooded 5–6 times annually, covering a total area of 33.59ha. The areas most susceptible to flooding cover 25.28ha, with an extensive flooding frequency of more than 7 times/year. Meandering rivers cause differences in flooding frequency in each sub-district.

Residential areas in the district of Bojonegoro flood 5–7 times each year and 47 per cent of the district is affected. Based on data from the Bojonegoro Regional Disaster Management Agency, there were as many as 16 floods in 2010. Figure 6 shows the impact flooding has had on residential areas in Banjarjo.

Figure 6. Photos of Banjarjo during flooding

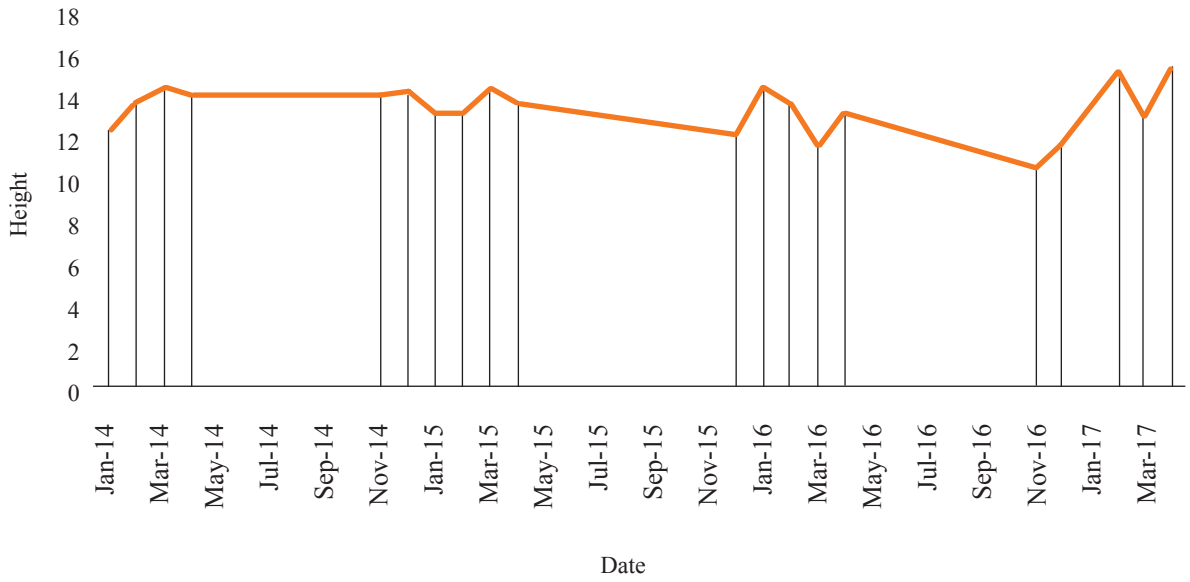
Source: Banjarjo Sub District Administration, 2010

Table 5. Flooding pattern, Bojonegoro

Date	Water height	Duration
2007	Alert I (13.10)	21 December 2007 12.00 WIT
	Alert II (14.10)	22 December 2007 07.00 WIT
	Alert III (15.00)	27 December 2007 19.00 WIT
	Highest peak (16.22)	27 December 2007 23.00–06.00 WIT
2008	Alert I (14.02)	4 January 2008 15.00 WIT
	Alert II (13.67)	10 March 2008 09.00 WIT
	Alert III (14.24)	10 March 2008 12.00 WIT
	Highest peak (15.70)	12 March 2008 07.00–09.00 WIT
2009	Alert I (13.10)	31 January 2009 20.00 WIT
	Alert II (14.06)	1 February 2009 03.00 WIT
	Alert III (15.10)	3 February 2009 01.00 WIT
	Alert I (13.60)	23 February 2009 06.00 WIT
	Alert II (14.10)	23 February 2009 21.00 WIT
	Alert III (15.00)	24 February 2009 12.00 WIT
2010	Alert I (13.05)	18 March 2010 03.00 WIT
	Alert II (14.05)	19 March 2010 15.00 WIT
	Highest peak (14.49)	19 March 2010 05.00–06.00 WIT
	Alert I (13.12)	14 May 2010 24.00 WIT
	Alert II (14.10)	16 May 2010 06.00 WIT
	Highest peak (14.75)	17 May 2010 12.00–20.00 WIT
2011	Alert I (13.75)	24 March 2011 06.00 WIT
	Alert II (14.02)	24 March 2011 08.00 WIT
	Highest peak (14.54)	25 March 2011 22.00–03.00 WIT

WIT (Western Indonesian Time)
Source: Bengawan Solo Water Resources Management Boards, 2013.

Figure 7. Water height in metres, 2010–2013



Source: Bengawan Solo Water Resources Management Boards, 2013.

High water discharge levels are common from November to April, the months when the study area is prone to flooding (see Figures 7 and 9). Over the last three years the greatest discharge occurred in April 2013.

In anticipation of flooding events, a levee was built along the river buffer in the district of Bojonegoro. The villages or sub-districts protected by the levee are Bojonegoro, Jetak, Klangon, Kauman, Ledok Kulon, Ledok Wetan and Banjarjo. The height of the embankment is different in every village, between 1–1.5 metres. The function of the levee is very poor in the sub-district of Bojonegoro, as the inhabitants open the levee to gain access from the unprotected areas to the protected city centre, e.g. entry point on Jendral Suprapto Street to Ledok Kulon sub-district. There are also open access points between the old and new levees. This poor functioning of the levees is mostly due to the inhabitants' behaviour.

Box 1. Existing flood-related policy in the research area

Bojonegoro is located in the Bengawan Solo River watershed, which suffers from flood impacts, a decline in water quality, sedimentation and a density of settlements along the riverbanks. To anticipate the danger of flooding and periodic inundation, there is a conservation plan for flood-prone areas, which includes:

1. Preservation and cross-stream management areas
2. Building levees/dams/catchment areas/storm drains/other waterworks in watershed areas or areas prone to flooding, and efforts to reduce/control water discharge during emergencies
3. Optimising the function of protected areas and water catchment areas
4. Optimising riparian and channel functions to allow for more gradual flooding
5. Preparing refuge areas and safe evacuation plans for residents
6. Normalisation/optimisation of drainage infrastructure as a form of flood control
7. Eliminating factors that impede the drainage of surface water
8. Activating and coordinating management of drainage development with other regions
9. Preparing a masterplan review for both integrated flood control facilities and infrastructure, so that sewers are connected to networks of primary, secondary or tertiary sewers and not linked to irrigation drains. This will require coordination and synchronisation between the programme and provincial government and regional plans.

Source: Bojonegoro Planning and Development Department (2011).

4.2 Settlement characteristics

The settlement is located between 0–20 metres from the Solo riverbank at high tide (see Figure 8). Houses were built during 1970–80 and the settlements have continued to grow along the river. Generally, almost 80 per cent of residents have homes built of permanent structures and just over 17 per cent have semi-permanent structures. Just over 3 per cent of houses are wooden (non-permanent).

The settlement characteristics are investigated from two physical indices: building density and infrastructure. Almost 42 per cent of high-vulnerability areas have a building density of 17–29 houses/ha, and 25 per cent have a building density of 30–41 houses/ha. In medium-vulnerability areas, 40 per cent have a building density of 7–16 houses/ha. Just over a third of low-vulnerability areas have a building density of 17–29 houses/ha (33.33 per cent) while 80 per cent have a building density of 7–16 houses/ha, and 20 per cent have 0–6 houses/ha (Widayanti *et al*., 2012).

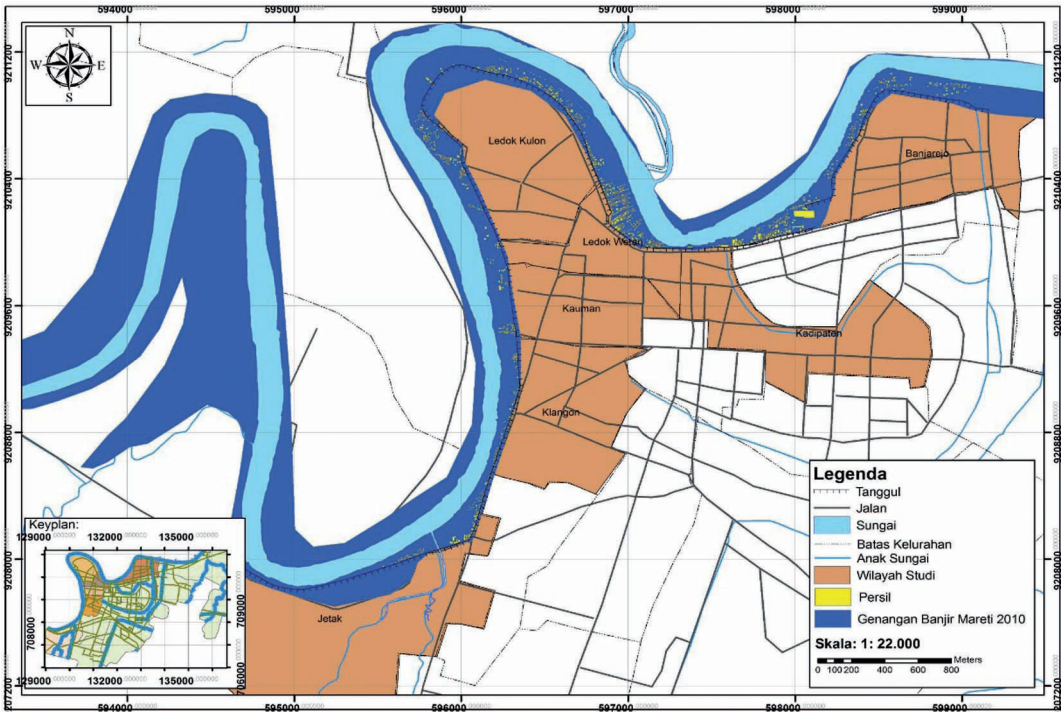
This paper classifies the vulnerability of settlements based on infrastructure and physical condition, and social and economic conditions. The assumption is that the more infrastructure and facilities an area has, and the more an area serves as an access or transport node, the more vulnerable the population will be if this area is exposed to climate impacts such as floods. Therefore, an area is considered highly at risk and high-vulnerability if it has many essential services and infrastructure such as health centres and access roads affected by floods. Amongst the high-vulnerability areas, 40 per cent have a minimum of two important facilities, and 33.33 per cent have more than three. In the medium-vulnerability category, 53.33 per cent of settlements have two public facilities, and 13.33 per cent have no facilities. In the low-

vulnerability category, 40 per cent of areas have no facilities and 60 per cent have one public facility. For accessibility, in the high-vulnerability settlements, 40 per cent of roads are paved with stone and 20 per cent are asphalt. In areas of medium vulnerability, 60 per cent of roads are paved, 13.33 per cent are asphalt, and for the areas of low vulnerability 100 per cent of roads are paved.

Figure 8. Photos showing how close the Bengawan Solo River is to houses

Photos: Survey, 2013

Figure 9. Area flooded during March 2010



Source: Widayanti *et al.* 2012

Most land in the study area (59 per cent) is private property (SHM/Petok D) and 55 per cent of repondents own their own private property even though their parents' names are on the certificate. Legally, river buffer land is government property, but residents have certificates legalising the illegal land status. Only 19 per cent of respondents live on government's property (HGB) and 3.67 per cent of the total sample live in rented houses.

4.3 Demographics in the research locations

Tables 6 and 7 and Figures 10 and 11 illustrate the occupation and levels of education and income of the 300 respondents, all of whom are household heads. There are two categories for age: productive and unproductive (in Indonesia, the productive age is considered to be in the range of 15 to 64 years old). There are also five education levels, ranging from having no education to having a bachelor's degree. A household head with no education means that s/he either did not finish or never began primary school education (the lowest level of educational standard in Indonesia that normally takes 6 years to complete).

The types of occupation of the household heads have been grouped into 19 types (Table 7). Some are unemployed. In general, they receive money regularly from family members – a son or daughter – who live outside the study area. Respondents who work as permanent workers in a private company are categorised as 'staff'. 'Drivers' are either company staff or they drive a motorcycle, public minibus, or rickshaw. For the second category, most do not own their own private vehicle but rent it from the owner. Some heads of household run small businesses or have a home industry. These are categorised as entrepreneurs. In addition, since the study area is located close to the district market, some heads of households work as labourers for the market.

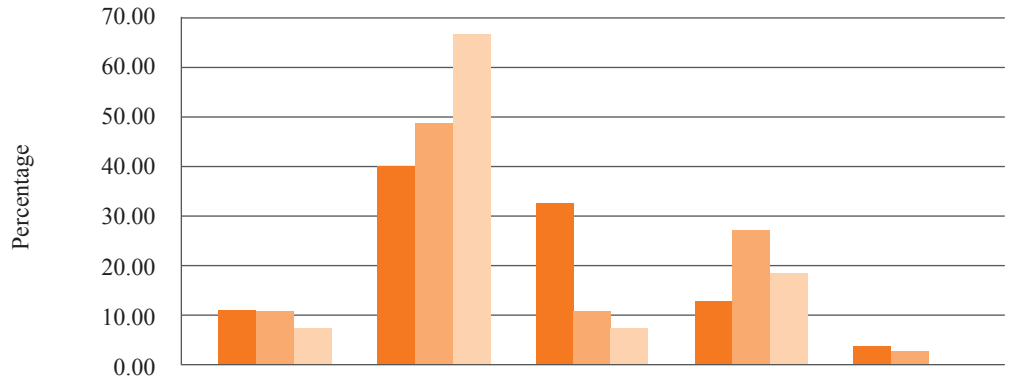
Finally, based on the result of the questionnaire survey, income levels per household are divided into five ranges: from less than IDR 500,000 to more than IDR 2 million. Based on Governor Regulation 72 in 2012, Governor Regulation 78 in 2013 about the recommended regional minumum wage (RMW) for regencys/cities in East Java Province, Bojonegoro Regency has a RMW of between IDR 1,029,500 (2012) and IDR 1,140,000 (2013). This means that households with an income of less than IDR 1 million have a lower income than the RWM standard for citizens in Bojonegoro Regency.

Table 6. Age of heads of household by area vulnerability category

Age	Low vulnerability	Medium vulnerability	High vulnerability
15–64	78.57%	91.89%	89.36%
> 64	21.43%	8.11%	10.64%
Minimum age	30	28	30
Maximum age	88	66	87

Table 6 illustrates that the majority of household heads in the study area are in the productive age range for all categories of vulnerability with the youngest being aged 28. The low-vulnerability communities have the most household heads in the 'unproductive' age range (21.43 per cent). It may seem risky for families with an older or very old household head to live in a flood-prone area. However, most families have a household head of productive age, and have a better chance of dealing with floods, assuming that the household head is able-bodied enough to take the necessary physical measures such as moving belongings.

Figure 10. Education levels for heads of households



	Bachelor's degree	High school	Junior school	Primary school	Uneducated
Low vulnerability %	10.91	40.00	32.73	12.73	3.64
Middle vulnerability %	10.81	48.65	10.81	27.03	2.70
High vulnerability %	7.41	66.67	7.41	18.52	0.00

Figure 10 illustrates that most household heads have a high school educational background, particulary in the high-vulnerability communities (64.29 per cent). For both medium- and high-vulnerabilty community categories, the second greatest percentage is primary school and for the low-vulnerability communities, it is junior school. However, the low-vulnerability communities have the highest percentage of household heads with a bachelor's degree, though the difference is small. While there are some heads of household with no education, it may be that the young generation has a better awareness of the importance of education.

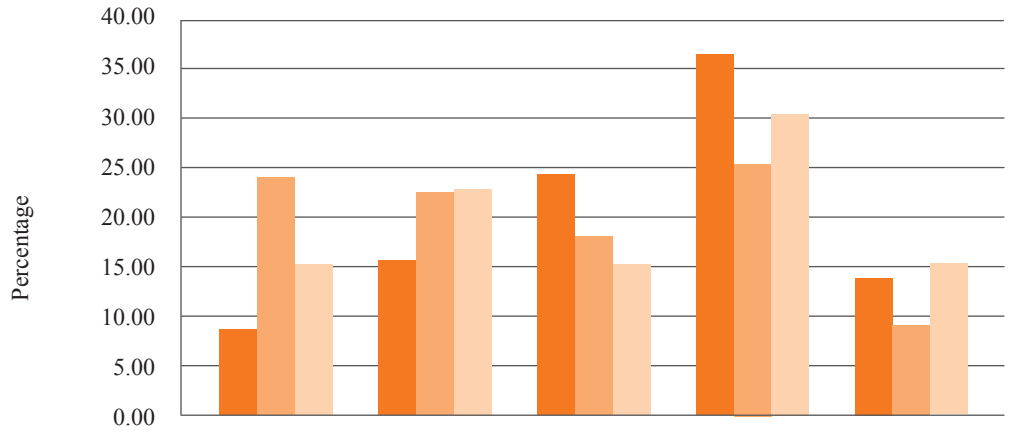
Table 7 illustrates the types of occupation, varying from monthly to daily paid workers. This means that some households earn a monthly income, while others face an uncertain income. Particularly, households with occupations such as fieldhands, labourers or construction workers might have irregular work since they seek employment from day to day. On the whole, it appears that the three categories of communities have similar socioeconomics conditions.

Table 7. Heads of household: occupations

Criteria	Low vulnerability %	Medium vulnerability %	High vulnerability %
Teacher	3.39	2.90	0.00
Entrepreneur	15.3	23.19	26.92
Unemployed	3.39	4.35	3.85
Civil servant	1.69	8.70	7.69
Driver	18.64	10.14	15.38
Construction worker	25.42	10.14	7.69
Merchant	8.47	4.33	7.69
Breeder	1.69	0.00	0.00
Security guard	5.08	4.35	3.85
Mechanic	5.08	7.25	0.00
Tailor	5.08	4.35	0.00
Pensioner	1.69	5.80	3.85
Cleaner	1.69	0.00	0.00
Staff	3.39	5.80	15.38
Fieldworker	0	2.90	3.85
Farmer	0	2.90	0.00
Navy worker	0	1.45	0.00
Labourer	0	1.45	0.00
Police	0	0.00	3.85
Total	**100**	**100**	**100**

Figure 11 illustrates five income levels, ranging from two categories below the RMW and three above it. The lowest monthly income is about IDR 200,000 while the highest is about IDR 3 million. For two of the categories of vulnerability (medium and high) more than 50 per cent of households have a higher income than the Bojonegoro Regency RMW. Interestingly, the income level of the low-vulnerability communities is somewhere between the lower and higher income levels and similar to the RMW of Bojonegoro Regency – 50.88 per cent and 49.12 per cent, respectively. Perhaps the more vulnerable their living environment is due to the threat of flooding, the more motivated residents are to earn more money to secure their family's welfare.

Figure 11. Income levels per household (IDR)



	> 2 million	1.5–2 million	1–1.5 million	0.5–1 million	< 0.5 million
Low vulnerability %	8.77	15.79	24.56	36.84	14.04
Middle vulnerability %	24.24	22.73	18.18	25.76	9.09
High vulnerability %	15.38	23.08	15.38	30.77	15.38

4.4 Exposure to flooding and adaptation mechanisms

Generally, before the floods (such as the annual floods) people make preparations to try and reduce their losses. During flooding, the most common adaptive activity is to store belongings higher up to protect them, which people are used to doing. Out of 300 respondents, 208 people (69.33 per cent) already perform this activity, while 43 respondents (14.33 per cent) prepare to evacuate to the levee when the floods come and 49 respondents (16.33 per cent) remain in their houses. For those who live in high-vulnerability areas, more have built storage for their belonging higher up (64.94 per cent), although the same is true for respondents in medium- and low-vulnerability areas.

The inhabitants have several alternative places to evacuate to when the floods happen. In the study area, respondents have a unique approach. They build temporary shelters or tents for themselves on the levee. So the levee performs an additional function: as well protecting the settlements and being used as a road, it is also a place of shelter during flooding events. Out of 300 respondents, 172 (57 per cent) inhabitant said they do this because even though they have evacuated to the safety of the levee, they can still monitor what is happening to their homes and belongings. And when the floods start to recede, they can quickly return to begin clearing the mud and debris from their houses (as if this is not done immediately, the damage to houses is more severe).

Of the rest, 57 respondents (19 per cent) chose to evacuate to a relative's house, while 37 chose to evacuate to the neighbour's. Some (34 respondents) evacuated to safer public places such as schools, sub-district halls or offices.

Based on the results of the questionaire, people in the district of Bojonegoro who are affected by floods every year suffer losses. These include properties being swept away, damage to properties and belongings, and the cost of home repairs after flooding. Total losses differ among inhabitants, generally between IDR 1–2 million, IDR 500,000 – 1 million, or IDR 0–500,000 per household per flood. Most respondents (57 per cent or 170 people) claimed that the average loss per household per flood is in the lowest range, IDR 0–500,000.

5 Factors influencing settlement location choices

Structural equation modeling (SEM) is a statistical technique that analyses the relationship between the latent constructs and indicators, latent constructs with one another and measurement error directly. Latent constructs includes abstract psychological variables – such as the 'moral values' – compared with manifest variables (indicators) used to measure these constructs. Measurement is considered difficult and susceptible to errors, so SEM analysis needs to adjust estimations so that they are not biased to the relationship between latent constructs. SEM allows the testing of a series of simultaneous relationships, established between one or more independent variables (Santoso, 2011), including analysis among multiple dependent and independent variables directly (Hair *et al*., 2006) to understand the relationship between variables.

SEM analysis is used here to identify the factors that influence the locations of the settlements in the study area. The analysis uses the basic theory of Doxiadis about the five elements determining settlements: nature, man, society, the shell and network. The first element is the 'shell', referring to built-up visible physical spaces, technology and aesthetics, such as buildings or groups of buildings from the local environment scale to the city scale. These can function as private spaces (housing) and public spaces, such as facilities to protect the inhabitant's quality of life (such as markets, recreation or household industries). 'Network' refers to infrastructure and public services. 'Nature' refers to ecosystems in shared elements with the biotic and abiotic climatological conditions: lighting, thermal, air movement, humidity. 'Man' and 'society' refer to human resources, both individual and collective. 'Man' and 'society' are the subject and object of the built-up space consisting of a 'shell' and 'network' which are made of both artificial and natural spaces (as natural resources).

The dependent Y variable is determined based on the results of the questionnaire respondents about overall perceptions of each element (nature, man, society, shell and network). The Doxiadis SEM analysis is then performed based on the level of vulnerability of the study area, namely high, medium and low. The independent variables are listed below, and the survey instrument is available in Appendix 1.

Discussion of factors that influence people's decisions about whether or not to live in flood-prone areas is done using a classification based on the level of vulnerability (high, medium or low), and then discussed as a whole for all areas of research. The level of vulnerability is constructed from the physical vulnerability indices, socioeconomic indices, and infrastructure indices as developed by Widayanti *et al*. (2012). This scheme can be made to determine the pattern of relationships and influences between dependent and independent variables. The hypothesis is that influencing variables will vary among community groups who have a degree of vulnerability to flooding.

Table 8. SEM independent variables

Category	Indicator	Number
Nature	Geology	X1
	Topography	X2
	Land	X3
	Water resources	X4
	Climate change	X5
Man	Biological needs	X6
	Perception and feelings	X7
	Emotional connection	X8
	Moral values	X9
Society	Population composition	X10
	Social groups	X11
	Customs and culture	X12
	Economic development	X13
	Education	X14
	Health services	X15
	Law and administration	X16
Shell	Housing	X17
	Community services	X18
	Markets and commercial services	X19
	Recreational facilities	X20
	Small-scale household industry	X21
	Disaster evacuation services	X22
Network	Water supply	X23
	Power supply	X24
	Transportation systems	X25
	Communication systems	X26
	Sewerage and drainage	X27
	Waste management	X28

The analysis process produces three things:

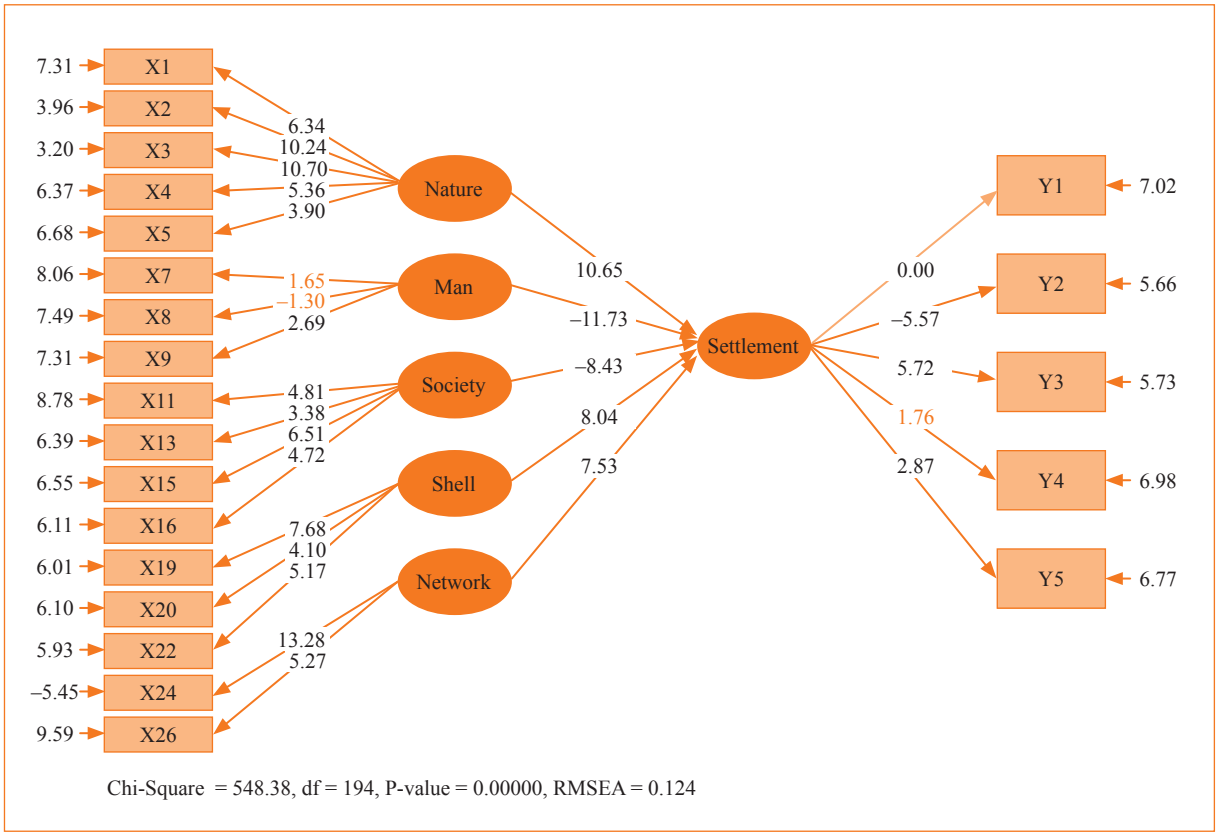
- The contribution and significance level of sub-variables to the independent variables (aspects of PCA or principal component analysis/CFA or common factor analysis),
- The contribution of connectivity between independent variables on the dependent variable (regression model), and
- The final pattern model which occurs (path analysis).

This mechanism often requires an iterative process to create a more refined model, while reducing the level of errors that occur, so that the final model is considered optimal or fit. Analysis was carried out for areas in each category of vulnerability: high, medium and low.

5.1 High-vulnerability communities

Five villages consisting of nine hamlets were surveyed in the high-vulnerability category, with 119 respondents (from a total of 300 samples). The analysis in high-vulnerability areas/clusters of settlements required the iteration process to be done twice, which ultimately resulted in a pattern (path) (Figure 12).

Figure 12. Path model for high-vulnerability communities

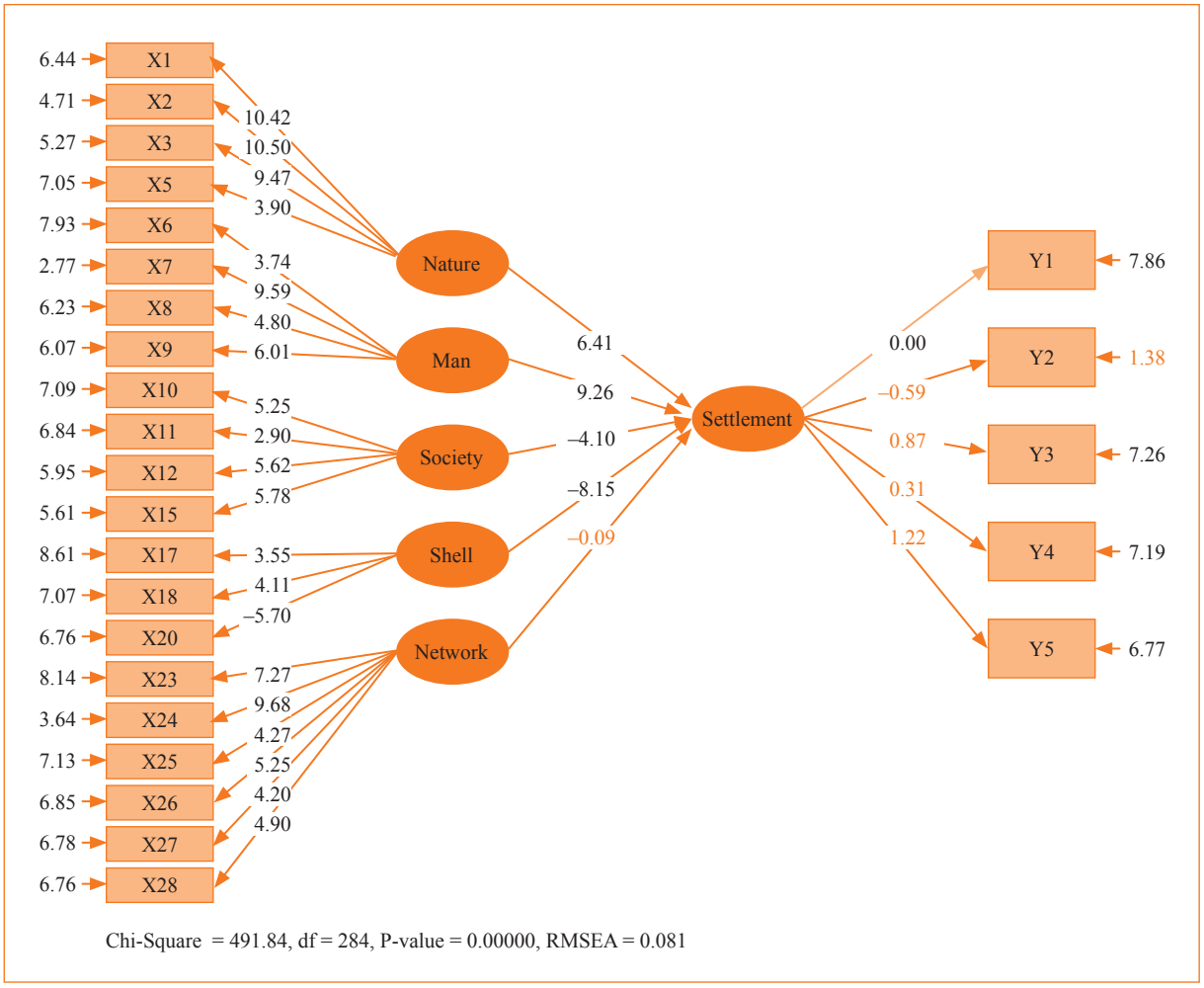


The results of the second iteration of SEM shows that the variables that most influence the settlement once a decision is made to reside in a location with high vulnerability are (in order of importance): shell, network, society, man and finally nature. If specified in more detail, for the 'shell' variable, successive sub-variables that have the strongest influence are: market and commercial services (X19), disaster evacuation services (X22), and recreational facilities (X20), suggesting that people decide to remain in an area despite the high flood risk due to the livelihood opportunities, and the flood evacuation path offering an rapid exit from risk. For the 'society' variable, successive sub-variables that have the strongest influence are: health levels (X15), social groups (X11), law and administration (X16) and economic development (X13). For the 'network' variable, sub-variables with the strongest influence are: electricity power supply (X24) and communication systems (X26). For the 'man' variable, only moral values (X9) play a significant role. For the 'nature' variable, successive sub-variables with the strongest influence are: land (X3), topography (X2), water resources (X4), geology (X1) and the last is climate change (X5).

5.2 Medium-vulnerability communities

Five villages of medium vulnerability were suveyed, consisting of 12 hamlets, where 112 respondents were sampled. The model was run through four iterations (see Figure 13).

Figure 13. Path model for medium-vulnerability communities



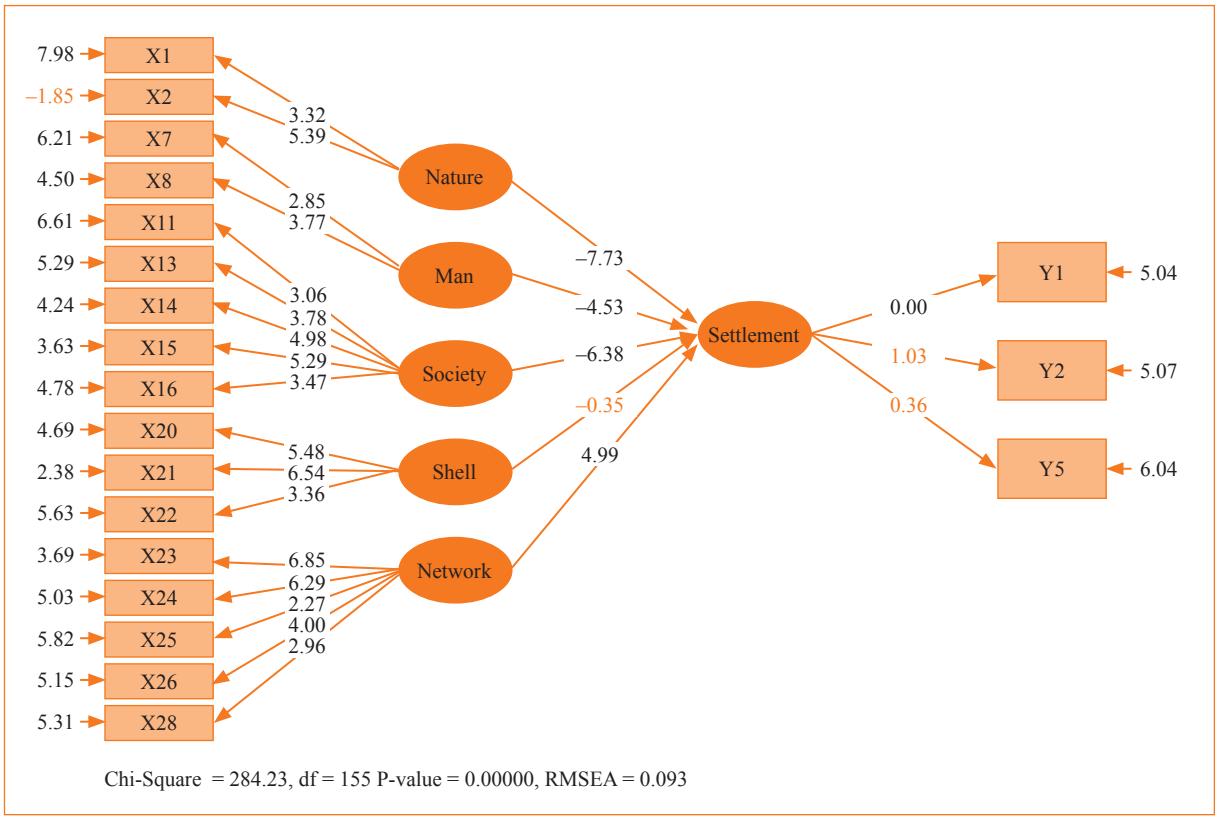
The results suggest that the variables that influence the decision to remain in settlements with moderate vulnerabilities are, in order of importance: society, man, nature, shell and finally network. For the variable 'society', the sub-variables with the strongest infuence are: law and administration (X16), customs and culture (X12), population composition (X10) and social groups (X11). Thus, social ties and legal conditions related to land tenure are the main reasons why people have chosen to remain in these locations.

For the variable 'man', sub-variables with the strongest infuence are: perception and feelings (X7), moral values (X9), emotional connection (X8) and biological needs (X6). For 'shell', successive sub-variables with the strongest infuence are: recreational facilities (X20), community services (X18) and housing (X17). For 'nature', sub-variables with the strongest infuence are: geology (X1), topography (X2), land (X3) and water resources (X4). The variable 'network' seems the least significant in shaping peoples' location decisions.

5.3 Low-vulnerability communities

Four villages were surveyed, consisting of 9 hamlets, where a total number of 69 household respondents. Through four iterations of the model, the following results were obtained (see Figure 14).

Figure 14. Path model for low-vulnerability communities

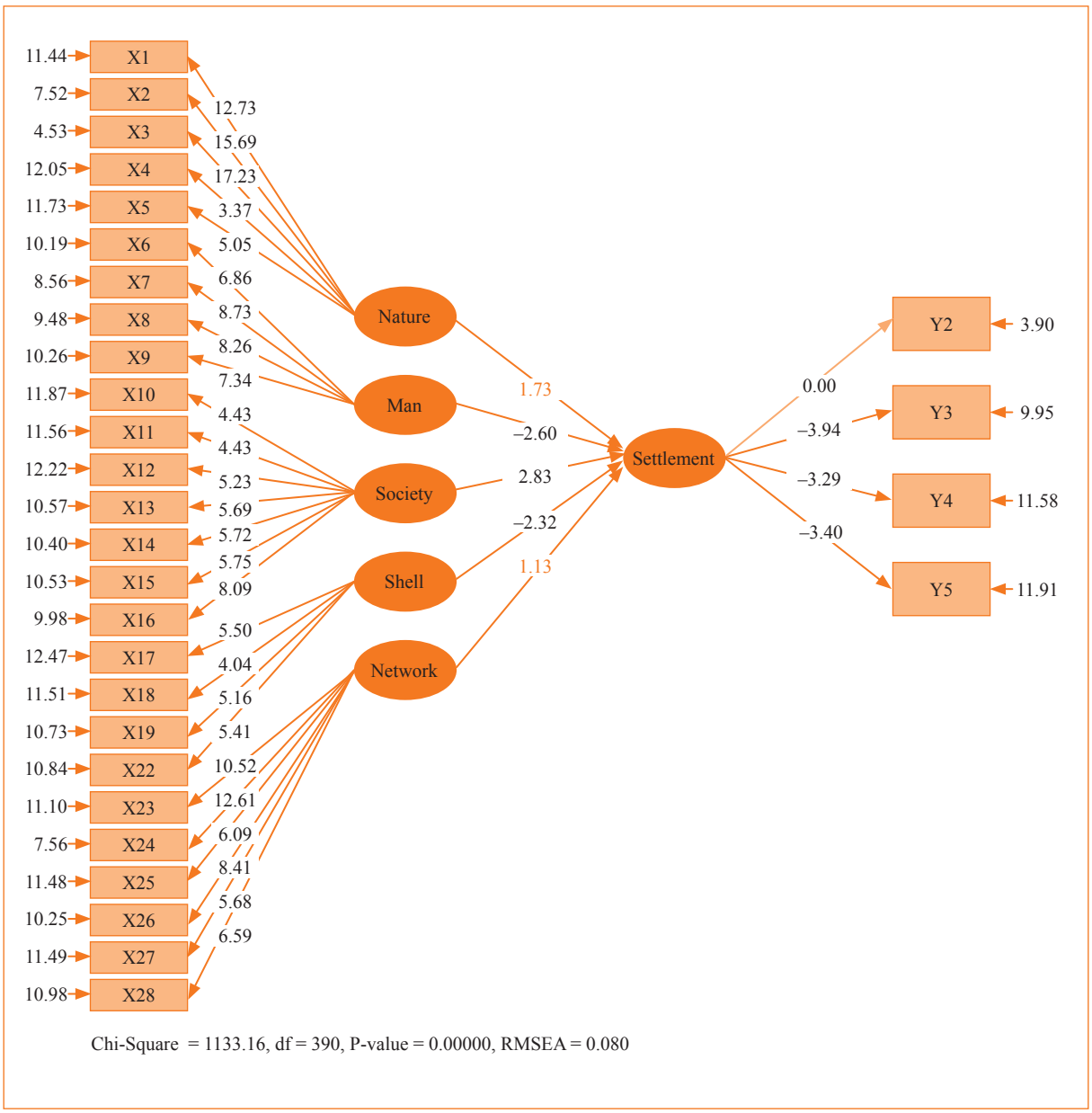


The variables that most influence people's decision to live in settlements in lower vulnerability locations are (in order of importance): network, man, society, nature and finally shell. Regarding the 'network' variable, successive sub-variables with the strongest influence are: water supply (X23), electrical power supply (X24), communication systems (X26), waste management (X28) and transport systems (X25). This suggests that areas of low vulnerability have infrastructure and services providing an incentive to remain on site. For the variable 'man', sub-variables with the strongest influence are: emotional connection (X8) and perception and feelings (X7). For 'society', sub-variables with the strongest influence are: health services (X15), education (X14), economic development (X13), law and administration (X16), and social groups (X11). Regarding 'nature', sub-variables with a significant influence are: topography (X2) and geology (X1). It appears that the 'shell' is the least significant variable in influencing settlement location decisions for low-vulnerability communities.

5.4 Combined results for the communities

Bringing together all of the hamlets in the six villages, three iterations to refine the model led to the following results (see Figure 15):

Figure 15. Path model for the combined communities



Sub-variables that are considered significant in influencing the perception of the population regarding the settlements in the study area are: geology (X1), topography (X2), emotional connection (X8), social groups (X11), law and administration (X16), markets and commercial services (X19), electrical power supply (X24) and communication systems (X26). The sub-variables that are considered most significant in influencing the perceptions of the population regarding the settlements in the study area are: community services (X18) and small-scale household industry (X21).

5.5 Structural equation models: discussion

Figure 16 shows which settlement elements per category of vulnerability have had the strongest influence on inhabitants' decisions to remain in settlement locations.

Most respondents in high-vulnerability areas are merchants, explaining why markets and shops are considered so significant. The existence of recreational facilities is also important in limiting stress levels. Moral values are an important factor for the inhabitants, because they allow people to bond through shared values, supported by existing social groups. An important variable for highly vulnerable settlements is the existence of the levee that also functions as a disaster evacuation path. Their principle adaptation measure when the floods occur is to relocate their family to the levee, and store their belongings in higher place in their houses. These mechanisms are efficient and effective because flooding is a routine event that happens several times every year.

Inhabitants are good at taking collective action to mitigate the effects of flooding, known in the local terminology as '*gotong royong*' (mutual cooperation). This phenomenon was also discovered by Watson *et al*. (2012). Traditional societies are the most knowledgeable when it comes to understanding natural phenomena in the surrounding areas, and to adapting. Flooding is considered as a natural occurrence that must be adapted to rather than as a real threat. Land is another factor considered important by inhabitants in areas of high vulnerability, because it is connected with their efforts to defend their ancestral inheritance. Community groups combine maintaining this legacy with a partial adaptation process.

For medium-vulnerability groups, social ties are the strongest factor determining where they decide to live, especially law and administration, common customs and culture, and social groups. Additionally, nonphysical factors such as feelings, perceptions, moral values, and the emotional bond between inhabitants in this area were also significant variables.

Physical infrastructure is considered important for the low-vulnerability settlements' inhabitants, where water supply, electricity, communications, waste management and transportation are the focus. The other important variables are emotional needs, feelings and perceptions, social groups, as well as the law and administration and basic health and education needs.

One of the sub-variables identified as a unique feature of the low-vulnerability settlements is water supply (X23). This could be related to the fact that these households are at a lower risk from flooding due to being further away the river, but consequently are also further from a source of water. Their limited economic circumstances mean that the provision of clean water is a burden and therefore is considered a significant factor influencing vulnerability.

In terms of the overall assessment of the study area, sub-variables that are considered significant in influencing the perception of the population regarding the vulnerability of settlements in the study area are: geology (X1), topography (X2), emotional connection (X8), social groups (X11), law and administration (X16), markets and commercial services (X19), electrical power supply (X24) and communication systems (X26).

The stability of the land (geology) refers to the fact that the banks of the Solo River become highly unstable during rainy seasons, and so is considered a significant driver of vulnerability. If the land around the house is stable, people are more likely to remain on site. However, if there is a high risk of landslides, this may drive people away as they will be vulnerable to the impacts of heavy rains. The topography of the area is hilly and protrudes into the river, making it highly exposed as a site for residential settlement. The costs to upgrade land to make an ideal settlement are very high, even though it could be done through the collective '*gotong royong'* system. But this is the factor that determines whether inhabitants choose to remain or move elsewhere.

The similarity of origin (78 per cent of respondents are indigenous), fate, conditions and socioeconomic characteristics, as well as a sense of shared causes and the emotional bond between people is very influential. Moreover, when reinforced with shared customs/cultural heritage to preserve their ancestoral heritage (55 per cent of households inherited their land from their parents), it means that there are strong social values in the society.

A further factor strengthening social groups and keeping them in this highly exposed area are the formal and informal communication systems strengthening social cohesion in the area. The number of and close nature of networks of social groups seems to play a key part in persuading residents to remain in this disaster-prone area. Another unique driver comes

from a legal standpoint. Technically, riverbank areas are protected from development and settlements – however, this has been interpreted differently by the courts, as the settlements pre-date the regulations regarding riverbank development, therefore these settlements are exempt from the regulations.

Box 2. Important factors influencing home locations

Not homes but land: land is mostly inherited. It is the communities' ancestral heritage which must be preserved, regardless of economic problems, a flood-prone environment, or the physical condition of people's homes.

Not floods but landslides caused by river erosion: regular flooding that occurs on average 5–7 times/year is considered normal, and communities have adapted to them well. Two common forms of adaptation are elevating building and storing belongings higher up in their houses (done by 69 per cent of the sample). Losses are about IDR 500,000, but it is considered not as significant as maintaining their ancestral lands. Their perspective is that the negative impacts of floods can managed, including disease or the physical damage to homes and belongings. The threat of landslides is considered much more dangerous as residents might have to leave and lose their ancestral lands.

Levees are important: levees have become one of the most important elements of the settlement because inhabitants use them as evacuation areas during the floods. Levees are more significant to high-vulnerability communities.

The level of health and education, not facilities available: having education facilities is not considered an important reason for remaining in the area. Most people do not think that education will improve their quality of life. Health facilities are also not a significant variable for home location preferences, because communities have an alternative traditional health system.

There are two indicators that demonstrate local government support towards this phenomenon in the area: the presence of government buildings (such as offices in Ledok Kulon village) and the unusually large amount of government funding provided for roads, drainage, and even public toilets at the study site. This means that the residents are not perceived by wider society as breaching regulations, which in turn means their settlements receive improvements. This is evident in the fact that 80 per cent of the buildings in the study area are permanent – an example of local government being supportive of local community needs.

The existence of markets and shops is also one of the key factors for the survival of local people, given that most people work as traders. While their incomes are relatively small (average IDR 500,000–1 million/month), as long as it can sustain the lives of the inhabitants, the existence of the markets and shops become a key factor that affects people's decisions to stay in the location. The supply of electricity is also regarded as a significant influence, as it supports economic activity that takes place at night, such as small-scale household industry.

Communities in the study area have strong social and cultural connections, so although there are slight differences in their characteristics, they are all connected by a very good communication system. In the end, the strength of the communication system and the closeness between people is the main reason why they choose to live in this disaster-prone area.

Effective adaptation in the face of flooding can build on two positive two factors: strong social ties, especially through organisations and social groups, and shared values relating to maintaining their ancestral heritage, especially related to land. This suggests that the sub-variables which need to be explored further as determinants of people's decisions to remain in the study area are: emotional connections (X8) and social groups (X11). One approach that can explain this phenomenon is social network analysis (SNA).

6 Community social structures

6.1 Community group profiles

There are fifteen community groups in the research area. These groups can be classified into eight types of organisation covering religion, microfinance, poverty alleviation, youth clubs, women's groups, safeguard groups, governance, and farmer groups. In general they can be regarded as voluntary associations – as 'any private group, voluntarily and more or less formally organised, joined and maintained by members pursuing a common interest, usually by means of part-time, unpaid activities' (Laskin, 1962 and Kerry, 1972 in Lohmann, 1992b). The common characteristics of voluntary associations can be summarised as (i) free and unforced participation; (ii) a common or shared purpose; (iii) common holdings; (iv) mutuality; and (v) fairness or justice (Lohmann, 1992a).

The religious organisations consist of Jamaah Tahlil, Jamaah Kausaran, Remaja Masjid, Pengurus Masjid, and Organisasi Keagamaan. The first two community groups are groups that have monthly meetings for the recitation of the Qur'an where the gatherings move from house to house. The second two community groups are a group of representative villagers with a better understanding of religion or popular villagers who form a committee in the local mosque. The last community group is a part of national religous organisation at the sub-hamlet level.

The cluster of microfinance organisations consists of the Arisan (a community savings and credit group) at sub-hamlet or village level plus the women's group or Arisan PKK at village level. This community group has also a monthly meeting, the main purpose of which is to conduct a money lottery during one full round – the round is stopped when all members have had their chance to benefit from the collective funds. In some circumstances, this community group is not limited to collecting money as their capital source, but also basic provisions such as sugar or eggs.

Membership for the farmers' group (Kelompok Tani) is open to landowners who use their land for agriculture as well as to those who work as farm labourers or field hands. This group has a specific purpose, focusing on sharing knowledge and skill for increasing agricultural productivity. Community groups at village level have a horizontal and vertical relationship with other farmer groups in different villages as well as at the district and regency levels under the Regency Agriculture Board.

The youth club (Karang Taruna) takes part in village programmes such as participating in village development activities or sporting competitions. There is also a group of male villagers whose main task is to conduct and manage nighttime patrols in their sub-hamlet or hamlet areas called Pos Ronda. All adult males take turns to patrol, as agreed by the villagers. These community groups are responsible for the safety of their neighbourhoods.

Some villagers (mostly men) are committee members at the level of sub-hamlet (*pengurus RT*), elected by community members. Pengurus Masjid and Remaja Masjid are committees of Islamic groups, for men and youth respectively. Additionally, there are formal religious organisations or Organisasi Keagamaan at the level of sub-hamlet (the smallest administrative area). These are branches of the national-level religious organisations, Nahdatul Ulama (NU) and

Muhamadiyah. Though these organisations have more formal structures, they are still a type of voluntary association whereby the committee members give their services voluntarily.

There are two types of community group dealing with poverty alleviation. PNPM is a poverty alleviation programme under the Ministry of Public Works, characterised by community participation. Membership of a PNPM community group is exclusive to several representative villagers at village level, but in the implementation phase, all villagers are allowed to participate in the project as part of an empowering community programme. BKM is an executive council of collective village societies at the village level with the main purpose of dealing with poverty alleviation, through a system of collective leadership with decisions based on quorum. There is a specific community group related to the police department namely PKK Bhayangkari, open only to wives of policemen.

Six community groups have a vertical relationship with a central organisation at the national level: Arisan PKK, PNPM, BKM, Organisasi Keagamaan and PKK Bhayangkari. It means that the members of these community groups may have a wider relationship with a broader network, with linkages at village, district, city/regency, province and national levels.

Table 9. Summary of community group types

Name	Activity	Meetings per month	Scope of activity
Jamaah Tahlil	Religious group	1	Sub-hamlet
Arisan RT	Microfinance	1	Village
Arisan Desa	Microfinance	1	Village
Arisan PKK	Microfinance	1	Sub-hamlet
Karang Taruna	Youth club	1	Village
PNPM	Poverty alleviation	2	Village
Kelompok Tani	Farmer group	Twice a year	Village
BKM	Poverty alleviation	1	Village
Pos Ronda	Nighttime patrols	1	Sub-hamlet
Pengurus Masjid	Religious group	3	Sub-hamlet
Remaja Masjid	Religious group	3	Sub-hamlet
Pengurus RT	Governance	4	Sub-hamlet
Organisasi Keagamaan	Religious group	1	Sub-hamlet
Jamaah Kausaran	Religious group	1	Sub-hamlet
PKK Bhayangkari	Women’s group	1	Village

6.2 Community group membership

The following three tables show the villagers' multiple memberships of fifteen community groups divided into three community vulnerability categories: high, medium and low (yellow indicates no membership). Numbers 1 to 15 correlate with the community groups listed in Table 9 above.

Table 10. Multiple memberships in the high-vulnerability communities

Village	Hamlet	Sub	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	∑
Banjarjo	RW1	RT3	10	10	0	1	1	0	0	0	0	0	1	0	0	0	0	5
Jetak	RW1	RT1	10	10	0	0	0	1	0	0	0	1	1	0	0	0	0	5
		RT2	9	9	0	0	1	1	0	0	0	0	3	0	0	0	0	5
		RT3	5	1	0	1	0	3	2	0	2	5	4	0	0	0	0	9
Klangon	RW2	RT8	0	0	0	5	0	0	0	0	2	1	0	0	0	0	0	3
Ledok Kulon	RW3	RT5	0	3	0	5	0	0	0	0	2	0	2	0	0	0	0	4
	RW4	RT2	8	0	0	3	4	0	0	0	3	0	3	0	1	0	0	6
		RT3	6	6	0	5	1	2	0	0	0	3	4	1	0	0	0	8
Ledok Wetan	RW1	RT2	6	10	0	7	4	2	2	0	6	5	8	0	0	0	0	9
		RT4	2	2	1	1	0	3	1	0	1	4	4	0	0	0	1	10
		RT6	6	11	0	2	1	1	1	0	3	2	3	0	0	0	0	9
		RT7	6	6	0	0	0	0	0	0	2	0	3	0	0	0	0	4
Total			**68**	**68**	**1**	**30**	**12**	**13**	**6**	**0**	**21**	**21**	**36**	**1**	**1**	**0**	**1**	

In the high-vulnerability category, Ledok Wetan (RW1, RT4) has the highest number of people participating in community groups, with ten types of community groups, meanwhile the lowest level of community membership is in Klangon (RW2, RT8) with only three types of community group. There are two community groups which do not have any membership in the high-vulnerability settlements: BKM and Jamaah Kausaran. This may indicate that villagers in this category tend to have a network limited to within the sub-hamlet. However, thirteen respondents participated in the PNPM poverty alleviation programme, although none of them is a committee member.

The community groups with the highest membership in the high-vulnerability communities are Jamaah Tahlil (religious group) and Arisan RT (village microfinance). Both community groups are active at the sub-hamlet level, with no connection with similar community groups in different sub-hamlets. Therefore, they have no relationship with similar community groups in different hamlets or in higher administrative areas.

Table 11. Multiple memberships in the medium-vulnerability communities

Village	Hamlet	Sub	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	∑
Banjarjo	RW1	RT6	13	8	1	8	0	3	0	0	3	3	5	1	2	1	0	11
		RT7	0	1	0	2	2	0	1	0	3	1	1	0	0	0	0	7
Jetak	RW1	RT4	7	0	0	0	0	1	1	0	0	0	0	0	0	0	0	3
		RT5	7	0	0	0	0	1	1	1	0	1	3	1	0	0	0	7
Kauman	RW1	RT11	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ledok Kulon	RW1	RT1	0	0	3	2	0	0	0	0	0	0	1	0	0	0	0	3
	RW2	RT5	1	0	4	1	0	0	0	0	0	0	1	0	0	0	0	4
	RW3	RT1	0	0	3	1	0	0	0	0	0	1	3	0	0	0	0	4
		RT2	11	1	0	0	0	0	0	0	0	0	1	0	0	0	0	3
	RW4	RT4	7	8	0	2	0	0	0	0	0	0	1	0	0	0	0	4
Ledok Wetan	RW1	RT1	1	2	1	3	1	2	0	0	2	3	3	0	0	0	0	9
		RT3	9	7	2	6	3	1	0	0	0	3	5	0	0	0	1	9
Total			**71**	**27**	**14**	**25**	**6**	**8**	**3**	**1**	**8**	**12**	**24**	**2**	**2**	**1**	**1**	

In the medium-vulnerability community category, Banjarjo (RW1, RT6) has the most community organisations with eleven types of community group, meanwhile the community with the fewest is Kauman (RW1, RT11) with only the religious group Jamaah Tahlil active.

The most popular community group is the religious organisation Jamaah Tahlil. As with the high-vulnerability communities, this is religious group is found at the sub-hamlet level but has no connection with similar community groups in different sub-hamlets. This may indicate that the residents the medium-vulnerability community category tend to have a network limited to within the sub-hamlet, though it is slightly wider than that of the high-vulnerability communities.

In the medium-vulnerability community category, one respondent became a member of the executive council of the collective village society BKM while eight respondents participate in the PNPM programme, though none is a committee member. So the community has linkages with poverty alleviation activities on a limited scale.

In the low-vulnerability communities, three hamlets have the highest membership – Banjarjo (RW3, RT23), Klangon (RW1, RT1) and Ledok Wetan (RW2, RT10) with affiliations to seven community groups. Meanwhile, a fifth of the possible community organisations have no members in the low-vulnerability communities. Whilst these low-vulnerability settlements have the fewest community groups, those community groups are active at the village level, which may indicate that residents in this category have a wider network than in the others.

One respondent is a committee member in BKM and another is a committee member in PNPM, both groups dealing with poverty allevation. Similar to the high-vulnerability communities, the most popular community groups in the low-vulnerability communities are Jamaah Tahlil and Arisan RT. As with the other community categories, this means that membership is restricted to the community within the sub-hamlet. Their monthly meetings for reciting the Qur'an and conducting microfinance activities do not extend beyond the sub-hamlet level.

Table 12. Multiple memberships in the low-vulnerability communities

Village	Hamlet	Sub	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	∑
Banjarjo	RW1	RT1	0	0	0	0	0	0	0	0	1	4	4	0	0	0	0	3
	RW1	RT2	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	1
	RW1	RT5	0	6	0	0	1	0	0	0	4	1	0	0	0	0	0	4
	RW2	RT9	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
	RW3	RT22	6	6	0	3	0	0	0	0	3	0	0	0	0	0	0	4
	RW3	RT23	3	2	0	1	3	0	0	0	2	3	3	0	0	0	0	7
Kauman	RW2	RT10	13	13	6	0	0	0	0	0	0	0	0	0	0	0	0	3
Klangon	RW1	RT1	5	6	6	2	0	1	0	1	0	0	1	0	0	0	0	7
Ledok Wetan	RW2	RT10	5	5	1	5	3	0	0	0	0	3	4	0	0	0	0	7
Total			**40**	**38**	**13**	**17**	**7**	**1**	**0**	**1**	**10**	**11**	**13**	**0**	**0**	**0**	**0**	

6.3 Typology of social structures

Social structures are formed of personal ties among people with similar values and beliefs or impersonal, formal and instrumental social links. Interpersonal relationships among actors, whereby the actors and their actions are viewed as interdependent units and linkages between actors are channels for the transfer or 'flow' of resources (Wasserman and Faust, 1994). The social structure of the community in the research area is measured through the actors' memberships of existing community groups in the form of affiliation data. The notion of density (from 0 to 1) is to identify the density of relationships between actors in the sub-hamlets of the three levels of vulnerable community. A higher level of density (closer to 1) means a denser community network, and implies a higher possibility for the community to mobilise their resources to deal with common problems through collective action. The notion of centrality is to identify the most important actors in a social network who are strategically located within the network, so that structure of the community can be defined (Wasserman and Faust, 1994). This research measures three indices of centrality to quantify the prominence of an individual respondent embedded in a network: (i) degree (ii) closeness and (iii) betweenness.

The 'degree' of centrality measures the activity levels of the actors, with those most active having the maximal centrality index. 'Closeness' measures the distance between actors within a network, while 'betweenness' measures a central actor who intersects many other shortest paths between pairs of other actors, meaning these central actors potentially might have some control over the interactions between the two non-adjacent actors (Wasserman and Faust, 1994). As a consequence, the central actors may have more interpersonal power over others.

Levels of centrality will vary from 0 to 1. In addition, centrality will be categorised into three levels covering low (0–0.333), medium (0.334–0.666) and high (0.667–1). This categorisation may make it possible to form a typology of social structure for each network of the sub-hamlet for the combined categories of vulnerable community.

6.3.1 Density of social networks

Using the SNA analysis methodology, two of the 12 sub-hamlets have a low density (0.2444 and 0.3956) in the category of high-vulnerability communities. Meanwhile, there are four sub-hamlets with a complete network indicated by a density of 1. There are four out of 12 sub-hamlets with low density, varying from 0.1905 to 0.2857 in the category of medium-vulnerability community. Meanwhile, there are also four out of 23 sub-hamlets with a complete network indicated by a density of 1. Two out of nine hamlets have low density in the category of low-vulnerability community – a similar number of sub-hamlets and with density values of 0.2857 and 0.3818 as for the high-vulnerability community category. Meanwhile, six out of nine of sub-hamlets have complete networks and one other has a high-density level of 0.8.

In general, this may indicate that residents in the low-vulnerability category have the highest density of social networks. It implies that these villagers have the strongest social ties. As a consequence, villagers in the low-vulnerability category may have a faster flow of resources than the other two categories. A strong social tie might mean they are better able to mobilise their collective resources to deal with community problems. Hence, they may have better opportunities to improve their daily lives as well as their neighbourhoods. With regard to floods, they may have a higher resiliency due to their strong social ties and be able to recover within shorter time periods compared to the other two categories.

In addition, residents in the low-vulnerability category have a wider network than those in the categories of high and medium vulnerability. The villagers are affiliated to the types of community group that are found at the higher village level. Moreover, some of the community groups have vertical linkages to the national level, as some villagers are committee members. It indicates that villagers are not only have strong social capital at the sub-hamlet level, but are also able to bridge this social capital i.e. via interrelations between other sub-hamlets and hamlets. Villagers can also link their social capital via their memberships of community groups that also have vertical linkages nationally. Residents in the low-vulnerability category represent a well-connected community who should be better able to mobilise local and extra-local resources to solve their problems more effectively than residents in the other two vulnerability categories (Putnam, 2000).

Table 13. Density level for the communities at all three levels of vulnerability

Location			Vulnerability category		
Village	**Hamlet**	**Sub-hamlet**	**High**	**Medium**	**Low**
Banjarjo	RW1	RT3	0.8182		
Jetak	RW1	RT1	1.0000		
		RT2	1.0000		
		RT 3	0.8667		
Klangon	RW2	RT8	0.5238		
Ledok Kulon	RW3	RT5	0.2444		
Ledok Kulon	RW4	RT2	0.3956		
Ledok Kulon	RW4	RT3	1.0000		
Ledok Wetan	RW1	RT2	0.6544		
Ledok Wetan	RW1	RT6	0.5500		
Ledok Wetan	RW1	RT7	1.000		
Ledok Wetan	RW 4	RT 6	0.7333		
Banjarjo	RW1	RT6		0.7833	
Banjarjo	RW1	RT7		0.1905	
Jetak	RW1	RT4		1.0000	
Jetak	RW1	RT5		1.0000	
Kauman	RW12	RT11		0.6863	
Ledok Kulon	RW1	RT1		0.1905	
Ledok Kulon	RW2	RT5		0.2857	
Ledok Kulon	RW3	RT2		1.000	
Ledok Kulon	RW3	RT1		0.2381	
Ledok Kulon	RW4	RT4		1.0000	
Ledok Wetan	RW1	RT1		0.6000	
Ledok Wetan	RW1	RT3		0.8545	
Banjarjo	RW1	RT1			0.2857
Banjarjo	RW1	RT2			1.0000
Banjarjo	RW1	RT5			0.3818
Banjarjo	RW2	RT9			1.0000
Banjarjo	RW3	RT22			1.0000
Banjarjo	RW3	RT23			0.8000
Kauman	RW2	RT10			1.0000
Klangon	RW1	RT1			1.0000
Ledok Wetan	RW2	RT10			1.0000

6.3.2 Centrality

The notion of centrality is to identify the most important actors who are strategically located within a network, so that strcuture of the community can be defined (Wasserman and Faust, 1994). The following three tables (Tables 14, 15 and 16) illustrate the level of centrality for each the three categories of vulnerability. Refering to Wasserman and Faust (1994), the index of centralisation is between 0 and 1 (see Appendix 2). Refering to Ari *et al.* (2013), the level of centrality is divided into three interval categories, covering low (0–0.33), medium (0.34–0.66) and high (0.67–1) as shown in the third column. Columns 4 to 6 describe the values of the three indices of centrality: degree, closeness and betweenness.

Table 14 illustrates the level of centrality for the category of high-vulnerability community. There are four out of 12 sub-hamlets with 0 per cent network centralisation – all respondents have a high level of centrality 'degree' and 'closeness', but all of them have low levels of 'betweenness', meaning connections and linkages with others. It means that everyone plays a prominent role as a hub since all of them are similar popular actors and they each have direct ties to others. Even more significantly, none of them acts as a mediator for other pairs. In these sub-hamlets, once resources are received by someone, it means that everyone has either received it or knows about it. Once information has been understood by someone, then it will be immediately disseminated to others since everyone is connected directly to each other. Therefore, no pair of actors is dependent on someone else.

Five of the 12 sub-hamlets have two levels of degree centrality linking the actors: a combination between low and high levels, medium and high levels, or a high or medium to high level of closeness of centrality and low betweenness of centrality. Some prominent actors have more influence over others and the rate of dissemination of information is fairly fast via actors with a medium or high closeness centrality, though no one is dependent on someone else.

There is one of 12 sub-hamlets with a high degree centrality but low closeness and betweenness centrality. Some actors are popular hubs, although none of them has direct links – the shortest path to all other actors as well as none of them lies on the many shortest paths between the pairs of other actors. Meaning that in this sub-hamlet, the flow of resources will move slower than in the first four sub-hamlets but it will be a slightly faster than the second two sub-hamlets.

In two of the 12 sub-hamlets, there are no central actors as no one shows a high level of centrality for all three indices. The hubs in these sub-hamlets have only low and medium degree centrality meaning that some are popular and some are not. In addition, all respondents have low levels of closeness and betweenness, meaning that they have a certain geodesic distance to others and that pairs of actors have connections through several actors as once. Consequently, in these sub-hamlets, the flow of resources moves very slowly and takes time to reach others. Thus, it will not be easy to mobilise resources within the communities.

Table 14. Centrality for high-vulnerability communities

Location	Level of centrality	Centrality indices		
		Degree	Closeness	Betweenness
2	3	4	5	6
Banjarjo RW1 RT3	0–0.33 (low)	1	0	12
	0.34–0.66 (medium)	0	0	0
	0.67–1 (high)	11	11	0
Jetak RW1 RT1	0–0.33	0	0	10
	0.34–0.66	0	0	0
	0.67–1	10	9	0
Jetak RW1 RT2	0–0.33	0	0	9
	0.34–0.66	0	0	0
	0.67–1	9	9	0
Jetak RW1 RT3	0–0.33	0	0	6
	0.34–0.66	1	0	0
	0.67–1	5	6	0
Klangon RW2 RT8	0–0.33	2	7	7
	0.34–0.66	0	0	0
	0.67–1	5	0	0
Ledok Kulon RW3 RT5	0–0.33	5	7	10
	0.34–0.66	5	0	0
	0.67–1	0	0	0
Ledok Kulon RW4 RT2	0–0.33	6	14	14
	0.34–0.66	8	0	0
	0.67–1	0	0	0
Ledok Kulon RW4 RT3	0–0.33	0	0	6
	0.34–0.66	0	0	0
	0.67–1	6	6	0
Ledok Wetan RW1 RT2	0–0.33	0	0	17
	0.34–0.66	13	0	0
	0.67–1	4	17	0
Ledok Wetan RW1 RT6	0–0.33	5	0	15
	0.34–0.66	0	5	1
	0.67–1	11	11	0
Ledok Wetan RW1 RT7	0–0.33	0	0	6
	0.34–0.66	0	0	0
	0.67–1	6	6	0
Ledok Wetan RW 4 RT 6	0–0.33	0	0	6
	0.34–0.66	3	1	0
	0.67–1	3	5	0

Table 15 illustrates the level of centrality for the category of medium-vulnerability community. There are four out of 12 sub-hamlets with 0 per cent network centralisation – all respondents have a high level of degree and closeness centrality, but also a low level of betweenness. It means that everyone plays a prominent role as a hub since all of them are similar popular actors with direct ties to others, and none of them acts as a mediator for other pairs. In these sub-hamlets, once resources are received by someone, everyone else will receive or know about them too. Once information has been understood by someone, it will be immediately disseminated to others since everyone is connected directly to each other. There are three out of 12 sub-hamlets with two levels of degree centrality – a combination between low and high levels or medium and high levels, and high or medium to high closeness of centrality and low betweenness of centrality. Some prominent actors have more influence over others and dissemination of information happens quickly through actors with medium or high closeness centrality, although no one is dependent on anyone else.

There are two out of 12 sub-hamlets with a high degree centrality but low closeness and betweenness centrality. Some actors are popular hubs, but none has direct links – the shortest path to all other actors (and none) lies in the many shortest paths between the pairs of other actors. Meaning that in these sub-hamlets, the flow of resources will move slower than in the first four sub-hamlets but will be slightly faster than in the second two sub-hamlets.

Four out of 12 sub-hamlets have no central actor since no one has a high level of centrality for all three indices. The hubs in these sub-hamlets have only low and medium levels of degree centrality meaning that some are popular and some are not. In addition, all respondents have low levels of closeness and betweenness meaning that they have a certain geodesic distance to others and that pairs have connections through several other actors at once. Consequently, in these sub-hamlets, the flow of resources moves very slowly and takes time to reach others. Thus, it will not be easy to mobilise resources in these communities.

Table 16 illustrates level of centrality for the category of low-vulnerability community. Five of nine sub-hamlets have 0 per cent network centralisation – all respondents have a high level of degree and closeness centrality, but all of them have low levels of betweenness. It means that no one plays a prominent role as a central hub as all of them are popular actors with direct ties to others, and none acts as a mediator for other pairs. In these sub-hamlets, once resources are received by someone, everyone will receive or know about them too. Once information is understood by someone, it will be immediately disseminated to others as everyone is connected directly to each other. Therefore, no pair of actors is dependent on someone else.

Only one of nine sub-hamlets has two levels of centrality – a combination between low and high or medium to high levels, and high or medium to high closeness of centrality and low betweenness of centrality. Some prominent actors have more influence on others and the dissemination of information happens rapidly through actors with a medium or high closeness centrality, although no one is dependent upon anyone else.

Two of the nine sub-hamlets have no central actor since no one has a high level of centrality for all three indices. The hubs in these sub-hamlets have only low and medium levels of degree centrality meaning that some are popular and some are not. In addition, all respondents have low levels of closeness and betweenness meaning that they have a certain geodesic distance to others and that pairs have connections through several actors at once. Consequently, in these sub-hamlets, the flow of resources moves very slowly and takes time to reach others. Thus, it will not be easy to mobilise resources for these communities.

Table 15. Centrality for medium-vulnerability communities

Location	Level of centrality	Centrality indices		
		Degree	Closeness	Betweenness
2	3	4	5	6
Banjarjo RW1 RT6	0–0.33	2	0	16
	0.34–0.66	0	2	0
	0.67–1	14	14	0
Banjarjo RW1 RT7	0–0.33	7	5	7
	0.34–0.66	0	0	0
	0.67–1	0	0	0
Jetak RW1 RT4	0–0.33	0	0	7
	0.34–0.66	0	0	0
	0.67–1	7	7	0
Jetak RW1 RT5	0–0.33	0	0	7
	0.34–0.66	0	0	0
	0.67–1	7	7	0
Kauman RW2 RT11	0–0.33	3	0	18
	0.34–0.66	0	0	0
	0.67–1	15	15	0
Ledok Kulon RW1 RT1	0–0.33	7	5	7
	0.34–0.66	0	0	0
	0.67–1	0	0	0
Ledok Kulon RW2 RT5	0–0.33	3	4	7
	0.34–0.66	4	0	0
	0.67–1	0	0	0
Ledok Kulon RW3 RT2	0–0.33	0	11	11
	0.34–0.66	0	0	0
	0.67–1	11	0	0
Ledok Kulon RW3 RT1	0–0.33	5	5	7
	0.34–0.66	2	0	0
	0.67–1	0	0	0
Ledok Kulon RW4 RT4	0–0.33	0	0	8
	0.34–0.66	0	0	0
	0.67–1	8	8	0
Ledok Wetan RW1 RT1	0–0.33	0	0	5
	0.34–0.66	5	2	1
	0.67–1	1	4	0
Ledok Wetan RW1 RT3	0–0.33	1	0	11
	0.34–0.66	0	1	0
	0.67–1	10	10	0

Table 16. Centrality for low-vulnerability communities

Location	Level of centrality	Centrality indices		
		Degree	Closeness	Betweenness
2	3	4	5	6
Banjarjo RW1 RT1	0–0.33	3	3	7
	0.34–0.66	4	0	0
	0.67–1	0	0	0
Banjarjo RW1 RT2	0–0.33	0	0	6
	0.34–0.66	0	0	0
	0.67–1	6	6	0
Banjarjo RW1 RT5	0–0.33	5	10	11
	0.34–0.66	6	0	0
	0.67–1	0	0	0
Banjarjo RW2 RT9	0–0.33	0	0	8
	0.34–0.66	0	0	0
	0.67–1	8	8	0
Banjarjo RW3 RT22	0–0.33	0	0	6
	0.34–0.66	0	0	0
	0.67–1	6	6	0
Banjarjo RW3 RT23	0–0.33	0	0	5
	0.34–0.66	1	0	0
	0.67–1	4	5	0
Kauman RW2 RT10	0–0.33	0	0	13
	0.34–0.66	0	0	0
	0.67–1	13	13	0
Klangon RW1 RT1	0–0.33	0	0	6
	0.34–0.66	0	0	0
	0.67–1	6	6	0
Ledok Wetan RW2 RT10	0–0.33	0	0	7
	0.34–0.66	0	0	0
	0.67–1	7	7	0

Looking at the three categories of communities combined, there are no central betweenness actors since the majority of communities have low levels of betweeness centrality, except for two of 24 sub-hamlets in the high- and medium-vulnerability community categories with low and medium levels of betweenness centrality. It may indicate that linkages or social ties in the research area are mainly formed from direct linkages among actors. Consequently, these communities have no actors with more interpersonal power that might able to exert some control over the interactions between other pairs of actors.

Residents in the category of low vulnerability have the highest indices of centrality. Central actors who form the shortest distances to others may bring a faster flow of resources, enabling the community to better mobilise their resources collectively in order to solve their problems. Consequently, this community category may have a higher resiliency to flooding disasters than the two other categories.

6.3.3 Rates of participation

Table 17 describes the rate of participation of the three vulnerability categories of community through their affiliation to community groups. Rates of participation are classified as ‘low’ or ‘high’.

Three of the 12 sub-hamlets in the high-vulnerability category have a high rate of participation, while four of 12 sub-hamlets in the medium-vulnerability areas have high rates. Four of nine sub-hamlets in the category of low vulnerability have a high rate of participation, of which two sub-hamlets have the highest rates of participation whereby all respondents participate in community groups.

The higher rate of participation indicates the higher number of community groups to which a certain actor belongs. Once an actor belongs to a certain community group, s/he has linkages to other actors in the same community group. The link between actors in a community group may allow the flow of resources to occur: hence, every actor may enrich his/her resources through their social ties. Therefore, the higher rate of participation means the higher possibility of a transfer of resources among the connected actors, which in turn can promote resilience.

In general, residents in the low-vulnerability category belong to community groups with a wider scope of activity both at village level and with vertical linkages to the national level. In other words, residents in the category of low vulnerability appear to have established strong social capital in the form of bonding, bridging and linking. This may result in more opportunities for the community to mobilise both local and extra-local resources (Putnam, 2000). Meanwhile, residents in the high- and medium-vulnerability community categories tend to affiliate to community groups which have a sphere of activity limited to the sub-hamlet level. In this sense, villagers in both these categories may also form strong social ties but this might be limited to bonding and bridging existing social capital, rather than vertically linking their social capital externally.

Table 17. Rate of participation of the communities in each category of vulnerability

Vulnerability	Village	Hamlet	Sub-hamlet	Rate of participation	Number of organisations	Level
High	Jetak	1	1	2,30	5	
			2	2,56	5	
			3	3,83	4	High
	Klangon	2	8	1,14	2	
	Ledok Wetan	1	2	2,94	5	
			4	3,33	5	High
			6	1,88	3	
			7	2,83	4	
	Ledok Kulon	3	5	1,20	2	
		4	2	1,57	4	Low
			3	4,67	5	High
	Banjarjo	1	3	1,92	3	
Medium	Jetak	1	4	1,29	3	Low
			5	2,14	6	Low
	Ledok Wetan	1	1	3,00	8	Low
			3	3,36	8	Low
	Ledok Kulon	1	1	0,86	1	High
		2	5	1,00	2	
		3	1	1,14	2	
			2	1,18	2	
		4	4	2,25	3	High
	Kauman	2	11	0,83	1	High
	Banjarjo	1	6	3,00	6	Mid
			7	1,57	2	High
Low	Klangon	1	1	3,67	7	
	Ledok Wetan	2	10	3,71	6	
	Banjarjo	1	1	1,29	2	
			2	1,00	1	Complete
			5	1,09	2	
		2	9	1,13	2	
		3	22	3,00	3	Complete
			23	3,40	4	High
	Kauman	2	10	2,46	3	High

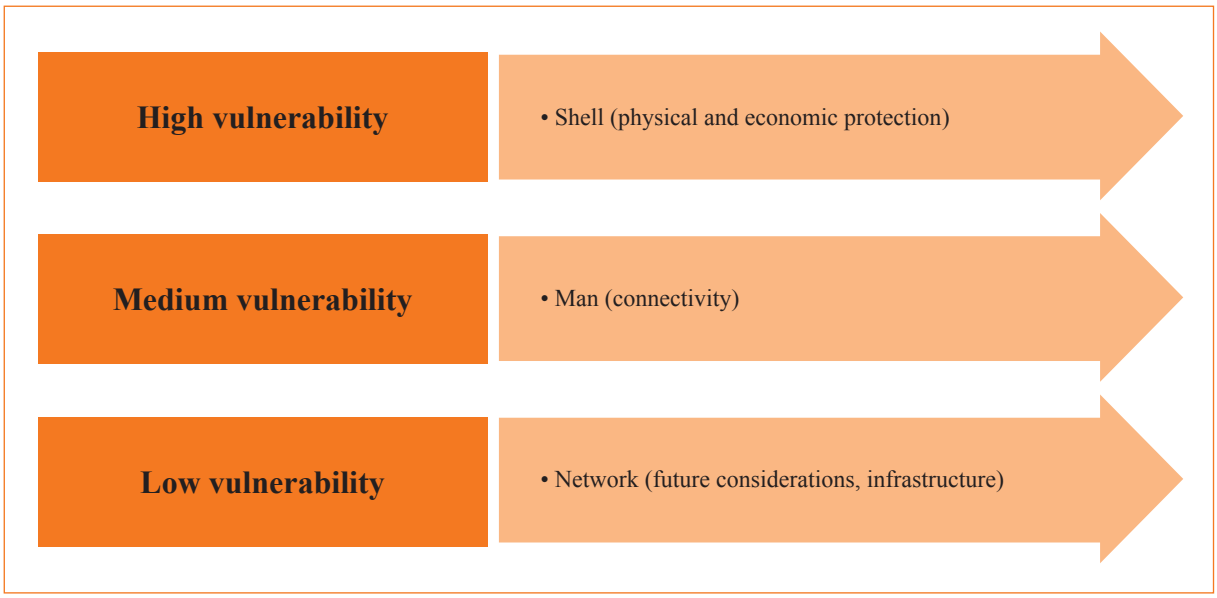
7 Conclusion

Building upon the work of Widayanti *et al*. (2012), this study has classified housing settlements along the banks of the Solo River into three levels of vulnerability to flood risk based on physical, economical, infrastructural and social indicies – low, medium and high. This study has sought to understand why residents in each category have chosen to remain on site. Using the framework of (Doxiadis, 1970) Doxiadis (1970), and the five determining elements of housing settlement – nature, man, society, shell and network – and structural equation modeling (SEM), this paper has sought to identify which factors have had the most influence on inhabitants' home location decisions.

For the most exposed and therefore most vulnerable communities, the settlement's 'shell' – meaning levees, community servies and housing etc. – has been the most prominent element influencing household decisions to settle in flood-prone areas. The levee is considered very important by residents in the high-vulnerability category, since they can use it not only as an evacuation route, but also as a camp during the floods. For those living in medium-vulnerability areas, the settlement element 'man' has been the most influential, in terms of their connectivity to their land and each other. For those living in areas of low vulnerability, the 'network' has been the most influential element, because with a lower level of vulnerability the inhabitants have the opportunity to consider their future needs for staying in the area, especially regarding infrastructure (e.g. power and water supplies, transport and communication).

In additional all communities in the three categories are all aware of the importance of health and education, even though the availability of these services is not significant. It indicates that they need more practical health and education services. The respondents seemed most concerned about losing their parcel of land due to the flow of torrential water when the dam upstream is opened. Maintaining their ancestral land sustainably from one generation to the next, rather than the value or physical appearance of their homes, is very important to them. As most respondents are market traders, the traditional market is more important to them than small-scale home industry.

Figure 16. Settlement elements with the strongest influence by category of vulnerability



Above all else, emotional connections and community groups are the two most significant sub-variables for each of the three categories of vulnerability community in the research area. This might assume that their home location preferences are strongly connected with social relationships among residents. To gain a deeper understanding, a social network analysis (SNA) approach was implemented to discover the typology of social structures of the three categories of communities using relational data taken from a household questionnaire. The survey explored residents' multiple memberships of local community groups, demonstrating their strong social ties. Using the framework of Wasserman and Faust (1994), three indices – density, centrality and rates of participation – were used to estimate factors influencing community home location preferences in these flood-prone areas. In this sense, this research has also touched on how social capital may help the communities to build their climate resilience.

Only six out of fifteen community groups are active within the villages, suggesting that residents' groups have limited networks that could potentially be developed.Consequently, the communities may have a limited ability to mobilise both local and extra-local resources (Putnam 2000). Only two out of fifteen community groups are linked to national-level poverty alleviation programmes, the PNPM and BKM under the Ministry of Public Works. There are few residents in the category of medium- and low-vulnerability who are committee members of those community groups; meanwhile no residents in the category of high vulnerability have any involvement in the BKM, although some residents participate in the PNPM both as committee members and participants. Thus, residents in the category of low vulnerability may be better able to mobilise local and extra-local reseources than residents in the other categories. It seems that residents in the category of low vulnerability may be better able to develop the three types of social capital – bonding, bridging and linking – than the high- and medium-vulnerability communities. It indicates that their stronger and wider social relationships may provide a better opportunity to enhance their quality of life through collective action than the other two communities. It is also possible that as they are better able to cope with flood events, their lives are less disrupted and therefore so is their ability to play a role in collective activities.

Most household heads in the research study area can be classified as of productive age (15–64 years), though a few household heads are very old, which might impact on their ability to protect their family and possessions during flooding. In general, more than 50 per cent of heads of households have an educational background level of high school or bachelor's degree, meaning that generally they have higher level of education than the minimum standard for Indonesian of nine years. It might indicate that the majority of communities in the research area are able to receive and understand important information, particularly related to their homes' vulnerable locations. Household heads have various occupations, ranging from permanent to impermanent. Some communities have a stable monthly income, while others may have irregular incomes. The highest household income is IDR 3 million, and the lowest IDR 200,000: more than 50 per cent of communities have an income lower than IDR 1 million, i.e. lower than the minimum regional wage for Bojonegoro regency and could therefore be described as a low income community. The three categories of community indicate quite similar demographic characteristics as low income community groups.

Amongst the low-vulnerability community category, six out of nine sub-hamlets have complete network of density, suggesting that the flow of resources is faster than in the other two categories. This is because the majority of community members are connected with each other. A reflection of human behaviour is embedded in networks of interpersonal relationships, as mentioned by Wasserman and Faust (1994). Thus, residents in the low-vulnerability category may have a higher resiliency when it comes to adapting their flood-prone neighbourhood than residents in the other categories.

At the sub-hamlet level, residents in the category of low vulnerability have the highest centrality. Communities with this characteristic may have a better flow of resources that reaches every resident equally at the same time and over a very short time period, since every resident has an almost similar power to influence others. It also means they have an almost direct connection to each other, requiring no mediator between residents to reach particular resources. In this sense, residents in this category may have excellent capabilities when it comes to anticipating and adapting to flood risks than the others.

At hamlet level, some prominent residents appear in each of the three categories of vulnerability. They play an important role in bridging between clusters and acting as central hubs. Since these prominent residents might be affiliated to community groups with vertical relationships, it means they might help the community to form not only bonding and bridging social capital, but also linking social capital. Furthermore, such residents might enhance the ability of the community to better mobilise their local and extra-local resources. Therefore it is important to identify prominent residents to strengthen the ability of the community to address their problems.

Residents in the category of high vulnerability have the lowest rate of participation, and residents in the category of low vulnerability have the highest. Most residents in the category of category of high vulnerability are affiliated to community groups with limited scopes of activity at the sub-hamlet level. The majority of residents in the category of medium vulnerability are affiliated to community groups with differing scopes of activity, from sub-hamlet to hamlet and village levels. In addition, a few residents are also committee members of certain community groups with vertical networks. Meanwhile, in two of the low-vulnerability sub-hamlets, every resident is affiliated to a community group in their neighbourhood.

In conclusion, residents in the category of low vulnerability may have the highest adaptive capacity in the research area than the others. It indicates that they have strong social networks that give them a better ability to cope with floods. The analysis suggests that residents in the category of low vulnerability have the power to mobilise local and extra-local resources through their strong network of interpersonal relationships. The residents in the high- and medium-vulnerability community categories might tend to copy the behaviour of their strongest neighbourhood even though they might be less able to mobilise their resources. In line with Putnam (2000) and Leenders (2002), perhaps the choice of residents to remain in flood-prone areas is determined by other influential residents in the low-vulnerability community category, who are better able to mobilise resources in reaction to the constraints and opportunities imposed by social system.

7.1 Recommendations

The analysis also allows a number of recommendations to be made.

1. One of the most important settlement elements for the high-vulnerability community category is the levee. However, this category has less extensive social capital than the other two categories of community. It indicates they are less able to mobilise resources to cope with flooding disasters. Of the three categories, they are likely to experience the worst impacts of floods, such as landslides. As a consequence, communities in this category need help from other actors outside of their group. An alternative could be a relocation programme initiated by the local government through its public works agency. Several residents who risked loosing their land due to landslides have already been relocated outside of the flood-prone areas.
2. Respondents from the medium-vulnerability community category indicated how important social elements are to their ability to deal with floods, even though they display a medium level of social ties. It suggests that the role of society is a significant factor allowing them to remain living in their current homes. To strengthen social ties among these communities, it is necessary to strengthen the flow of information and knowledge between residents and groups. This should be initiated by the local government. The more information is understood by the wider community, the easier it will be for them to enhance their ability to respond to flooding problems. The low-vulnerability community category seems as to be the most resilient when it comes to dealing with flooding disasters than the other two categories. They are better able to recover and adapt. This indicates that it is essential to develop both physical and social aspects, so that communties have the opportunity to live in a better living environment. This requires improving basic infrastructure as part of the 'network' improvements, as well as health, education, economic development and law and administration as part of wider societal improvements. Although they demonstrated strong ties to each other and had formed wider social capital through their social networks, it is still necessary to improve the flow of information and knowledge throughout the community. This may enhance the whole community's resiliency in the event of a flooding disaster, while improving living conditions and their better ability to mobilise local and extra-local resources.

On the whole, since most residents have chosen to remain in the flood-prone areas, enhancing community resiliency to cope with flooding is indispensable. This could be done both using both physical and social approaches. A principal physical improvement would be related to construction and legal rights to remain, so that the community might increase their sense of belonging, except for those residents who may have no choice but to relocate. The social approach would be for the whole community, particularly those in the high-vulnerability category, to link their existing social ties to those at higher levels. This would improve the flow of information and knowledge, especially related to programmes dealing with floodin disasters.

These communities have the potential to improve their lives rather than just taking increased incidences of flooding from generation to generation for granted. Increasing the involvement of influential local actors in local and national government activities should also enhance and strengthen the whole community's ability to build their climate resilience.

References

Adger, N. (1999) Social Vulnerability to Climate change and extremes in coastal Vietnam. *World Development,* 27(2), pp. 249-269.

Adger, N. (2003) Social Capital, Collective action, and adaptation to climate change. *Economic Geography,* 79(4), pp. 387-404.

Adger, W. N. and Vincent, K. (2005) Uncertainty in adaptive capacity. IPCC special issue on describing uncertainties in climate change to support analysis of risk and options, *Comptes Rendus Geoscience* 337(4): 399–410.

Ari, Ismu Rini Dwi, Hayeong Jeong, Kakuya Matsushima, Kiyoshi Kobayashi (2014) Network Analysis of Commuity Based Water Management (cp. 12) pp 197-217 in Community Based Water Management and Social Capital, Kiyoshi Kobayashi, Ibnu Syabri, Ismu Rini Dwi Ari and Hayeong Jeong (editors), 2014, IWA Publishing, UK

Ari, I.R.D, Ogi, K., Matsushima, K. and Kobayashi, K. (2013) Community participation on water management: case Singosari District, Malang Regency, Indonesia. *Procedia Environmental Sciences* 17, 805–813.

Banjarjo Sub District Administration (2010) *Flood Documentation.* Bojonegoro: Banjarjo Sub District Administration.

Bengawan Solo Water Resources Management Boards (2013) Bengawan Solo Watershed Tecnical Operation Unit Report, Bojonegoro: Bengawan Solo Water Resources Management Boards.

Bojonegoro Planning and Development Department (2011) Bojonegoro regional spatial planning document (Rencana Tata Ruang Wilayah Kabupaten Bojonegoro) 2011–2031.

Bradley, R. (2005) Growing in the greenhouse: protecting the climate by putting development first. WRI: Washington DC. See www.wri.org/publication/growing-greenhouse

Cruz, R.V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C. and Huu Ninh, N. (2007) *Asia climate change 2007: impacts, adaptation and vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds.) Cambridge University Press: UK, 469–506. www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter10.pdf

Diposaptono, S., Budiman and Agung., F. (2009) *Menyiasati Perubahan Iklim di wilayah Pesisir dan Pulau-Pulau Kecil.* Bogor : Penerbit Sarana Komunikasi Utama.

Doxiadis, C.A. (1970) Ekistics, the science of human settlements. *Science* 170: 3956. 393–404.

Everett, M. and Borgatti, S.P (2005) Ego network betweenness. *Social Networks* 27, 31–38. See http://steveborgatti.com/papers/egobet.pdf

Faust, K. (1997) Centrality in affiliation networks. *Social Networks* 19, 157–191. See www.socsci.uci.edu/~kfaust/faust/research/articles/faust_centrality_sn_1997.pdf

Firman, T., Surbakti, I.M., Idroes, I.C. and Simarmata, H.A. (2011) Potential climate-change related vulnerabilities in Jakarta: challenges and current status. *Habitat International* 35, 372–378.

Fuchs, R. (2010) Cities at risk: Asia's coastal cities in an age of climate change. *Asia-Pacific Issues: Analysis from the east west centre*, July.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. and Tatham, R.L. (2006) Multivariate data analysis, 6th ed. Prentice Hall, Upper Saddle River, NJ.

IPCC (2007) IPCC fourth assessment report: climate change 2007. 1st edition, Cambridge University Press: Cambridge.

IPCC (2001) *Climate Change 2001: Impacts, Adaptation and Vulnerability*. J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, eds. Cambridge University Press, Cambridge, UK and New York, USA.

Koestoer, R.H. (ed) (2001) Dimensi Keruangan Kota: Teori dan Kasus, UI Press, Jakarta.

Kusno, A. (2000) *Behind the postcolonial: architecture, urban space and political culture in Indonesia.* 1st edition. Routledge: London.

Leary, N., Conde, C., Kulkarni, J., Nyong, N., Adejuwon, J., Barros, V., Burton, I., Lasco, R. and Pulhin, J. (eds.) (2008) Climate change and vulnerability (Volume II). Earthscan: UK and USA.

Leenders, R.T.A.J. (2002) Modeling social influence through network autocorrellation: constrcting the weight matrix. *Social Networks* 24, 21–47.

Lohmann, R. (1992a) The commons: a multidisciplinary approach to nonprofit organization, voluntary action, and philanthropy. *Nonprofit and Voluntary Sector Quarterly 21*, 309–324.

Lohmann, R. (1992b) *The commons: new perspectives on nonprofit organizations and voluntary action.* 1st edition. Jossey-Bass: San Francisco.

Naylor, R.L., Battisti, D.S., Vimont, D.J., Falcon, W.P. and Burke, M.B. (2007) Assessing risk of climate change variability and climate change for Indonesian rice agriculture. Proceedings of the National Academy of Sciences USA. See www.pnas.org/content/104/19/7752.full

Martawati, L., Adidarma, W. and Wisuda, M. (2010) Perubahan Banjir Sungai Bengawan Solo Akibat Perubahan Tata Guna Lahan dan Perubahan Iklim serta Teknik untuk Menekan Peningkatan Banjir. *Jurnal Teknik Hidraulik* 1: 2, 167–180.

McPherson, J.M. (1982) Hypernetwork Sampling: Duality and Diffrentiation among Voluntary Organization, *Social Networks*, 3: 225-249.

Putnam, R. (2000) Bowling alone: the collapse and revival of America's civic community. 1st edition. Simon and Schuster: New York.

Rapoport, A. (1977) Human aspects of urban form: towards a man–environment approach to urban form and design. Urban and Regional Planning Series 15, Pergamon Press.

Ratna, D., *Suharso*, T.W. and Usman, F. (2011) Arahan Konservasi Wilayah Sungai Bengawan Solo yang Melalui Perkotaan Bojonegoro. Tata Kota dan Daerah.

Santoso, Singgih (2011) *Structural Equation Modeling (SEM), Konsep dan Aplikasi dengan AMOS 18*. Penerbit Elex Media Komputindo. Jakarta.

Scott, J. (2000) Social network analysis: a handbook. 2nd edition. Sage Publications: London.

Sinulingga, B.D. (1999) Pembangunan Kota: Tinjauan Regional dan Lokal. Pustaka Sinar Harapan: Jakarta.

Statistics of Bojonegoro Regency (2013) *Bojonegoro in Figures ,* Bojonegoro: BPS- Statistics of Bojonegoro Regency.

Surmaini, E. and Susanti, E. (2009) Global climate index and its effect on extreme climate events in Indonesia. *Indonesian Journal of Agriculture,* 2: 2, 129–136. See http://pustaka.litbang.pertanian.go.id/publikasi/ja022099.pdf

Tjahjono, S. (2008) Ekspedisi Bengawan Solo: Kehancuran Peradaban Sungai Besar. Gramedia: Jakarta.

Turner, J.F.C. (1976) Housing by people: towards autonomy in building environments. Marion Boyars: London.

Wasserman S, and Faust, K. (1994) Social network analysis: methods and application. 1st edition. Cambrige: Cambridge University Press.

Watson, A., Stumpf, L.A. and Meidinger, J. (2012) Traditional wisdom and climate change. *The International Journal of Wilderness,* 18: 2, 21–25.

WHO (World Health Organization) (2007) Emergency and Humanitarian Action News Update, February and March 2007 World Health Organization, Regional Office for South-East Asia. Available online: http://www.searo.who.int/LinkFiles/Newsletter_EHA_February_and_March_2007.pdf

Widayanti, R., Anggraeni, M. and Subagyo, A. (2012) Konsep Relokasi Permukiman Berdasarkan Tingkat Kerentanan di Sempadan Sungai Bengawan Solo Kecamatan Bojonegoro. Tata Kota dan Daerah.

Appendix 1. Household survey: structural equation models

Social perceptions questionnaire

Settlements and environmental conditions

General information about respondent

Name:

Gender: (F/M)

Age:

Address:

Phone number:

Length of stay:

Number of family members:

Education:

Date:

Duration of interview: (from/to)

	1	2	3	4	5	6	7	8	9	10
A										
B										
C										
D										
E										
F										
G										

RESPONDENT CODE:

Number:

Interviewer:

Photograph number:

Coordinate:

This questionnaire is part of a research project conducted by the Urban Settlement and Environmental Laboratory, Brawijaya University and the Modelling Laboratory, National Institute of Technology, Malang. It is funded by the International Institute of Environment and Development (IIED). This project is called Climate Change and Home Location Preferences in Flood Prone Areas of Bojonegoro Regency: Social Networks Approach. The main objective to understand social perceptions about the settlements and environmental conditions along the Bengawan Solo River, Bojonegoro Regency.

Preliminary questions

	Father	Mother	Child 1	Child 2
Age				
Sex				
Education				
OcCupancy				
Income				
Work location				
Transport to work				

1. Sir/madam, are you:
   a. Native inhabitant, or
   b. Migrant
2. If you are a migrant, when did you move to this area? What were your reasons for moving here?
3. If you are a native inhabitant, how many generations of your family have lived here? Where did your ancestors come from?
4. What is your land-holding status?
5. Do you have any relatives living in this area (*RW*)?
6. What is your main reason for staying in this area?
7. What social organisation are you a member of (at RT/RW level, district level or above)?
8. What is your opinion on the threat of flooding?
9. What do you usually do to cope with flooding? What about the early warning system?
10. What do you usually do when the floods come? Where do you evacuate to? Foods and supplies? Evacuation route? School? etc.)
11. What steps do you usually take for recovery after the floods?
12. How long did you need to recover from the flood?
13. What is the average financial loss you suffered, and from which source the funds needed to recover from the floods?

Structural equation model (sem) questionnaire

Guidance:

Please mark (X) in the box which best suits your perceptions of each variable and sub-Variable.

SD: Strongly disagree

D: Disagree

N: Neutral

A: Agree

SA: Strongly agree

No	Variable	sub-Variable	Perception	SD	D	N	A	SA
1	*Nature*	Geology (X1)	The stability of the land in this area is suitable for a settlement					
		Topography (X2)	The topography of this area is not a problem for me living here					
		Land (X3)	The land in this area is not a problem for me living here					
		Water supply (X4)	The water supply of this area is sufficient for me to live here					
		Climate (X5)	The climatic condition, temperature and rainfall of this area are not a problem for me living here					
2	*Man*	Biological needs (space, air, temperature, other) (X6)	Conditions at this settlement make me want to live here					
			The air n this area is very healthy					
			The temperature in this area is very healthy – for general living and for conducting daily activities					
		Perception and feeling (X7)	This location is a good place to live					
			I am pleased to live here					
		Emotional needs (interpersonal relationships, safety, beauty) (X8)	Relationships between neighbours are very good and an incentive to stay here					
			Security (floods and crime) here is adequate, there no need to consider moving to another place					
			This location has beautiful scenery					
		Moral values (X9)	People's behaviour and habits are good so I felt comfortable staying at this location					

No	Variable	sub-Variable	Perception	SD	D	N	A	SA
3	*Society*	Population composition and density (X10)	The religious diversity of the population here is not a problem					
			The diversity of ethnic groups here is not a problem					
			The ratio of men to women here is not a problem					
			The diversity of education levels here is not a problem					
			I feel the level of population density here is not a problem					
		Social groups (X11)	The presence of social groups here is helpful and positively affects my life					
		Customs and habits (X12)	The customs and habits here are positive and make life comfortable					
		Economic development (X13)	Economic development in this location is good and supports living					
		Education (X14)	Education and educational facilities here are adequate and have a positive impact on my life					
		Health (X15)	Health and health facilities here adequate and have a positive impact on my life					
		Administration and law (X16)	Legal and administrative services here are adequate and have a positive impact on my life					
4	*Shells*	Housing (X17)	Houses in this area are secure (from flooding) and meet the needs of everyday life					
		Facilities (schools, hospitals etc.) (X18)	Facilities such as schools, healthcare and post offices here meet the needs of everyday life					
		Market and stalls (X19)	The market and stalls in this region already meet the needs of everyday life					
		Recreation facilities (X20)	Recreational facilities here are adequate for the entertainment of residents, so that people feel less stressed					
		Home industry (X21)	The existence of domestic industry does not interfere with and even helps/protects the local economy and settlements here					
		Disaster evacuation routes (X22)	The existing flood evacuation route is adequate for me/my family/community in emergencies					

No	Variable	sub-Variable	Perception	SD	D	N	A	SA
5	*Network*	Water supply (X23)	The clean water system here serves the needs of residents e.g. we do not have to buy gallons of water, dig artesian wells or install water purification plants etc.					
		Electricity supply (X24)	The electricity network services here serve the needs of residents, e.g. there are no electricity blackouts)					
		Transportation (X25)	The transport system here serves the needs of residents, so it is easy to travel from this location to another					
		Communications (X26)	The communication system here serves the needs of residents, there are no related problems.					
		Drainage (X27)	The drainage system serves the needs of residents, there are no problems due to poor drainage (clogged drains, puddles, etc.)					
		Waste (X28)	The solid waste system here serves the needs of residents, so there are no related problems.					

Appendix 2. Calculations for social network analysis

The data forms an affiliation matrix $X = \{x_{ij}\}$ whereby the rows represent actors and the columns represent community groups – each actor i in rows is affiliated with events j in column (Everett and Borgatti, 2005; Wasserman and Faust, 1994).

$$x_{ij} = \begin{cases} 1 \text{ if actor } i \text{ is affiliated with event } j \\ 0 \text{ otherwise} \end{cases} \quad \text{(x.1)}$$

a. Density

The influence of an actor's social relationships on his/her participation in community group – where the strength of a relationship can be measured by the number of interlocks that it involves – is revealed by the density of interlocks in the adjacency matrix. Measuring density depends on two parameters of network structure: the 'inclusiveness' and the 'sum of the degrees of its points.' Inclusiveness refers to the number of connected points – the total number of points minus the number of isolated points expressed as a proportion of the total number of points. And the degree of a point is shown by the number of non-zero entries for that point in its row or column entry in the adjacency matrix. In addition, two points that are connected by a line are said to be adjacent to one another so that two actors represented by points are directly related or connected with one another (Scott, 1991).

Every network has associated with it an adjacency matrix, which is a binary $n \times n$ matrix A in which $a_{ij} = 1$ and $a_{ji} = 1$ if point i is adjacent to point j, and $a_{ij} = 0$ and $a_{ji} = 0$ otherwise. In addition, this research assumes that once two actors become joint participants in the same community group, this means they form a direct relationship with one another.

$$\text{Density} = 2l/n(n-1)$$

Thus, the density of a network is defined as the number of lines – labelled as n – in a network divided by the number of possible relationships, except to their own. Level of density is between 0 and 1. The higher level of density means the more dense the relationships between actors in the network.

b. Centrality

The notion of centrality is to identify the most important actors in a social network that are located in strategic locations within the network, so that the strcuture of the community can be defined (Wasserman and Faust, 1994). This research measures three indices of one-mode centrality to quantify the prominence of an individual respondent embedded in a network. These are (i) degree (ii) closeness and (iii) betweenness. In addition, index of centralisation is between 0 and 1 as a result of non-directional relationships.

(i) Degree of centrality

It measures the activities of the actors, so that the most active actors have a maximal central index. Regarding Wasserman and Faust (1994), in two-mode data, the degree of centrality for an actor is the degree of the node, $d(n_i)$ and hence they define $C_D(n_i)$ as an actor-level degree centrality index. In addition, since we deal with non-directional relationships, then $x_{ij} = x_{ji}$ in the form of symmetric adjacency matrix.

$$C_D(n_i) = d(n_i) = x_{i+} = \Sigma_j x_{ij} = \Sigma_j x_{ji} \quad \text{(x.3)}$$

To measure the degree of centrality that can be compared across networks of different sizes of data, it needs to normalise the raw degrees of nodes as the proportion of nodes that are adjacent to n_i which depends on the event size g, so that its maximum value is g – 1.

$$C'_D(n_i) = \frac{d(n_i)}{g - 1} \quad \text{(x.4)}$$

(ii) Closeness centrality

It measures how close the 'distance' of an actor is to all the other actors in the network, and indicates that increasing geodesics in length between actors means decreasing the centrality of the actors (Wasserman and Faust, 1994). Referring to Freeman (1979) and Sabidussi (1966) in Wasserman and Faust (1994), the distance between actors i and j, denoted as $d(n_i, n_j)$ can be the number of lines in the geodesic linking actors i and j, as a distance function and is the length of any shorthest path between the actors. Hence, the total distance that i is from all other actors is $\Sigma_{j=1}^{g} d(n_i, n_j)$, in which the sum is taken over all $j \neq i$.

$$C_C(n_i) = \left[\Sigma_{j=1}^{g} d(n_i, n_j)\right]^{-1} \quad \text{(x.5)}$$

To make comparisons of values across networks, Wasserman and Faust (1994) defined standardised closeness centrality as suggested by Beauchamp (1965):

$$C'_C(n_i) = \frac{g - 1}{\left[\Sigma_{j=1}^{g} d(n_i, n_j)\right]} = (g - 1)C_C(n_i) \quad \text{(x.6)}$$

In addition, since the geodesic distances of the isolated actor, n_k (with degree 0 because the actor cannot be reached) from other actors are infinitely long, $d(n_i, n_k) = \infty$ for all $i \neq k$, so that the isolated actor will be eliminated from the measurement (Wasserman and Faust, 1994; Faust (1997).

(iii) Betweenness centrality

This measures a central actor who intersects with many of the shortest paths between pairs of other actors, meaning these 'other actors' potentially might have some control over the interactions between the two non-adjacent actors (Wasserman and Faust, 1994). As a consequence, the actors' 'betweenness' may have more interpersonal power influence over the others.

Along with the estimations of Freeman (1977) in Wasserman and Faust (1994), the actor betweenness index for n_i is the sum of these estimated probabilities over all pairs of actors not including the i ith actor for i distinct from j and k.

$$C_B(n_i) = \Sigma_{j<k} g_{jk}(n_i)/g_{jk} \quad \text{(x.7)}$$

The number of pairs of actors not including n_i is the maximum value that is $\frac{(g - 1)(g - 2)}{2}$ thus, the standardised betweenness centrality is formulated as follows:

$$C'_B(n_i) = C_B(n_i)/[(g - 1)(g - 2)/2] \quad \text{(x.8)}$$

c. Rate of participation

Measuring rates of participation means describing people's rates of participation in social activities in the bipartite matrix (McPherson, 1982; Wasserman and Faust, 1994).

The following formula is the standardised actor's rate of participation.

$$\bar{a}_{i+} = \frac{\sum_{i=1}^{g}\sum_{j=1}^{h} a_{ij}}{g} = \frac{a_{++}}{g} = \frac{\sum_{i=1}^{g} x_{ii}^{N}}{g} \qquad \text{(x.9)}$$

Climate change, floods and homes: A social networks approach to understanding location preferences in Indonesia

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