# Flood Risk Assessment and Community Resilience to Flood Disaster: A Case Study of Da Nang City, Central Vietnam

**(**洪水リスク評価と水害に対するコミュニティレジリエンスに関する研究 - 中部ヴェトナム，ダナン市における事例 - **)**

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# Flood Risk Assessment and Community Resilience to Flood Disaster: A Case Study of Da Nang City, Central Vietnam

A dissertation presented to

The United Graduate School of Agriculture Sciences,
Tottori University in partial fulfillment of the requirements for a degree of
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# Declaration

This thesis is submitted for the degree of Doctor of Philosophy at the United Graduate School of Agricultural Sciences, Tottori University. This dissertation is the result of my own work and has not been and is not being, in part or wholly, submitted for another degree, diploma, or similar qualification.

Do Thi Viet HUONG

***To my beloved Son, Husband, and Family***

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# Fieldwork sites

Đà Nẵng city, Center of Vietnam


Hòa Vang district, Đà Nẵng city


Tây An village, Hòa Châu commune


Cẩm Nê village, Hòa Tiến commune

Túy Loan Đông 2 village, Hòa Phong commune

Hội Phước village, Hòa Phú commune


Lộc Mỹ village, Hòa Bắc commune

# List of Abbreviation

**ALOS** - Advanced Land Observing Satellite

**ASTER GDEM** - Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model

**AVNIR-2** - Advanced Visible and Near Infrared Radiometer type 2

**CA** - Cluster Analysis

**CCFSC** - Central Committee for Flood and Storm Control

**dB** - Decibels value

**DARD:** Department of Agriculture and Rural Development

**DEM** - Digital Elevation Model

**DNCFSC** - Da Nang Committee for Flood and Storm Control

**DNDONRE** - Da Nang Department of Natural Resources and Environment

**DNPC** - Da Nang People's Committee

**DNSO** - Da Nang Statistical Office

**GIS** - Geographic Information System

**GPS** - Global Position System

**HVPC** - Hoa Vang district People's Committee

**HVSO** - Hoa Vang Statistical Office

**JAXA** - Japan Aerospace Exploration Agency

**KMO** - Kaiser-Meyer-Olkin Measuring of Sampling

**LANDSAT ETM$^+$** - LANDSAT Enhanced Thematic Mapper

**LANDSAT TM** - LANDSAT Thematic Mapper

**NASA** - Nation Aeronautics and Space Administration

**MARD** - Ministry of Agriculture and Rural Development

**METI** - Japanese Ministry of Economy, Trade and Industry

**PCA** - Principle Component Analysis

**PALSAR** - Phased Array L-band Synthetic Aperture

**QNDNSO** - Quang Nam - Da Nang Province Statistical Office

**SRTM** - Shuttle Radar Topographic Mission

**SAR** - Synthetic Aperture Radar

**UNISDR** - United Nations International Strategy for Disaster Reduction

**UTM** - Universal Transverse Mercator

**WGS84** - World Geodetic Systems 1984

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# CHAPTER 1 INTRODUCTION

## 1.1. Research Background

### 1.1.1. Global Trends: Natural Disasters, Flood Risk, Urbanization and Community Resilience

Over last decades, disaster risks associated with hazards such as tropical cyclones, floods, earthquakes and other natural hazards has increased in frequency, extensity, intensity, and constituted a critical challenge to development (UNISDR 2009, UNISDR 2011), especially in coastal areas/regions (Coastanza and Farley 2007) and in countries with low GDP and weak governance (UNISDR 2011).

According to the Annual Disaster Statistical Review 2012 (Guha-Sapir, Hoyois et al. 2013), in 2012 a total of 375 natural disasters caused more than 9,655 people die, made 122.9 million victims and caused a record amount of US$ 157.3 billion damages (Figure 1). Hydrological disasters such as floods still took the largest share in natural disasters occurrence, occupying 49.4% (Guha-Sapir, Hoyois et al. 2013). The disaster risk trend is expected to continual increase in the future due to poverty, limitation of adaptation, badly planned and managed urban and regional development, as well as ecosystem decline (UNISDR 2011). The Asia and Pacific region has experienced the highest number of natural disasters from 1990 to 2011 (EM-DAT 2013).

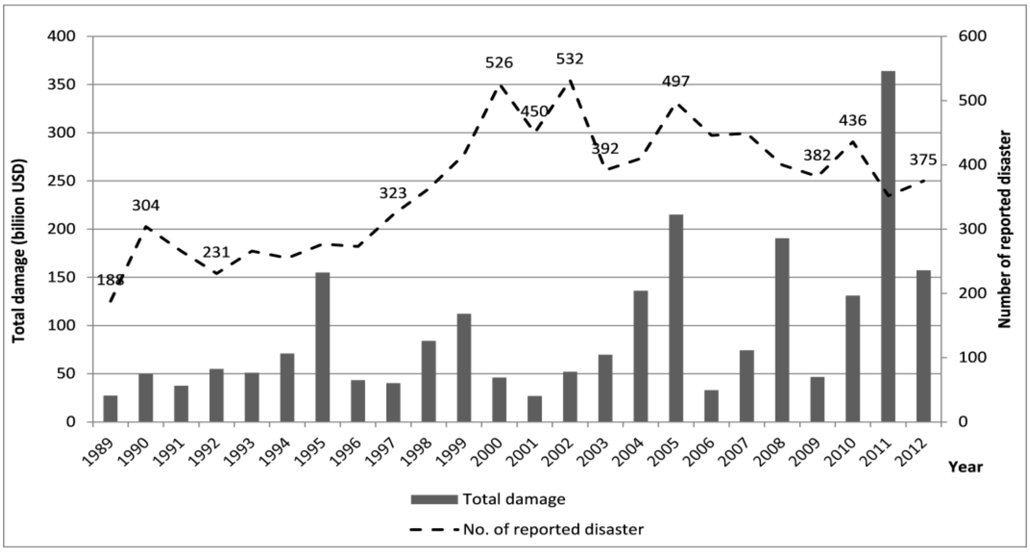


**Figure 1 World trend of natural disaster in occurrence and total damages** (Source: EM-DAT 2013)

Floods hazard is widely considered to be the most hazardous, frequent and widespread source of disaster risks throughout the world (Wisner, Blaikie et al. 2003, Liu, Smedt et al. 2004, Afeku 2005, Kron 2005, Taubenbock, Wurm et al. 2010). The huge impact of floods, which include river floods, flash floods, storm surge or tsunamis, has caused hundreds of thousands of deaths, loss of livelihoods and infrastructure, interruptions of economic developments and the loss of property worth billions of dollars (Taubenbock, Wurm et al. 2010). It has become more frequent and has increased in magnitude of damage though people have attempted many efforts to reduce flood impacts for many centuries. Flood risk was mainly associated with hazard occurrence probability and considered as the combination of the hazardous phenomenon of flooding and a vulnerable system susceptible to suffer loss (Eleitério 2012). Flood risks tend to increase more due to the combination of population growth pressure, land use intensification, unsustainable development (Taubenbock, Wurm et al. 2010), the degradation of ecosystems, and increasing of poverty and inequality (UNISDR 2009). Moreover, urban expansion in flood prone areas and the expected effects of climate change recently are elevating the risk of flooding due to increase the peak discharge, the speed of runoff and shorten the time to peak (Liu, Smedt et al. 2004, Banasik and Pham 2010, Singh and Singh 2011, Suriya and Mudgal 2012) and also to the explosive, uncontrolled urban sprawl, and changing pattern that increased vulnerability (UNISDR 2011). This high pressure on urban space and hence, fast uncontrolled spatial growth and densification created settlements in inappropriate areas most likely to be exposed to natural hazards (Taubenbock, Wurm et al. 2010).

As highlighted in the Global Assessment Report on Disaster Risk Reduction 2011, rapid urbanization is one of the significant factors contributing to increase disaster risk trend. Focusing on the major basin flooding, the world's population increased by 87% (from 3.7 billion to 6.9 billion) between 1970 and 2010 correspond with the average numbers exposed to flooding every year increased by 114 % (from 32.5 to 69.4 million annually). In which, more than 90 percent of the global population exposed to floods live in South Asia, East Asia and the Pacific (UNISDR 2011). Over the coming decades, the level of urbanization is expected to increase in Asia from 17.5% in 1950 to 64.4% in 2050. The proportion of population in the low-income countries exposed to flood and tropical cyclone is higher and grows faster than in higher-income countries. Such those low-income countries also have less capacity to absorb and recover from flood disaster (United Nation 2012).

In many developing countries, urban expansion has been able through the expanding of informal settlements to the hazards prone areas, the vulnerability housing, the lack of provision of infrastructures and local services. As a consequence, those settlements are susceptible prone to urban disaster risk due to theirs limitation on the accessibility to well-site and safe houses (UNEP 2002, UNISDR 2009, UNISDR 2011). Recently increasing attention is also being paid to the relationship between land use/cover change and flood management as well as between urbanization and flood risks (Liu, Smedt et al. 2004, Nirupama and Simonovic 2007, Banasik and Pham 2010, Taubenbock, Wurm et al. 2010, Singh and Singh 2011). Therefore, examining flood risk in concerned with urbanization impacts process is essential for flood risk management as well as urban planning (Zhang, Ma et al. 2008, Suriya and Mudgal 2012).

By addressing the underlying risk drivers that translate human to disaster risks such as poor urban governance and planning, vulnerable rural livelihoods, and environment and ecosystem decline, it is possible to develop in a way that contribute the best way to disaster risks reduction. Given the increasing concern about the impact of disaster, The United Nation General Assembly declared 1990-1999 was the International Decade for Natural Disaster Reduction and aim to promote a comprehensive approach to risk assessment and thus enhance the effectiveness of efforts to reduce the loss of life and damage caused by flooding, violent storms, earthquakes and volcanic eruptions (UNISDR 2004). In the first World Conference on Disaster Reduction (1994), The Yokohama Declaration and Plan of Action for a Safe World provided guideline for national and international action on natural disaster prevention, preparedness and mitigation. And ten years later in 2005, the Hyogo Framework for Action (HFA) World Conference on Disaster Reduction in Kobe Japan called for building the resilience of nations and communities to disasters. Since the adoption the HFA, more attentions have been paid for building community resilience to disasters risk reduction. Resilience and vulnerability have been increasingly considered as vital components of disaster risk reduction strategies (UNISDR 2009). Recent models have shifted away from post disaster relief or “loss reduction”, “reducing vulnerability” models to more comprehensive models of "building community resilience", which shift people's attitudes and behaviors towards coping with natural disasters, analyzing vulnerability, and building community resilience (UNISDR 2004, Mayunga 2007, Cutter, Barnes et al. 2008). Therefore, community resilience to disaster is crucial in reducing vulnerability and disaster risk and for achieving sustainable development in recent years.

### 1.1.2. Flood Disasters Issues in Centre of Vietnam

The common natural disasters include typhoons, tropical storms, floods, landslides, and droughts, of which typhoons and floods are by far the most frequent and severe. Every year, natural disasters cause significant economic, social, and environmental damages, directly hindering the country from sustainable socio-economic development. Vietnam is one of 10 countries in the world that usually suffer severe consequences of natural disasters and it has been predicted to be one of the country's most vulnerability and likely to be significantly impacted by climate change (Smyle and Cooke 2011). Located in a tropical monsoon area in the Asia Pacific region, with a coastline of around 3,440 km, combined with a diverse and complex topography, Vietnam is prone to many natural hazards (typhoons, tropical storms, flood, landslide, and droughts) that caused an estimated USD 7.9 billion in economic losses from 1980 to 2010 (EM-DAT 2013). Vietnam has been ranked as a "Natural Disaster Hotspot", ranking the 7$^{th}$ on economic risk, the 9$^{th}$ on the percentage of land area and population exposed, and the 22$^{nd}$ on mortality from multiple hazards (Smyle and Cooke 2011). Approximately 70% of the country's population is exposed to risk from these natural hazards, of which floods occur most frequently and most devastating hazard causing significant economic, social and environmental damages, directly hindering the country from sustainable socio-economic development (CCSFS 2006, World Bank 2009). Flood is the most reported with 48% of the total natural disaster records over a period of twenty years, from 1989 to 2010 (Oanh, Thuy et al. 2011).

Natural disasters in Vietnam have been increasingly severe in terms of intensity, frequency, spatial extent, duration and timing as well as volatility. In addition, rapid population growth, high rate of urbanization in some big cities combined with pressures on natural resources, extreme events and climate change, have in deep increased the exposure and vulnerability of the population to these hazards and result in disaster risk. As a consequence, those factors in turn hamper the accomplishments Viet Nam towards poverty reduction and achievement of the Millennium Development Goals (Oanh, Thuy et al. 2011).

Particularly, the central region, which is a narrow land strip along the coastlines on the eastern side of Truong Son mountain range and has a complex terrain sloping towards the East Sea, suffers the most frequent influence of typhoons, tropical storms, and floods (counting for 65%). Storms often happen repeatedly in a short time, even two or three storms of high intensity occur in one month, and floods appears quickly and strong, resulting in serious damages. Over 25 years (1995-2010), flood disasters have caused over 1,786 missing and dead people, 1,036 injured people and severity of the loss is estimated at approximately 14,797 billion VND (Figure 2) (CCSFS 2013).

### 1.1.3. Disaster Risk Management in Vietnam

Natural disasters are factors that directly impede the sustainable socio-economic development and accelerate the poverty. With profound awareness of human casualties and material losses caused by natural disasters, the Government of Vietnam has considered natural disaster management and mitigation as one of the important activity of sustainable development processes (MARD 2012).

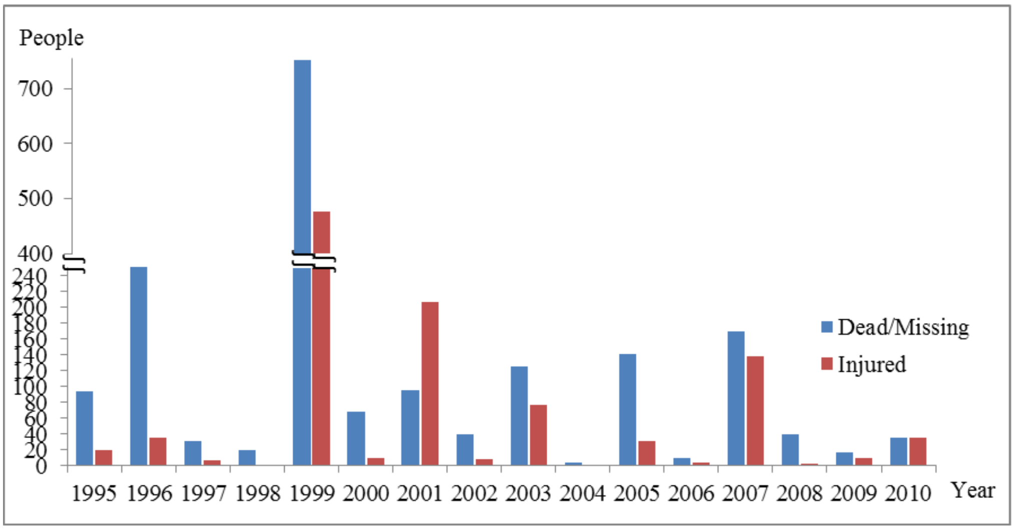


**Figure 2 Number of people dead/missed and injured in flood disasters from 1995 to 2010 in Center Region of Vietnam**

Source: Central Committee for Flood and Storm Control - Disaster Database. Available in http://www.ccfsc.gov.vn/KW6F2B34/CatId/G986H8324D/Summary-of-damages.aspx

In 1946, the Democratic Republic of Vietnam has been established the Central Committee for Dike Maintenance - the predecessor of the current Central Committee for Flood and Storm Control (CFSC). Since that time, the legal documents have been step by step accomplished for creating a legal corridor for flood and storm control and natural disaster mitigation including the Ordinance on Dike (1989), the Ordinance on Flood and Storm control (1993) and the Water-related Disaster Control Strategy (1994) (ADB 2008).

The year 2003 marked the first breakthrough in the common concerns of Vietnam for phenomenon of climate change: Announcing the first National Report of Vietnam under the Framework Agreement Climate Change of the United Nations (Son, Phung et al. 2011). In year of 2004, Vietnam published the National Report on Disaster reduction in Vietnam for preparing the World Conference on Disaster Reduction in Kobe-Hyogo, Japan (Social Republic of Vietnam 2004). Three year later, the Government developed "National Strategies for Natural Disaster Prevention and Mitigation to 2020" which included tasks of ensuring safety for dyke systems and improving anti-storm capacity of embankment system in the Central coastal region, ensuring safety of reservoirs, particularly those near dense population areas and sensitive areas in economic, politic, and cultural terms, as well as near the important works relating to national security and defense (Oanh, Thuy et al. 2011, MARD 2012). The Vietnam's 2007 National Strategy also identified floods as one of the country's most important natural hazards and focused on how to take measures to reduce the risks, enhance the forecasting floods capacities as well as enhance the community resilience. One year later, Vietnam government approved the Decision No 158/2008/QD-TTG of National Target Program to respond to climate change (Social Republic of Vietnam 2008). In 2011, Ministry of Agriculture and Rural Development (MARD) issued its Action to response to climate change of the Agriculture and Rural Development in period 2011-2012 and Visions to 2050 (Smyle and Cooke 2011). Thus, in a very short time, Vietnam has continuously issued policy documents related to climate change and mitigation of natural disasters. Notably, in 2010, the Vietnam Government promulgated Decision No 800/QĐ-TTg of the National Target Program on New Rural Development for entire communities until 2020. The goal is to undertake comprehensive rural development including economic, social, environmental, and political fields that concern climate change responses as well as natural disaster prevention and mitigation (Son, Phung et al. 2011). However, most of these policies are often developed on a general scale (e.g., Nationwide, North region, Central region, and South region) and little attention has been paid to a detailed regional scale based on specific geographic features, especially at the village level. Although Vietnam has launched the Nation Target Programme to respond to climate change, there have still not yet been particular policies on integrating resilience building into development plans of city, district and commune level (Institute for Social and Environmental Transition 2011).

In recent years, despite growing recognition of shifting tendency from "post disaster relief" model to "building resilience community" in natural disaster management, Vietnam national policies as well as local policies have still not yet been receiving adequate attention in how to enhance building community resilience capacity to natural disaster. The impacts of climate change and unpredictable natural hazards will exacerbate the existing vulnerability communities if we don't make efforts in building resilience community to face climate change and associated disasters risk.

## 1.2. Objective and Research Questions

Recently, the increasing and intensifying of flood risks in developing countries has caused deaths, livelihood losses, destruction of infrastructure, environmental degradation, disruption of economic activity and the loss of property worth billions of dollars (Taubenbock, Wurm et al. 2010). Da Nang city is located in the central of Vietnam and considered as one of the coastal cities high expose to severe consequences of natural disasters. On average, each year the city is directly or indirectly influenced by 2-3 typhoons and 2-3 great floods spells. During last 10 years, Da Nang suffered from some severe natural disasters in 1964, 1999, 2006, 2007, 2009 and 2011 caused damage to life, houses, infrastructure, and agriculture products. In recent years, urbanization has taken place rapidly in Da Nang city. As most of the population is living in low-lying river basin and coastal areas is estimated to be exposed to risk from flood hazards. What is more, there has been increasing urban population growth in these areas, causing high pressure on urban spaces. This results in the creation of settlements in inappropriate areas that are most likely to be exposed to natural hazards, especially flood hazards (Taubenbock, Wurm et al. 2010, Huong and Pathirana 2011). The coastal and central areas of Da Nang city with a high rate of urbanization may face risk of flooding and environmental degradation, especially during the rainy season. The growth of its commercial port, international airport, industrial zones, and new urban areas, as well as the expanding tourism sectors along the coastal area, has resulted in huge developments in the socio-economic aspects and spatial structure of the Da Nang city. On the other hand, the decline in agricultural and aquacultural lands, due to strategy investment as well as the sprawl of human settlements, industrial parks, and infrastructure in flood prone zones, has led to the congestion of storm water drainages that causes flooding.

After Vietnam government approved the National Target Program to respond to climate change, Da Nang city authority subsequently approved the Action Plan of Responding to Climate Change and Sea Level Rise to 2020 (Decision No.6901/QĐ-UBND on August 24$^{th}$ 2012) in city level as well as in district level (DNPC 2012). The action plan focused on flood drainage planning, vulnerability assessment of climate change to urban development, however little paid attention on building the community resilience to natural disasters.

Hence this dissertation research conceptualized of flood risk in concerning with urbanization and addressed the dimensions that affect community resilience and capacity to cope with uncertainty in the floodplain of Da Nang city for disasters risk management. In these contexts, the purpose of this dissertation was first to explore the interrelationship between flood risk and urbanization and then assessed the community resilience based on typology potential vulnerability villages and measurement of community resilience via capital - based approach.

The objectives of the research have been formulated as follow:

(1) To contribute the ongoing development of flood risk assessment and analyze the relationship between flood risk and urban expansion by utilizing remote sensing and Geographic Information System (GIS) techniques.

(2) To appraise how differential community resilience to flood disaster in the context of socio-economic conditions, historical flood disaster as well as the policies of the local authorities.

In addressing these objectives, this research particularly concentrated on answering the following questions:

To study the flood risk, first the following main questions were addressed:

*(i) Which definition of risk concept and its relation to hazard, vulnerability, and resilience is used in the context of flood risk management?*

*(ii) How remote sensing and GIS is applicable in flood risk assessment?*

*(iii) How urban is expanded and where are exposed to high flood risks during 20 years in Da Nang city?*

Secondary, the assessment community resilience to flood risk was carried out on the case study of rural district of Da Nang city, in which the following questions were addressed:

*(iv) Which frameworks and methods can be useful for assessing community resilience?*

*(v) Which indicators can be used to assess the community resilience?*

*(vi) How resilient are the studied communities?*

## 1.3. A Synopsis of the Research Methodology

To achieve the above mentioned objectives, this research followed the concept of study that explained clearly through the relationship between RISK, HAZARD, VULNERABILITY and RESILIENCE. In which Risk, Vulnerability and Hazards has been described as the function: Risk = Hazard x Vulnerability given by International Strategy Disaster Reduction (UNISDR 2004). Resilience partly opposite to vulnerability and both resilience and vulnerability notions have the common components of interest - the shocks and stresses, the response of the system and the capacity for adaptive action. Community resilience to disaster is crucial in reducing vulnerability and disaster risk for achievement of sustainable development.

Remote sensing and GIS have become essential tools for monitoring urban expansion (Thy, Venkatesh et al. 2010), as well as for mapping flood hazards and assessing flood risks (Suriya and Mudgal 2012). In this research, we focused on applying remote sensing and GIS to assess the flood hazard, flood risk and to determine the land use/cover changes. By using multi-temporal satellite images from 1990 to 2010, spatial urban expansion in Da Nang city and temporal trends in its urban development were elucidated to comprehend the city's evolution during different period. The Phased Array L-band Synthetic Aperture (PALSAR) onboard the Advanced Land Observing Satellite (ALOS) in combination ASTER Global Digital Elevation Model (GDEM) and other ancillary data were utilized in mapping and assessing flood risk. The aim of this study was to analyze the flood risk and urbanization and their relationship during 20 years of urbanization. The typology and household questionnaire survey were employed to assess the community resilience to flood disaster. First typology was conduct to quantitatively classify the flood affected village based on figuring out the similar social and topographic characteristics. Then base on the result of typology potential vulnerability villages, a combination of household's questionnaire survey and quantitative spatial analysis using GIS data were employed focus on the dimensions of community resilience in order to analyze the level of resilience in the target villages. Examining the relationship between potential vulnerability typology and community resilience in concern with actual condition of flood disaster related we have taken the assessment of community resilience.

## 1.4. Dissertation Outline

This dissertation is divided into six chapters. The focus of this first Chapter is to provide the background, objectives and brief statement on the methodology used of the whole thesis.

Chapter 2 is a review chapter provides Theoretical and Conceptual Framework of research by drawing from literature on natural hazard, flood risks, community resilience, and the applications of remote sensing and GIS in flood risks assessment.

Chapter 3 describes the Background of study area including characteristics of physical geography, socio-economic profile, urbanization characteristics and flood status disasters during last 20 years.

Chapter 4 examines the urban expansion and flood risk change in Da Nang city. This chapter demonstrates the contribution of utilizing ALOS PALSAR and ASTER GDEM in mapping potential flood hazards. The main argument of this chapter is that the urban expansion has been increasing in the present study area into regions where settlements are subject to significant flood risk.

Chapter 5 conducts a community resilience assessment to flood disaster in the rural district based on the potential vulnerability typology of flood affected villages and then to measure the resilience of the community via a capital-based approach by using questionnaire survey. Based on the result of assessment, a number of solutions for improving rural community resilience for each village will be identified.

Finally, in the Chapter 6, overall conclusions and discussion are given.

# CHAPTER 2 THEORETICAL AND CONCEPTUAL FRAMEWORK

## 2.1. Theoretical Approaches of Flood Risks

### 2.2.1. Definition of Hazard

Hazard is defined as a potential damaging physical event, phenomenon or human activities, which may cause the loss of life or injury, property damage, social and economic disruption or environment degradation (UNISDR 2004). Hazard can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro meteorological and biological) or induce by human processes (environmental degradation and technological hazards). Hazard is characterized by its location, intensity, frequency and probability. In this research we focus on flood hazard originating from hydro meteorological hazards hereinafter referred to as floods.

Floods can be defined as a temporary covering of land by water outside its normal confines that happen in small or large river basins, in estuaries, at coasts and locally (Schanze, Zeman et al. 2004). Flooding is a natural and recurring event for a river or stream resulting from a heavy or continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of river, stream and coastal areas (Department of Regional Development and Environment Executive of American States 1991). Each flood event can be characterized by features such as water depth, flow velocity, matter fluxes and temporal and spatial dynamics (Schanze, Zeman et al. 2004). We can distinguish some types of floods and their characteristics as local floods, riverine floods, flash floods, and coastal floods (Table 1).

Flood hazard is defined as the exceeding probability of the occurrence of potential damaging flood situation within a given area and within a specified period of time (Thieken, Merz et al. 2006). A hazard does not automatically lead to a harmful outcome, the potential of harm occurring depend upon the exposure to the hazard and the characteristics of the receptor (Schanze, Zeman et al. 2004).

Due to global warming and climate change impacts, high increase trend of flood was shown in intensity, frequency, spatial extent as well as duration and time (IPCC 2007). Extreme climate change impacts lead to important concentration of rainwater that flows over landscape and concentrate in river channels. The concentration of water in riverbeds leads to the overflow of rivers that spread over the floodplain inundating areas that are not generally occupied by water (Eleitério 2012). Urban areas where located in the low-lying areas, middle or downstream are particularly exposed to extensive riverine floods. Urban growth has expanded over some of the floodplains, reducing the areas into which floods can naturally overflow, consequently increasing flood risk and may cause devastating urban flooding (World Meteorological Organization 2008).

**Table 1 Different types of floods**

| Type of flood | Description of the flood type |
|---|---|
| Local flood | Local flood is referred to a very high rainfall intensity and duration. Local flood in the rainy season sometimes caused by seasonal storms and was exacerbated by saturated or impervious soil. The build of cities has been generated higher surface run-off that is in excess of local drainage capacity, thereby causing local floods |
| Riverine flood | Riverine flood is triggered by heavy rainfall or snow melt in upstream areas, tidal influence from the downstream, even failure or bad operation of drainage or flood control works upstream. River flood occurs when the river run-off volume exceeds local flow capacities. The ground becomes fully saturated and the soil's capacity to store water is exceeded. River level rises slowly and the period of rise and fall is particularly long, lasting a few weeks or even months, particularly in areas with flat slopes and deltaic areas. |
| Flash flood | Flash flood occurs as a result of the rapid accumulation and release of runoff waters from upstream mountainous areas, which can caused by very heavy rainfall, cloud bursts, landslides, the sudden break-up of an ice jam or failure of flood control works. It is characterized by a sharp rise followed by relatively rapid recession causing high flow velocities. Discharge quickly reaches a maximum and diminishes almost as rapidly. Flash flood is not only associated with fast flowing water in steep terrain, but also with the flooding of very flat areas, where the slope is too small to allow for the immediate runoff of storm water. |
| Coastal flood | High tides and storm surges caused by tropical depressions and cyclones can cause coastal flood in urban areas located at estuaries, tidal flats and low-lying land near the sea in general. Tsunamis, mainly triggered by powerful offshore earthquakes, can also cause coastal flood though infrequently. |

Source: (Kron 2005, World Meteorological Organization 2008)

### 2.2.2. Definition of Vulnerability

Damage by hazards depends on the vulnerability of exposed elements (Schanze, Zeman et al. 2004). Vulnerability, broadly defined as the potential for loss, is an essential concept in hazards research and is central to the development of hazard mitigation strategies at the local, national, and international levels (Cutter 1996). The term of vulnerability is used many ways in various researches, such as in livelihood security, food security, natural hazards, risk management, health community, global environmental change and climate change (Buika, Goosby et al. 2003, Wisner, Blaikie et al. 2003, Fussel and Klein 2006). Because of the complicated features, subjective opinions, the vulnerability definition have not been unified among the researchers due to the origins of vulnerability (Cutter 1996, Wisner, Blaikie et al. 2003, Smith and Petley 2009). From natural hazards perspective, there are representative of researchers such as Cutter (1996), Wisner, Bleikie et al. (2003), and UNISDR (2004). As defined by Wisner, Bleikie et al. (2003), vulnerability is "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard". It involves a combination of factors that determine the degree to which someone's life and livelihood are put at risk by a discrete and identifiable even in nature or in society. The degree of vulnerability can be defined by several indicators of socio-economic status such as poverty, ethnicity, gender, disability, age, class, occupation and immigration status (Wisner, Blaikie et al. 2003, Rygel, O'sullivan et al. 2006).

People and groups that are socio-economically disadvantage, such as the poor and immigrants, are often consigned to more vulnerable locations (Uitto 1998, Fothergill and Peek 2004). Poor people suffer the greatest disaster losses and have the most limited access to public transportation, private recovery assets, communication, little control over their life, as well as hold little power (Flynn, Slovic et al. 1994, Clark, Moser et al. 1998, Wisner, Blaikie et al. 2003, Fothergill and Peek 2004). Fothergill and Peek (2004) found that people who are of a lower socio-economic status are more likely to be involved in higher risk or more hazardous occupation. The poor typically live in poorly built and inadequately maintained housing and located in vulnerable locations such as floodplain, coastal areas (Morrow 1999). Mostly the poor people in urban areas often live in the informal squatter settlements where they typically lack of sewage and drainage systems, access to health facilities and sanitation services, and other resources to reduce their risk (Lawler 2011).

Disaster research has indicated that between gender and disaster exist a clear relation (Enason, Fothergill et al. 2004, Rygel, O'sullivan et al. 2006) and women generally are more vulnerable than men to disaster (Willinger 2008). Women tend to suffer disproportionately in every stage of disaster response (Morrow 1999). Women are more vulnerable during disaster because their caregiving responsibilities always place the wellbeing of others, particularly their children, and the elder over their own (Rygel, O'sullivan et al. 2006, Willinger 2008). Moreover, women also bear most of the responsibility for meeting the daily needs of family members, particularly dependent children and elder. And in post disaster, almost women are hardly to get a job and they face with difficult time for surviving in a community disaster (Morrow 1999). Wilinger (2008) and UNICEF (2012) also argued that women typically have less access to resources such as transportation, education, saving, less of control over decision-making and economic resources result in more encumbered to evacuate readily and recover quickly when disaster occur (Willinger 2008, UNICEF 2012).

The population structure clearly represents as significant indicators of social vulnerability denoting the resistance capacity to hazard (Hsieh, Su et al. 2011). Both young and old population also may be unable to resist to disaster on their own (Clark, Moser et al. 1998). The elders are more apt to lack the suffer health-related consequences and be slower to recover to disaster (Morrow 1999). Individuals who are sixty-five or older are more likely than others to suffer from chronic diseases, including arthritis, hypertension, heart disease, diabetes, and respiratory ailments (Aldrich and Benson 2008). Therefore they are more likely to require particular attention because of their frailties as well as need disaster-related assistance. Children are especially sensitive to changes in the climate and other climate-related exposure and are also likely than adults to be killed or injured during disaster (Lawler 2011). Especially, children who lack adequate family support are high vulnerability to disaster (Morrow 1999). Hoffman (2009) has argued that children are one of the most the vulnerable populations due to their susceptibility to injury and their dependence on others for livelihood, decision making and emotional support. During and after disaster events, they are often identified as the population groups that should be prioritized for evacuation, taking care and relief efforts (Hoffman 2009).

Vulnerability assessment is increasingly being considered as a key step towards effectively disaster risk reduction (Birkmann 2006). Therefore since 1989, the United Nations has declared the 1990s as the "International Decade for Natural Disaster Reduction with their framework encompassed vulnerability assessment for determining the potential damage and loss of life from extreme natural event (UNISDR 2004).

### 2.2.3. Definition of Flood Risk

During the last two decades, risk definitions have inundated in the literature. The term of risk has a different in range of meanings and multiple dimensions relating to safety, economic, environmental and social issues reflecting the needs/purposes of particular decision-makers (Gouldby and Samuels 2005). According to the definition of Business Dictionary, fundamental Risk is defined as the exposure to loss from a situation affecting a large group of people or firms, and caused by (a) natural phenomenon such as earthquake, flood, hurricane, or (b) social phenomenon, such as inflation, unemployment, and war (Business Dictionary 2013).

Although there is a wide variation and comprehensions in term of risk due to the difference of topic, purpose, and the scientific disciplines with their corresponding objects of research (Kron 2005, Huttenlau and Stotter 2011), the common acceptable/agree understand of risk is the consequences associated with some particular hazards and the probability and severity of the hazard (Kron 2005, Fedeski and Gwilliam 2007). A number of definitions of risk in concern with natural hazards are presented in Table 2.

Flood risk emerges from the convolution of flood hazard and flood vulnerability (UNISDR 2004). In this research, we adopted the risk definition of the United International Strategy for Disaster Reduction (UNISDR 2004) which is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. The purpose of a risk assessment is to determine the natural and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability. In this study, floods and urban areas are considered as hazards factor and vulnerability factor, respectively. As the flood risk is a function of the flood hazard, the exposed values and their vulnerability, the increase in flood losses must be attributed to changes in each of these aspects (Kron 2005). We can reduce the flood risk by controlling the hazard and/or by reducing the vulnerability of the assets exposed to flood events.

**Table 2 Definition of Risk**

| Author (s) | Risk definition |
|---|---|
| Alexander, 1991 | Total risk = Impact of hazard x Elements at risk x Vulnerability of elements at risk |
| Blong, 1996 | Risk = Hazard x Vulnerability |
| Helm, 1996 | "R = P x C". The level of "Risk" may be calculated as the product of the "Probability" of an event or adverse outcome (chance/likelihood/frequency, expressed as occurrences per unit time) and a measure of the "Consequences" of the event (damage/detriment/severity, expressed numerically as a specific value measure such as lives lost or financial damage per event). |
| Stenchion, 1997 | "Risk might be defined simply as the probability of the occurrence of an undesired event [but might] be better described as the probability of a hazard contributing to a potential disaster… importantly, it involves consideration of vulnerability to the hazard". |
| Crichton, 1999 | "R = H x V x E". Risk is the probability of a loss, and this depends on three elements, hazard, vulnerability and exposure". If any of these three elements in risk increases or decreases, then risk increases or decreases respectively. |
| Downing et al., 2001 | Expected losses (of life, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period |
| Wisner et al., 2003 | Risk of disaster is a compound function of the natural hazard and the number of people, characterized by their varying degrees of vulnerability to that specific hazard, who occupy the space and time of exposure to the hazard event<br>R=H x V, R: Risk, H: Hazard, V: Vulnerability |
| UNISDR, 2004 | Determines Risk is a particular system has two factors.<br>Risk = Hazard x Vulnerability |
| Kron, W., 2005 | Three components determine the flood risk: Risk = Hazard x Value x Vulnerability<br>The hazard: the threatening natural event including its probability of occurrence<br>The values or values at risk: the building/items/humans that are present at the location involved<br>The vulnerability: the lack of resistance to damaging/destructive forces. |

Source: (Kelman 2002, Brooks 2003)

## 2.3. Community Resilience and Resistance to Flood Risk

### 2.3.1. Concept of Community Resilience

The notion "Resilience" has been analyzed from various scientific disciplines as the notion of "bouncing back", "leap back" or "recoil" which originated from Latin "resilire" (Klein R.J.T 2003, Wilson 2012). The authors expressed the notion of resilience in difference ways (Table 3).

**Table 3 Definitions of Resilience**

| Citation | Field | Definition |
|---|---|---|
| Holling, 1973 | Ecological system | The persistence of relationship within a system; a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist. |
| Klein, 2003 | Ecological systems | The ability of a system that has undergone stress to recover and return to its original state; more precisely (i) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction and (ii) the degree to which the system is capable of self-organization |
| Resilience Alliance (Homepage - Accessed on December 25, 2012) | Ecological systems | "Resilience" as applied to ecosystems, or to integrated systems of people and the natural environment, has three defining characteristics:<br>• The amount of change the system can undergo and still retain the same controls on function and structure<br>• The degree to which the system is capable of self-organization<br>• The ability to build and increase the capacity for learning and adaptation |
| Gunderson and Holling, 2002 | Extended-ecological systems | The magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior. |
| Walker et al., 2004 | Social-Ecological | The capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain the same function, structure, identity and feedbacks |
| Adger et al., 2005 | Social-ecological | The capacity of a social-ecological systems to absorb recurrent disturbances (...) so as to retain essential structures, process and feedbacks |
| Brand, F.S., et al 2007 | Social - ecological | Resilience has become a "boundary object" which can be highly useful as a communication tool in order to bridge scientific disciplines and the gap between science and policy. |
| Cutter et al., 2008 | Social-Ecological | The ability of a social systems to respond and cover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event. |
| ISDR, 2004 | Social resilience | Resilience is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures |

| Citation | Field | Definition |
|---|---|---|
| Adger 2000 | Social/Community resilience | Social resilience as the ability of human communities to withstand external shocks to their social infrastructure, such as environmental variability or social, economic and political upheaval. |
| Magis, 2010 | Community resilience | The existence, development and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability, and surprise. Members of resilience communities intentionally develop personal and collective capacity that they engage to respond to and influence change, to sustain and renew the community, and to develop new trajectories for the communities' future. |

There is a high agreement in literature that the concept of resilience was first focused on notions of ecological resilience (Holling 1973, Folke, Carpenter et al. 2002, Folke 2006, Cutter, Barnes et al. 2008). Ecologist C.S. Holling (1973) defined resilience in field of ecosystem as "a measure the persistence of relationships within a system and of the ability to absorb change of state variable, driving variable, and parameters and still persist". His resilience meaning focuses on the persistence of communities at the ecosystem level and corresponds to both the overall area (Brand and Jax 2007).

From the late 1970s to 1990s there has been redefined and extended the ecological resilience to Socio-Ecological Resilience definition (Walker B. 2004, Brand and Jax 2007, Willon 2012). Resilience here is defined as a "boundary object" between natural and social science (Brand and Jax 2007), the capacity of a system to absorb disturbance and reorganize while undergoing change to still retain essentially the same function, structure, identity, and feedback (Walker B. 2004, Adger, Hughes et al. 2005, Folke 2006), ability of a system to adjust to change, moderate the effects, and cope with disturbance (Cutter, Barnes et al. 2008). However, the social-ecological resilience framework approach has been criticized due to "measuring socio-ecological resilience is challenging, particularly because in order to clarify features that contribute to it, institutional and organizational processes must be understood as carefully as ecological ones" (Oudenhoven, Mijatovic et al. 2010), and the research integration on resilience between natural and social science approaches "is still in its infancy" (Folke 2006). Adger (2000) also argued "it is not clear whether resilience ecosystems enable resilient communities".

This was echoed by Davidson (2010) and she also argued “the means by which social system can be readily cast into the ecological terms encompassed by the resilience framework must be critically examined”.

From those criticisms, a new resilience approach has been emerged focus on the resilience of human systems and communities, referred to as *social resilience* (Adger 2000, Brand and Jax 2007, Davidson 2010). The notion of social resilience is strongly focused on human learning pathway and how these may affect the resilience of community. It includes not only the outcome linked to improved adaptive capacity of community but also the process linked to dynamic changes over time associated with community learning and the willingness of communities to take responsibility and control of their development pathways (Chaskin 2007, Wilson 2010). The notion of socio/community resilience is referred to assess how community develops adaptive capacity to respond to endogenous threats (e.g. political upheaval, revolution) or exogenous threats (e.g. climate change, volcanic eruptions, flooding) (Adger 2000, Magis 2010). The ISDR (2004) also definition emphasized resilience as a property of a social system, which is able to adapt and reorganize in order to better cope with future hazard. “Resilience is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures”.

In this research domain, we focus on the Community Resilience as a subset of research on social resilience which was defined as the ability of groups or communities to respond and recover from disaster and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social systems to re-organize, change, and learn in response to a threat for better future protection and to improve risk reduction measures” (Adger 2000, UNISDR 2004, Cutter, Barnes et al. 2008, Willson 2012).

Community here which defined as an entity that has geographic boundaries and shares fate composing of build, natural, social, and economic environment that influence one another in complex way (Norris, Stevens et al. 2008).

### 2.3.2. Resilience and Vulnerability

Vulnerability, resilience and the related concepts of risk, hazard are widely used in flood risk assessment and management. Vulnerability is a key concept of natural hazards studies which presented in the notation of "Risk = Hazard x Vulnerability" given by International Strategy Disaster Reduction (UNISDR 2004). Vulnerability is defined as the characteristic of a person or group and their situation that influences their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazards threatening their life, well - being as well as livelihood (Wisner, Blaikie et al. 2003); as degree to which a system is likely to experience harm due to exposure to a hazard, either a perturbation or a stress (Turner, Kasperson et al. 2003). Vulnerability used here does not imply the adoption of a pathogenic framework but indeed this definition contains elements (e.g., "cope with", "resist") consistent with the concept of resilience (Douglas Paton 2000, Paton 2005)). Vulnerability registered not only by exposure to hazards alone but also resides in the resilience of the system experiencing the hazard (Turner, Kasperson et al. 2003). Focus on disaster risk reduction, resilience is defined as "the capacity of a system, community or society potential exposed to hazards to adapts, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measure (UNISDR 2004).

The origin of two concepts of vulnerability and resilience is different. Resilience describes how a system reacts to a disturbance, while vulnerability relates to why a socio-economic system responds in a given way. The resilience concept is derived from stability theories and theirs central issue focus on the reaction of the system to flood wave while the vulnerability is mainly used in social science and theirs central issue focus on vulnerability people and their livelihoods (Bruijin 2005). Although the concept of resilience is in part the opposite of vulnerability, but both notions have common components of interest - the shocks and stresses, the response of the system, and the capacity for adaptive action (Adger 2000, Adger, Hughes et al. 2005, Wilson 2012). Risk can be reduced by minimizing the degree of vulnerability within the entire community or, in other words, by enhancing the resilience of the community. Therefore, examination of the resilience in relation to vulnerability and risk is an essential conceptual framework for understanding how communities respond and adapt to natural disasters, in order to assess community resilience.

Building community resilience is considered as an effective way for community preparedness, awareness, coping and recovery from hazards and disaster. Social/Community resilience is more closely associated with normative judgment about "good resilience" and "bad vulnerability" in which the ability of a human system to absorb impacts/disturbance and to re-organize into fully functioning system (but qualitatively difference) is associated with the notion of "positive" quality, while community vulnerability - usually used to describe exposure and sensitivity of a human system not able to cope with risks, hazards and slow or catastrophic change- is generally associated with "negative" quality (Brand and Jax 2007, Cutter, Barnes et al. 2008, Alliance 2010, Wilson 2010). From a social resilience perspective, resilience/vulnerability can be expressed as a simple spectrum in which extreme ends of a spectrum are usually most easy conceptualized while the normative assumptions become more blurred as we move along the spectrum (Figure 3) (Wilson 2010).


**Figure 3 The relationship between Resilience and Vulnerability represented in a spectrum**

Source: (Wilson 2010)

### 2.3.3. Framework of Community Resilience to Flood Disaster

The concept of community resilience is increasingly being embraced as a framework for enhancing disaster readiness and response capability (Kathleen Sherrieb 2012). Assessing community resilience is a complicated process due to the dynamic interaction of populations, communities, societies as well as the environment. There are number of models and frameworks developed in order to assess community resilience (Table 4).

**Table 4 Community Resilience Frameworks**

| Author/Year | Type of Framework | Dimensions of Framework of Community Resilience |
|---|---|---|
| (Wilson 2012) | Community Resilience and Environmental Transitions | Economic capital, Social Capital, and Environment Capital. |
| (Cutter, Barnes et al. 2008) | A Place-based community Resilience Model | Ecological, Social, Economic, Instructional, Infrastructure, Community Competence. |
| (Cutter, Burton et al. 2010) | Disaster resilience Indicators for benchmarking Baseline Conditions | Social, Economic, Intuitional, Infrastructure, and Community capital. |
| (Indian Ocean Tsunami Warning Program 2007) | Coastal community resilience | Governance, Society and economy, Coastal resources management, Land use and structure design, Risk knowledge, Warning and evacuation, Emergency response, Disaster recovery. |
| (Magis 2010) | Community resilience | Community resources, Development of Community resources, Engagement of Community Resources, Active agent, Collective action, Strategic action, Equity, Impact. |
| (Norris, Stevens et al. 2008) | Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness | Economic Development, Social Capital, Information and Communication, and Community Competence. |
| (Mayunga 2007) | A capital based approach on Community Disaster Resilience | Social Capital, Economic Capital, Human Capital, Physical Capital, Natural Capital. |

Such dimensions include economic capital, social capital, environmental capital, community capital, natural capital, physical capital, human capital. Although these frameworks are conceptualized the dimensions of community resilience in a relatively different expression, they seem to focus on the community capitals that could reduce vulnerability and enhance the community resilience. There was a relatively high agree on conceptualizing community resilience linked with social, economic and environmental capital (Bourdieu 1987, Adger 2000, Stimson, Western et al. 2003, Cutter, Barnes et al. 2008, Magis 2010) and clearly explained in community resilience framework of Wilson (2012).

The primary focus of this research is community resilience as it applies to climate-related disaster, particularly here is flood disaster. The resilience of a system to floods is referred to the potential of this system to recover from perturbations caused by flood hazard events for reducing the long-term negative consequences of them (Eleitério 2012). This paper utilized the inherent community resilience framework given by Wilson (2012) as its conceptual basic. This model presented the interaction between 3 pillars of resilience including economic capital, social capital and environmental capital. Figure 4 depicts the conceptual framework on how 3 capitals of resilience can contribute to the community resilience.

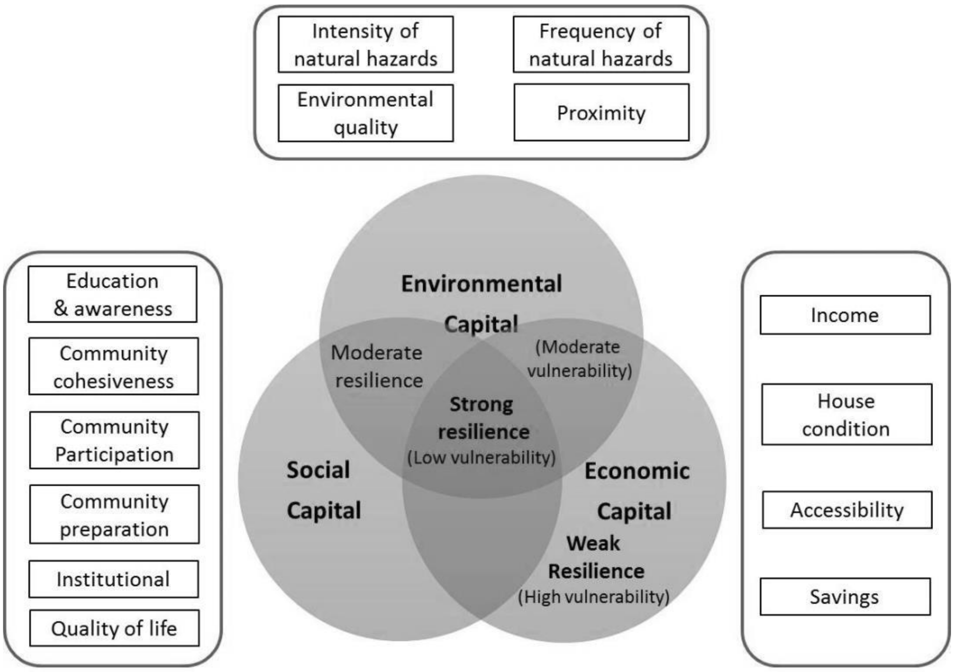


**Figure 4 Conceptual framework on the interaction between environmental, social and economic capital of Community Resilience**

Source: Modified from Wilson 2010

- *Economic capital:*

Economic capital is the key foundation of financial and economic well-being of a community (Adger 2000). It is defined as monetary income and financial assets (Bourdieu 1987) or the financial resources available to be invested in the community for business development, civic and social enterprise, and wealth accumulation (Magis 2010). Economic capital contributes for increasing the ability and capacity of individuals, groups and community to absorb disaster impacts as well as accelerate the recovery process. It is also considered as an important determinant of community resilience (Mayunga 2007). Factors such as availability of funding, high levels of community or household income, well-developed community infrastructure or well-established trade flows, are usually associated with strong economic capital (Bardhan 2006). The proposed indicators for measuring economic capital include income, employment status, economic sector, dependence on external funds, housing status, accessibility, poverty status, and financial and savings.

- *Social capital:*

Social capital is one of the key sociological foundations for community survival and generally describes how well social, political and culture network are developed in a community (Coleman 1988, Stimson, Western et al. 2003). The concept of social capital here is relatively wide including human capital (often used in the context of skills and knowledge available in community), political capital (the inclusiveness of the political process and the extent of institutional processes) as well as culture capital (ideological standpoints of a community) (Bourdieu 1987, Wilson 2012). It is defined as capital mobilized through social network and relations, the ability and willingness of community members to participate in actions directed to community object and process of engagement (Bourdieu 1987, Magis 2010). Social capital consists of norm, values, social network and trust that foster cooperation among people and its well-developed is seen as the key ingredient for resilient communities, especially the context of bonding (group cohesion), bridging (ties between groups), linking (vertical relationships) and capitals (Pretty and Ward 2001, Bhandari and Yasunobu 2009, Magis 2010). The factors are generally seen as key ingredients for strong social capital such as strong social ties, well-established trust and participatory, inclusive and democratic process (Beierle and Cayford 2002). Social capital here can be measured through population, education and knowledge, community cohesiveness, participating in community activities, community preparation during disaster, institutional, quality of life.

- *Environmental capital:*

Environment capital is the most recent type for any community relies on "healthy" environment for survival (Magis 2010). Environment capital is seen encompass both natural capital and bio-capacity that seeks to assess demand and supply of natural resources available to a community (Ekins, Simon et al. 2003, Ostrom 2009, Wilson 2010). Natural capital is also considered the capacity of natural processes and components to provide resources and services that directly or indirectly satisfy human needs (Groot 1992). Natural capital which made up of resources (such as water, mineral land, soil) and ecosystem services from the natural world (that maintain clean water, air and a stable climate) is influenced by individual and collective human action, but also presents opportunities and constraints on human, social, culture and financial capital (Costanza, d'Arge et al. 1997, Force and Machlis 1997, Goodwin 2003). Indicators for strong environmental capital linked to human survival needs such as healthy soils, water or resource available or well managed land and environmental resources (Folke, Carpenter et al. 2002, Folke 2006). The indicators for measured environmental capital are collected through intensity of natural hazards, frequency of natural hazards, and sustainability of resources.

The conversion of environmental and economic capital into social capital highly depends on power relations within community including power as a resource mobilized to achieve desired objectives and power as an inscribed capacity to control or direct the actions of other. Environmental, economic, and social capital are seen as the glue to hold the society/community together. Therefore, community resilience and vulnerability can be better conceptualized on the basic how well the critical triangle of economic, social and environmental capital are developed in a given community and how these capitals interact (Wilson 2010).

Figure 4 shows the conceptual model of how interaction of economic, social, and environmental capital creates different spaces of resilience with the strongest form of community resilience can be found at the intersection between strong economic, social and environmental capital. Community where only two capitals are well developed can be characterized as only moderately resilience, or indeed as moderately vulnerability, while community that have only one (or no) well-developed capital are generally characterized by weak resilience/high vulnerability. Community resilience can be seen as the balance between economic, environment and social needs of communities through the robustness, the rapidity, the redundancy and resourcefulness to find ways to address the internal and external challenges threatening (Wilson 2010).

## 2.4. Flood Risk Management

Flood risk management is understood as all actions that intend to reduce adverse consequences of flooding and improve the capability to cope with flood hazards. Management here is defined as decisions and actions undertaken to analyze, assess and try to reduce flood risks (Schanze, Zeman et al. 2004). Schanze, J. 2005 defined flood risk management as 'holistic and continuous societal analysis, assessment and reduction of flood risk'. In which 'holistic' refers to the flood risk system which should be considered as comprehensive as possible and 'continuous' expresses the need for an ongoing assessment of flood risks, their dynamic change and effects of reduction activities. Analysis, assessment and interventions for risk reduction as common elements of a development model are dedicated to the 'managing entity'.

Flood risk management takes place as a decision-making and development process of authorities that varies depending on the political, administrative, planning and cultural systems. Flood risk management comprehends three phases of a management process: the pre-flood, the flood event management and the post-flood (Schanze, Zeman et al. 2004). For structuring the management activities of flood risks, three tasks were defined including risk analysis, risk assessment and risk reduction (Figure 5).

Risk analysis provides information on previous, current and future flood risk basing on the determination of the flood hazard, the flood vulnerability and the flood risk itself. Risk assessment comprehends the perception of risk and the weighting of the tolerability of risks.

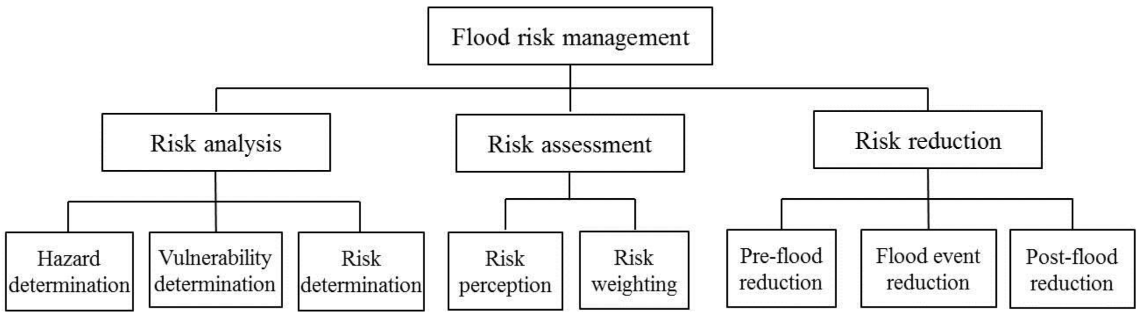


**Figure 5 Tasks of flood risk management**

Source: Schanze, Zeman et al. 2004

Risk reduction is dedicated to interventions with a potential to decrease the risks in three phases of pre-flood, flood event management and post-flood. Pre-flood interventions cover prevention, protection and preparedness. Flood event management consists of forecasting and warning of an ongoing event, flood control, flood defense and emergency response. Post-flood interventions encompass recovery as relied and reconstruction (Schanze, Zeman et al. 2004).

Flood risk management implies two types of measures due to their aim: structure measures and non-structure measures. The structure measures aim to modify the flood pattern such as the reservoirs, levees, embankments, etc., whereas the non-structure measures aim to reduce/lower flood damages by planning and regulating the way of floodplain use, flood proofing, enhancing preparedness, educating and warning the inhabitants or by redistributing flood damages in time and space by insurance, flood relief and other financial instruments (Bruijin 2005).

The reaction of flood risk management systems to the disturbance of the event depends on its resilience and resistance. As mentioned above, community resilience is defined as the ability of a groups or communities to respond and recover from disaster (Adger 2000, UNISDR 2004, Cutter, Barnes et al. 2008). Therefore, in context of flood risk management, resilience can be defined as the ability of the systems response and recovery to the disturbance of flood hazards. Flood risk management strategies then will be carried out/implemented that aim to enable a region normally at present and in the future despite disturbance by flood hazards (Bruijin 2005).

## 2.5. Remote Sensing and GIS in Flood Risk Management

### 2.5.1. Role of Remote Sensing and GIS Technology in Natural Disaster Management

A disaster is defined as a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental loss which exceeds the ability of the affected community or society to cope using its own resources. A disaster is a function of the risk process resulting from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk (UNISDR 2004). Natural disaster can be classified according to the geological origin (earthquake, tsunami, volcanic activities…), hydro meteorological origin (floods, storm surges, drought…), or biological origin (outbreaks of epidemic diseases, plant or animal contagion…) of hazards.

Remote sensing and GIS are among many tools available to disaster management professionals today making the effectives project planning very much possible and more accurate now and then ever before (Nirupama 2002). GIS provides a range of techniques which allow ready access to data, and the opportunity to overlay graphical location based information for ease of interpretation. Remote sensing is the science of acquiring information about the Earth using remote instruments, such as satellites which are inherently useful for disaster management. Satellites offer accurate, frequent and almost instantaneous data over large areas anywhere in the world. When a disaster strikes, remote sensing is often the only way to view what is happening on the ground.

The remote sensing satellites with variety of spectral bands in VIS (visible), NIR (near infrared), IR (infrared), SWIR (short wave infrared), TIR (thermal infrared) and SAR (Synthetic Aperture Radar). Microwave/Radar provides adequate spectral coverage for the purpose of observing natural hazards. Many are useful for disaster monitoring such as thermal sensors spot active fires, infrared sensors can pick up floods, and microwave/radar sensors (that penetrate clouds and smoke as well as available day and night, any weather conditions) can be used to measure earth deformation and ground movement before and during earthquakes or volcanic as well as flood mapping and forecasting (Lewis 2013).

Remote sensing and GIS are used almost every phase of disaster management such as creating the scenarios, determining the risks, monitoring the natural events, early warning simulate the complicated natural phenomenon, vulnerability analysis generating the sustainable plans, damage assessment implementing the applications etc. (Nirupama 2002, Sakamoto, Nguyen et al. 2007, Vijayaraghavan, Thirumalaivasan et al. 2012, Lewis 2013). Urban and regional planning activities also play important roles in mitigating phases of natural disasters. Remote sensing represents the effective tool for monitoring land use change as well urban expansion (Yuan F. 2005, Thy, Venkatesh et al. 2010, Taubenböck, Esch et al. 2012).

### 2.5.2. Remote Sensing and GIS Technology in Flood Risk Assessment

Remote sensing and GIS are increasingly considered as very useful and effective tools in disaster management (Vogt, Riitters et al. 2007, Vijayaraghavan, Thirumalaivasan et al. 2012), especially in flood hazard mapping, flood risk monitoring, and flood risk assessment (Mason D.C 2007, Suriya and Mudgal 2012). These provide a broad range of tools for determining flood areas and assessing the extent of a flood hazard. Taubenblock (2011) used the multi-sensorial approach including space bone optical sensors like MODIS, LANDSAT or IKONOS as well as active sensors like TERRAS SAR-X and the Shuttle Radar Topography Mission (SRTM) for risk assessment in urbanized areas. His results demonstrated the capability of remote sensing to provide multi-scale and multi-temporal products for specific question on flood risk issues.

Synthetic Aperture Radar (SAR) remote sensing with its weather capability (despite any presence of haze, light rain, snow, clouds or smoke) and day or night capability as well as its sensitivity towards smooth open water surface has been employed effectively in previous studies for delineation of flood inundation mapping and monitoring in a humid temperate climatic environments (Townsend and J.Walsh 2001, Nirupama 2002, Schumann, Matgen et al. 2007, Samarasinghea, Nandalalb et al. 2010). By detecting flooded area in SAR image, it is generally performed by acquiring two imageries taken during a flood and during a dry time. The flood extent map can be overlaid with data such as land use data or vulnerability map from GIS database for obtaining flood risk map (Samarasinghea, Nandalalb et al. 2010, Vijayaraghavan, Thirumalaivasan et al. 2012).

Sanyal and Xu (2005) integrated LANDSAT Enhanced Thematic Mapping (LANDSAT ETM+) and EDS SAR imageries to classify non-flooded areas and flood depth within flooded zones and to delineate human settlement at village level (Sanyal and Lu 2005). By adding high resolution hydrologic information and demographic data, it enhances the capacity of the spatial database to estimate vulnerability of individual settlement to an extreme flood event. Another approach based on geomorphology was done by Loan and Umitsu (2011) for assessment flood hazard in alluvial plain area (Loan and Umitsu 2011). They developed an integrated method for classifying micro-landform and flood hazard zones utilizing SRTM and LANDSAT ETM+ data combined with field investigation. This method demonstrated the usefulness of using satellite data (STRM and LANDSAT) for mapping flood hazard where hydrological and meteorological data or other information needed to develop a flood model, are limited and remote sensing images taken during flood events are not available.

Remote sensing also was useful for assessing damage to building and infrastructure or impact of flooding on environmental concerns such as coastlines, forests… after flood hazards by using an image taken after the flood events (Nirupama 2002). Another use of remote sensed data in flood management is in forecasting of floods based on the presence of rain-bearing clouds. Flood prediction based on monitoring the clouds associated with heavy rain can be achieved by using satellite imagery (Nirupama 2002). From those achievements of GIS and remote sensing application on flood risk assessment, it interferes that GIS and remote sensing has been an effective tool contributing to natural disasters management.

# CHAPTER 3
# STUDY AREA CHARACTERISTICS - DA NANG CITY, CENTRAL OF VIETNAM

## 3.1. Natural Conditions

### 3.1.1. Geographic Location

Locating in the middle of Vietnam, Da Nang has the essential position in socio - economic and national defense - security and is considered one of the important gateways to the sea of the Central Highland of Vietnam and the Mekong region countries. Da Nang city is limited in 15°55'15" - 16°13'15" North latitude and 107°49'05 - 108°20'18" East longitude, bordered with Thua Thien Hue Province to the North and Northwest, Quang Nam province to the South and Western South, and the East sea to the East (Figure 6). Lying on the East - West Economic Corridor connecting Myanmar, Thailand, Laos and Vietnam with the East Sea, Da Nang is a dynamic city of the key economic zone in the center of Vietnam with its international airport, deep-water seaport and National Highway 1.

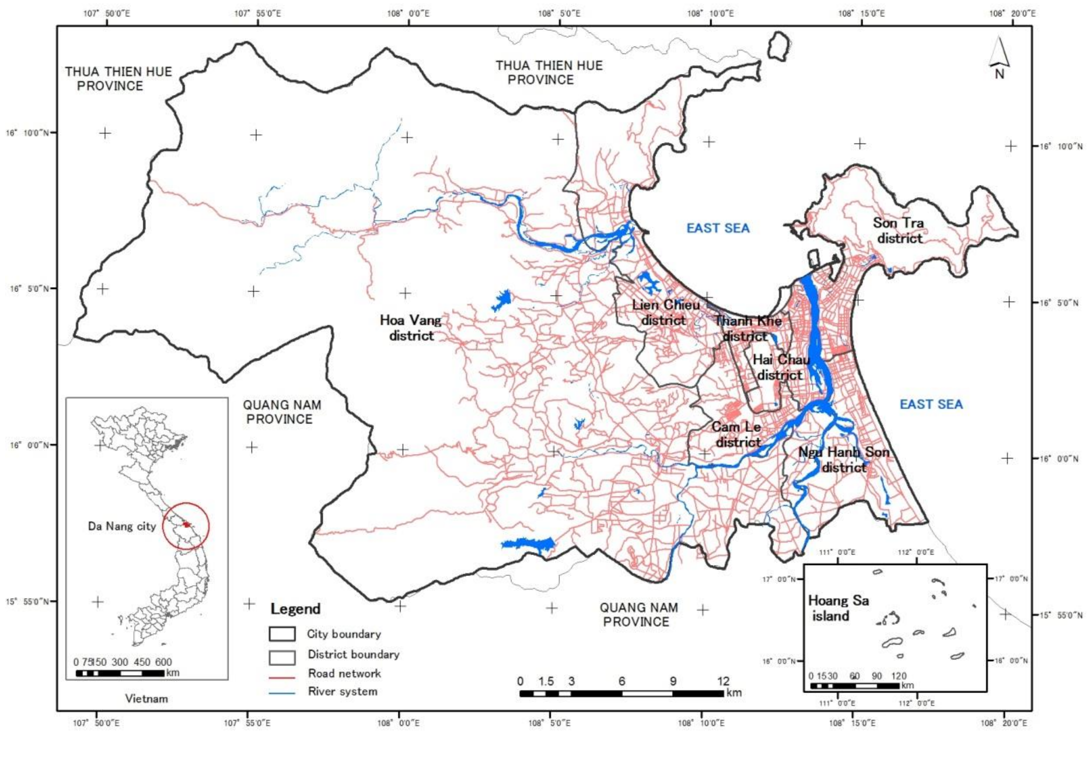


**Figure 6 Geographic location of Da Nang city**

With a coastline of 92 km, Da Nang has advantages in developing sea travel and seaport services. The geographic location will help promote economic development, tourist services, social and cultural exchange among countries in Southeast Asia in general and in Da Nang in particular.

According to 2009 statistic (DNSO 2010a), Da Nang city has an area of 1283.42km$^2$ including 8 districts in which there are 6 urban districts (Hai Chau, Thanh Khe, Son Tra, Ngu Hanh Son, Lien Chieu, Cam Le), 1 suburb district (Hoa Vang) and 1 island district (Hoang Sa).

### 3.1.2. Topographical Characteristics

Da Nang's topography is very diverse, combining mountains and coastal plains with high sloping mountains dominating the north and northwest (Figure 7). Mountains with a height of 700-1.500m and slope more than 40$^0$ account for the largest area and are the watersheds forests that protect the city ecology. The elevation of terrain gradually descends from West to East, with a narrow distance between hills and the plain. In the North is Hai Van Mountain which is average 700m in height, connecting Bach Ma Mountain with Chua Mountain (1,487m in height), Mang Mountain (1,712m in height) and Dong Den (868m in height). In the East is Son Tra peninsula. Those mountains form an arc obstructing the entire North, West and Southwest of the city. There are some mountain ranges running into the sea and some hill alternate with narrow coastal plains. The narrow plain area occupies just ¼ of Da Nang area and mainly lies on the East and Southeast of the city. The coastal plains and hill area are separated by many short and steep streams from the West and Northwest of Quang Nam province.

The coastal plains are low lying with some salting to the South and East and several white sand beaches along the coast. There are major agriculture, industrial, service, military area as well as the residential land and functional offices here. With the specific of the geographic and topography above, it has affected the climate and hydrology regime of Da Nang, creating a different climate regime, hydrology of other localities in the central region such as the radiation, precipitation patterns and flow regimes (DNDONRE 2004).

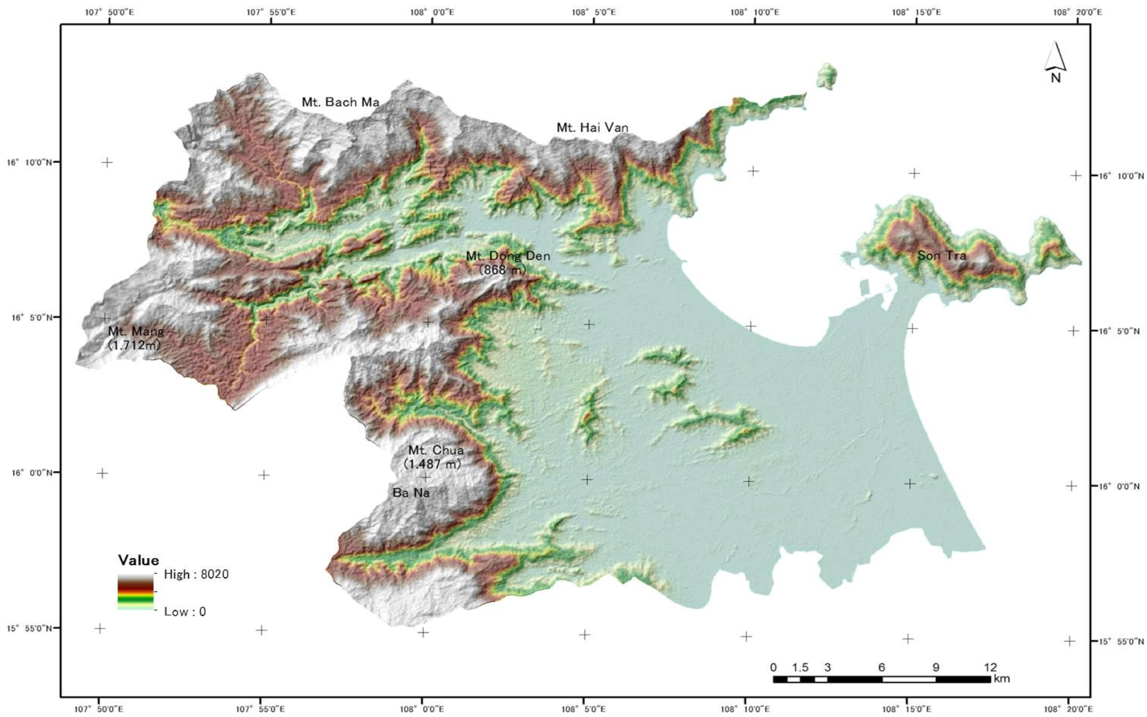


**Figure 7 Topographical characteristic of Da Nang city**

### 3.1.3. Meteorological Characteristics

Da Nang is located in a typical tropical monsoon zone with high temperatures and equable tropical climate. The city's weather is a combination of climatic features of northern and southern Vietnam, with the northern having the more distinct influence. Cold spells are occasional in winter but they are not severe and very short. The average humidity is 83.4%, in which the highest is 85-87.67% in October and November; the lowest is 76.67 - 77.33 % in June and July.

**Temperature characteristic**

Da Nang has a high temperature background and rather stable through the year. The average temperature yearly is 25-26$^{o}$C. In year there has a peak in June or July with the average temperature is around 28-29$^{o}$C. The lowest temperature is on December or January with the average temperature is 21-22$^{o}$C. The 1.500m high Mountain Ba Na has an average temperature of 20$^{o}$C.

**Precipitation**

The precipitation in Da Nang is varying during the year. On average in the period of 1995-2010, the city receives 2,504.881mm of rainfall a year, mainly concentrated in October and November. Depending on the topography, the total precipitation gradually increases toward to the Northwest - Southeast and the altitude. In year, there are two distinct seasons' namely rainy season and dry season. There is a great fluctuation in rainfalls between dry season and rainy season (Figure 8).

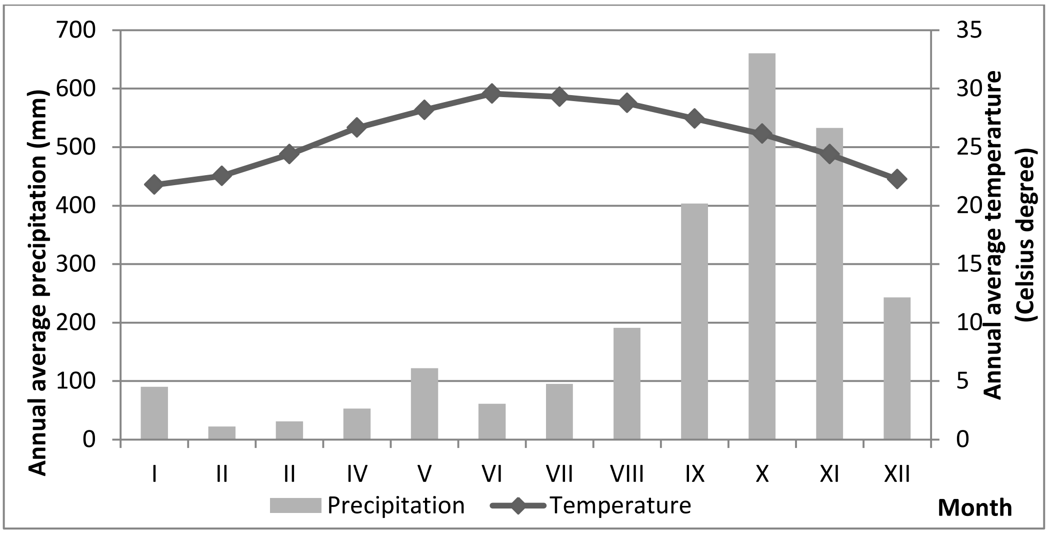


**Figure 8 Average temperature and precipitation in many years from 1995 to2010**

Source: DNSO 2011

The rainy season is 4 months long lasting from August to December. The rainfall concentrates mainly in October and November which occupies 40 - 60% total rainfall per years. In this season, there are some high intensity rainy spells lasting 2 - 3 days. The flood and storm often occurs in this time bringing about severe inundation in many areas.

The dry season lasts in 8 months from January to July. From January to April, the total rainfall is very few and occupies just 8% of the year. At the end of May and beginning of June, some heavy rain occurs and can create the summer flood. The drought often occurs in this time making lack of water and saline intrusions.

**Wind**

Annually Da Nang is influenced of Northeast monsoon. During the time of Northeast monsoon operation, together with the tropical turbulence, it often brings out heavy rain and lasts in many days causing serious flooding in many areas (DNDONRE 2004).

### 3.1.4. Hydrographical Characteristics

The rivers of city originate from the West and Northwest of Quang Nam province and Da Nang city. Most of the local rivers spring from the mountainous area and they are very short and sloping with a narrow riverbed, steep banks and many cascades. Most the rivers basin here are relatively wide with fan-shapes and tree-shaped tributary which concentrate large and high speed flows, often causing rapid and serious flooding.

There has two main rivers namely Cu De River and Han River. In addition, there are also others such as Tuy Loan, Yen, Qua Giang, Vinh Dien, and Phu Loc (Figure 9). In particular, Tuy Loan River and the Cu De River basin catch water independent and locate inside of Da Nang city whereas the others are the downstream of Thu Bon and Vu Gia River system in Quang Nam Province. All the rivers flow to the Gulf of Da Nang.

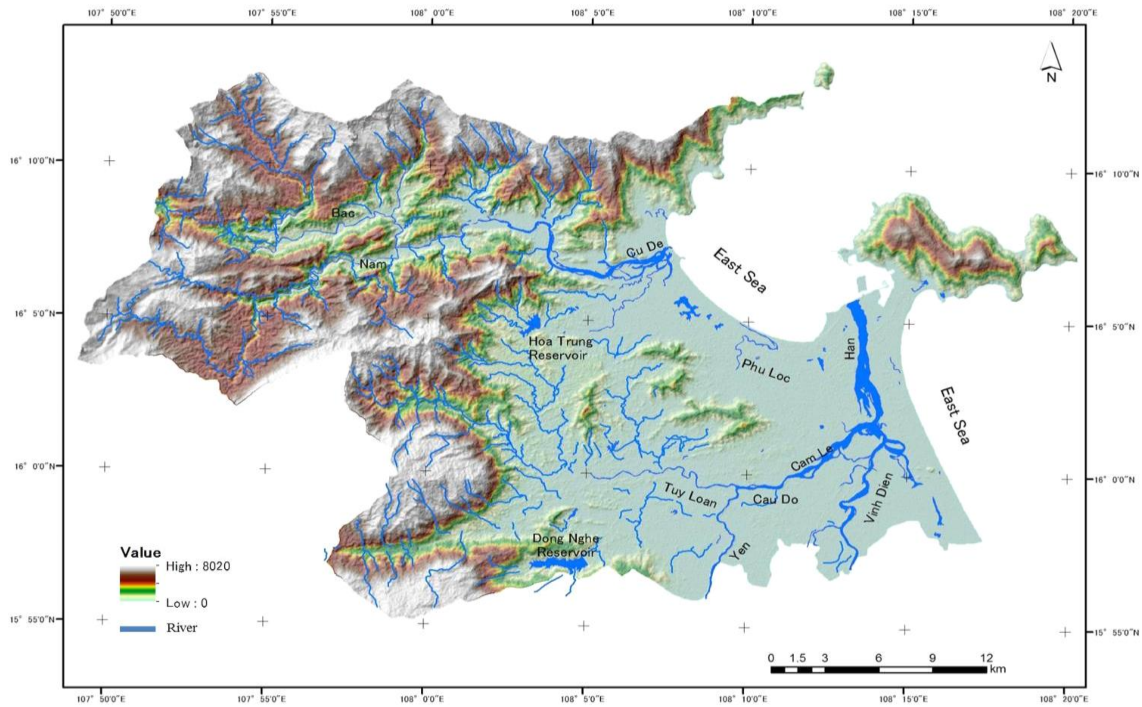


**Figure 9 Hydrology systems of Da Nang city**

Han River: Han River is the lower section of Vu Gia - Thu Bon river (the big river system of center region) originating from the Ngoc Linh mountains. The total length of Han River is 204 km. It receives the flow water from Yen River, Tuy Loan River and Vinh Dien River before running into Da Nang estuary. The regime of Han River strongly is influenced by tidal system. Flood from this river often threats directly to the plain areas in the South of city.

Cu De River: Cu De originates from the Northwest mountainous area with the total length is 47km toward to the Northeast-Southwest direction. Because the river is short, sloping with the feather shape, the rate of water concentration is high easily causing flash flood. In the upstream there are many small streams flowing sinuously and continually change direction toward to the high canyon. The whole river basin is 472km$^2$ in area tilting from the North East to the South West. Cu De River upstream has two tributaries namely Bac River and Nam River. The lower section of Cu De River basin often intrusions by salt water, especially in the dry season almost a half the length of river is affected.

Tuy Loan River Basin lies on the left of Vu Gia River and adjacent to the Cu De river basin. Tuy Loan River is 28km in length originating from eastern mountainside of Ba Na Mountain (1,478m). The total of basin is 160 square km in area. Yen River is the downstream part of Vu Gia River with the length of 12.7km. At Ai Nghia, Vu Gia is named as Quang Hue River and flows to Thu Bon River.

Vu Gia River is separated into two tributaries of Yen and Chu Bai. Yen tributary runs to An Trach barrage, integrates with Thuy Loan forming Cau Do Bridge - Cam Le River then flows to Han River in Da Nang. Vinh Dien River is a branch of Thu Bon River supplementing water from La Tho and Qua Giang River before flowing into Han River.

Phu Loc River is a small river within Thanh Khe district. It mostly is no source and mainly its flow depends on the tidal regime of Da Nang marine.

In the rainy flood season, water from the upstream flows into the East Sea through the mouths of only two small rivers, the Dai (at Hoi An city) and the Han (at Da Nang city), causing inundation (DNDONRE 2004).

## 3.2. Socio - economic Characteristics

### 3.2.1. Da Nang's Evolution of Urban System

Since 1986 "Doi moi" reforms, Vietnam's urban population in general and Da Nang's urban population in particularly has begun to grow. By 01/08/1975, Da

Nang city included 26 wards, 16 communes and 239 villages[1] with a population of 414 thousand people. Before 1997, Da Nang city included Da Nang township, Hoang Vang rural district (belong to Quang Nam - Da Nang province) and Hoang Sa island district with an area of 974.6 $km^2$ (QNDNSO 1990, DNSO 2005) (Table 5).

**Table 5 Administrative units of Da Nang city in 1979**

| Administrative unit | Number of ward/commune | Area ($km^2$) | Population (person) |
|---|---|---|---|
| The whole Da Nang city | 42 | 974.6 | 474637 |
| Da Nang township | 26 | 95.2 | 318653 |
| • Quan 1 | 12 | - | - |
| • Quan 2 | 5 | - | - |
| • Quan 3 | 9 | - | - |
| Hoa Vang rural district | 16 | 879.4 | 155984 |

Source: (QNDNSO 1990, DNSO 2005)

From the 1st January of 1997, Da Nang was split from Quang Nam - Da Nang province becoming a city directly responsible to the Central Government by the Resolution at the 10th section of National Assembly IX of the Socialist Republic of Vietnam. The new city of Da Nang consists of 6 urban district, 1 suburban district and 1 island district (DNSO 2005) (Table 6).

With the development following the direction of "Industry - Service - Agriculture", the promotion of advantages in commercial port city as well as the support of Central Government, many of important infrastructures, industrial zones is constructed, upgraded and modernized. Some industrial zones began to shape in the Northwestern of the city (Hoa Khanh, Lien Chieu urban district) (DNSO 2005). Da Nang is strategically chosen as a key economic growth pole and supposed to function as such for the Central region.

[1] The administrative classification system of Vietnam includes three levels: provincial, district, and communal/ward levels (the commune is the lowest basic administrative level). Mountainous communes are characterized by populations from 1,000-14,000 people with an area in range of 1,000-8,000 hectares. Plain communes are characterized by populations from 2,000-16,000 people with an area of 500-6,500 hectares (Vietnam Government Decree No.159/2005/NĐ-CP Classification administrative unit of Commune, Ward and Township). The village is an important form of society in rural Vietnam. A commune is a gathering of some villages. A village is not considered an administrative level in the administrative system of Vietnam. It is an autonomic/self-governing organization of a certain community in the common local residents. The government operation of a village is managed directly at the commune level. Villages in the plain areas have population sizes of over 200 households, villages in mountainous, frontier, and island areas have population sizes of over 100 households.

**Table 6 Administrative units of New Da Nang city in 1997**

| Administrative unit | Number of ward/commune | Area (km²) | Population (person) |
|---|---|---|---|
| The whole Da Nang city | 47 | 1247.60 | 672468 |
| Hai Chau urban district (Quan 1) | 12 | 23.730 | 186671 |
| Thanh Khe urban district (Quan 2) | 8 | 8.920 | 145038 |
| Son Tra urban district (Quan 3) | 7 | 60.170 | 95972 |
| Ngu Hanh Son urban district | 3 | 36.520 | 42798 |
| Lien Chieu urban district | 3 | 75.740 | 61051 |
| Hoa Vang rural district | 14 | 737.520 | 140938 |
| Hoang Sa island district | - | 305.0 | |

Source: (DNSO 1998)

In 2003, Da Nang officially became a Class - I city remarking the significant developments of the city (under Decision of Prime Ministry 145/2003/QD-TTG on July 15th 2003). From this time, Da Nang began with a period of rapid expanse. Building much new urban area, industrial zones, widening and opening of road network as well as provisioning the bridges across rivers have changed significantly the transport infrastructure and the face of city. From 2005, the expansion urban is marked by forming a new urban district namely Cam Le according to the Decree of Government 102/2005/ND-CP. Also during this period, the Da Nang city has changed and established some administrative ward units in some districts (Table 7).

**Table 7 Administrative units of Da Nang city up to present**

| Administrative unit | Number of Ward/Commune | Area (km²) | Population 2005 (Person) |
|---|---|---|---|
| The whole of Da Nang city | 56 | 1283.42 | 781023 |
| Hai Chau urban district | 13 | 21.35 | 192884 |
| Thanh Khe urban district | 10 | 9.36 | 163679 |
| Son Tra urban district | 7 | 59.32 | 116999 |
| Ngu Hanh Son urban district | 4 | 38.59 | 51915 |
| Lien Chieu urban district | 5 | 79.13 | 82363 |
| Cam Le urban district | 6 | 33.76 | 65506 |
| Hoa Vang rural district | 11 | 736.91 | 107677 |
| Hoang Sa island district | - | 305.0 | - |

Source: (DNSO 2006)

Due to promote the advantages of the commercial in the past, with this development orientation, and with the support of the Central Government, many of the important infrastructure such as seaports, airports, railways, roads, electricity systems, water supply, training facilities, health care is constructed, upgraded and modernization. Da Nang is gradually creating an urban development towards the modern due to development of economic, ensuring national defense - security and enhances people's lives. As a result of this, the Gross Domestic Product (GDP) of Da Nang which was 3,208.82 billion in 1997 has increased rapidly to 39,021.72 billion in 2011. The gross output of industry section took the largest share in GDP and was followed by services, agriculture forestry and fishery (DNSO 2012). The Da Nang urbanization is mainly driven by the administrative and economic transitions.

### 3.2.2. Population Growth over the Periods

Da Nang is the fifth largest city in Vietnam (after Ho Chi Minh, Ha Noi, Hai Phong and Can Tho city) and recent years has been experienced a rapid rate in population growth (World Bank 2011) (Figure 10). Within 30 years, Da Nang's population increased more than double from 443,600 in 1979 to 894,510 in 2009. The annual population growth rate was 2.62 increasing as twice the national rate of 1.2%. On average, each year the population increases 20.2 thousand people (DNSO 2000, DNSO 2005, DNSO 2010a, DNSO 2010c). With a population growth rate as in recent years, Da Nang will reach 1.1 million in early of year 2018.

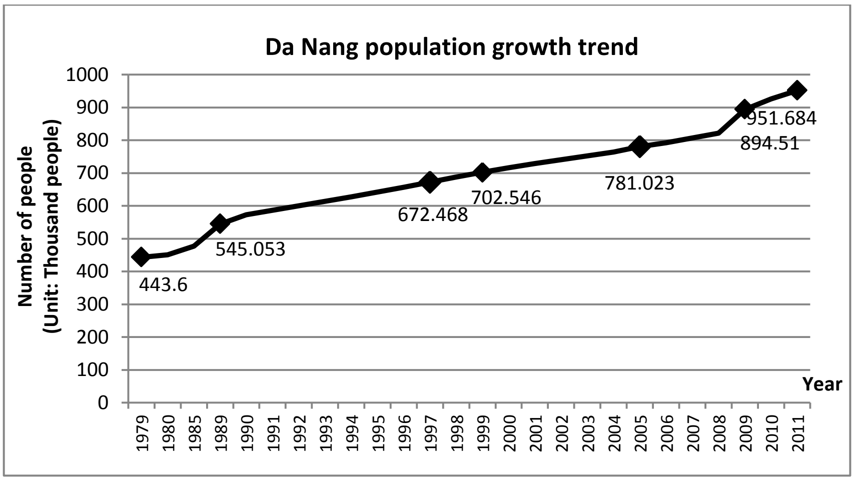


**Figure 10 Trend of population in Da Nang city from 1979 to 2011**

Sources: (QNDNSO 1990, DNSO 1998, DNSO 2000, DNSO 2006, DNSO 2007, DNSO 2010a, DNSO 2010b, DNSO 2010c, DNSO 2011, DNSO 2012)

The population density of Da Nang city was 345 people/$km^2$ in 1979; 546 in 1999; 695 in 2009; and increased to 740 people/$km^2$ in 2011. After being separated to become a Class - I city in 1997, Da Nang population increased by 100 thousand within 8 years. But since 2005, Da Nang has increased additional nearly by 150 thousand people within just only 5 years. In 1999 Da Nang ranked the $53^{th}$ in term of population in the whole nation and is considered the least population in the Southern Center Coastal provinces of Vietnam. By 2009, Da Nang reached the $43^{th}$ in population size and its population had more than those provinces in the same region (DNSO 2010b).

**Population growth trends by region in Da Nang city**

In the past 30 years, Da Nang in general and each residential area in particular had a different population change reflecting the stages of development and construction of the city. The rate of population growth increased in urban districts areas faster than in suburb district (Figure 11).

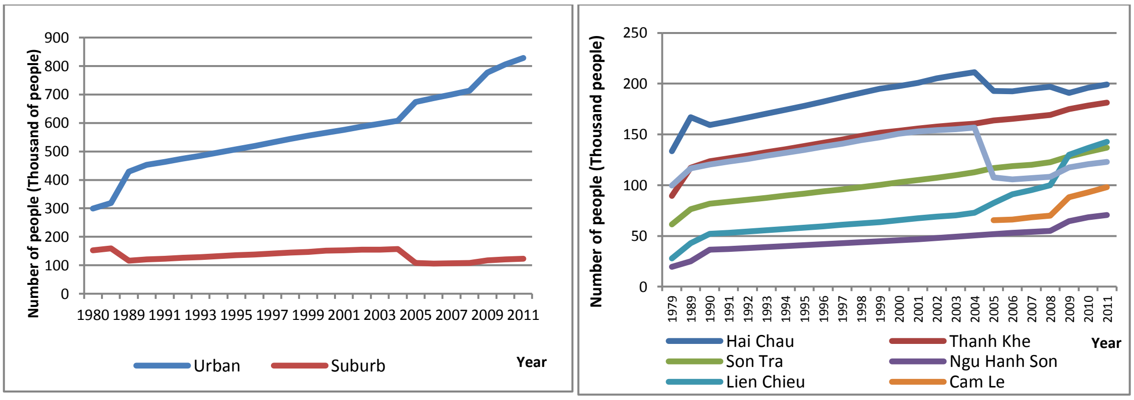


**Figure 11 Trend of population growth by region from 1980-2011**

**(a) Urban and rural area (b) District level**

In the period of 1979-1989, urban population noticeable bounced from 298,938 to 428,640, whereas suburb population showed the fall down trend. This can be explained because this was the stage of forming and setting the administrative units of new Da Nang city. Some of administrative unit from suburb were transferred to urban districts. During this period, the urban population grew rapidly and uniformly in the whole city. The areas along the center city had faster growth rates those in central urban and rural areas.

The urban districts had a gradually go up trend of population growth in the period of 1989 - 2004, but slower than the previous period. Son Tra, Thanh Khe and Hai Chau district showed a relatively high rate of population growth. Meanwhile the rural district revealed a slow increase during this period.

Since 2004, population increased significant in urban areas. This is because of one part of population was added from the transformation some administrative units of Hoa Vang rural districts. Therefore the suburban's population rapidly plunged from 156,652 in 2004 to 107,677 in 2005. In addition, the residents moved/transferred from the central areas (with slow and negative population growth rates) and the rural areas to the new resettlement areas, the industrial zones and universities areas in Lien Chieu, Ngu Hanh Son district. Cam Le was established in 2005 and it gathered and attracted amount of new residents from the rural district and the clearance zones to live here. Therefore from 2005 to 2011 its population showed a relatively high increased.

In the past 10 years, Lien Chieu had the highest average annual population growth rate (7.4% per year) and followed by Cam Le and Ngu Hanh Son ward. Those wards are not located in the center of city. Although Hai Chau locates in the center of city, it had the slowest growth rate at only 0.7% per year during this period. The rate of urbanization had increased due to the mechanic population growth. Since 1997, the migration of people to Da Nang urban areas had raised mainly migrants from rural areas and other provinces, freelance laborers, populations under resettlement programmers for working and studying in industry zones, universities.

## 3.3. Natural Hazards and Flood Disaster in Da Nang City

Da Nang is one of the cities in Vietnam most affected by natural disaster such as typhoon, flood, drought, erosion, saline intrusion, etc…., among which typhoon and flood are two most hazardous. The natural disasters have been increasing due to various factors such as urbanization, population growth, destruction of natural environment and climate change. Da Nang has steep terrain; narrow coastal plains, and many low-lying areas high vulnerable to natural hazards due to climate change impacts. Da Nang has a long coastal line (about 90km coastline), typhoons often directly hit the city, particularly the coastal districts of Son Tra, Lien Chieu, Cam Le, Hai Chau, Thanh Khe, Ngu Hanh Son and Hoa Vang and cause severe damages. Typhoon always lasts only 3 - 4 hours but before, during and after the typhoon coming, heavy rain caused flash flood, flood, landslide may occur. There is an annual average of 1-2 typhoons and 2-3 floods of level III or higher directly hitting the city. In Da Nang almost natural hazards occur in period of September to December, some particular may occur early in April to May. In recent years, natural disasters tend to increase in number and intense threatening to socio-economic development of city. Global climate change contributes to higher frequency and intensity of natural hazards. Before 1997, average 10 years there appeared one serious floods or typhoons. However from 15 years back many severe floods and typhoons have occurred. In period of 1997-2011, there were 44 floods and 26 typhoons directly affected Da Nang (DNCFSC 2011, Institute for Social and Environmental Transition 2011). The number of typhoons and floods is increasing in recent years (Figure 12).

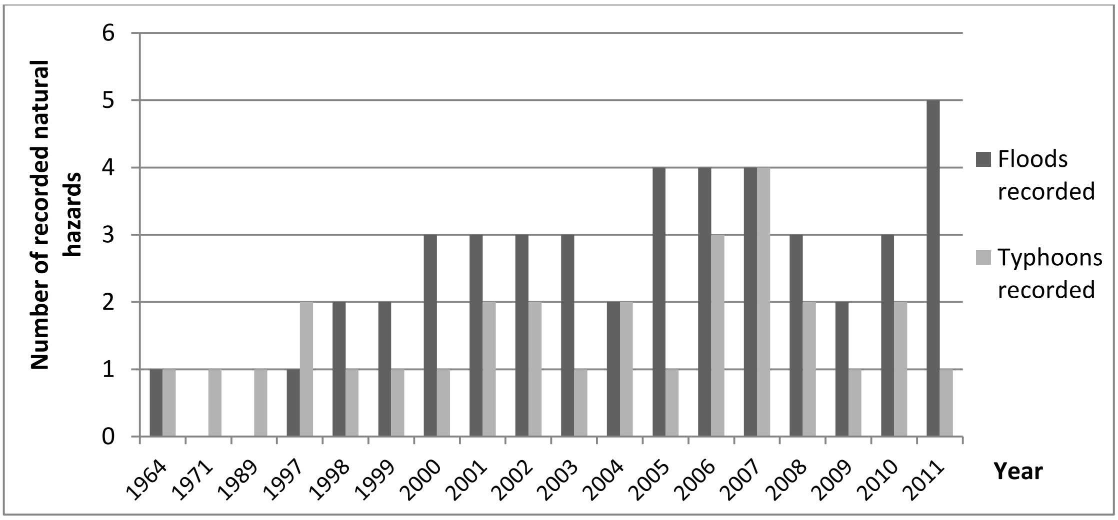


**Figure 12 Number of floods and typhoons affected Da Nang from 1964-2011**

Source: (DNCFSC 2011)

Natural disasters caused loss of human lives and health (particularly to women, children, and the elderly), damaged to infrastructure (destruction of houses, traffic system, and social welfare, loss of property and facility of local people…), caused environment population, disrupted livelihood (especially ago-forestry-fishery activities). Over two last decades, natural disasters, particularly floods and typhoons killed a significant number, a total of 400 people were killed and 391 people were injured. The estimated economic lost from natural disasters were approximately 9,450 billion Vietnam Dong (Table 8). Typically the Typhoon No.6 in 2006 (Xangsane) caused severe damage to city: 30 people were killed, 14,138 houses collapsed, 112,691 houses partly damaged or lost roots, and damaged infrastructure. Total economic lost up to 5,290 billion VN Dong. The particular flood in 1999 with great intensity rainfall caused historical flash flood in Cu De and Tuy Loan River, killed 37 people, injured 61 people, washed away and collapsed 4,579 houses, damaged agriculture infrastructure. The total damages were estimated as 611 billion VND. The serious flood in 2007 that killed 3 people, injured 3 people, swept away more than 40 houses in river banks, flooded 28,269 houses, and damaged thousands ton of rice and agriculture crops, transport infrastructure and irrigation systems. The total damage was up to 1,524 billion VND (DNCFSC 2011).

In 2009, the weather changed erratically and the severe typhoon Ketsana killed 8 people, damaged up to 495 billion VND to agriculture activities (DNPC 2009). From the evident figure (Figure 12), it can be seen that flood has caused serious damage to the life of residents in Da Nang city in recent years.

The precipitation in this area is unevenly distributed in the year, falling mainly in the rainy season (about 80% of the total annual rainfall) causes some serious floods. Due to complicated of topography (more than 70% hill and mountain area), short rivers, and narrow riverbed, the flow of flood water occurs very fast with high insensitive. River flooding usually occurs (Cu De, Tuy Loan River) due to heavy and concentrated precipitation and extended rains. In addition, due to the change of rainfall in the last 10 years, flood has occurred earlier, in a sudden and unpredictable manner with higher frequency and more extreme intensity. Before 1998, there was one flash flood every 10 years. Between 1998 and 2009 there were six flash floods occurring in 1998, 1999, 2004, 2005, 2007 and 2009. All floods were above level III[2] and one reached approximately the level of historical flood of 1964.

Besides natural factors, flooding in Da Nang city is also exacerbated by incomplete and improper urban development and planning (e.g. many flood

[2] Water warning level is issued by Vietnam state agency. It is used to alert when river water levels appear to exceed those warning level. According to the Decision No 632/QD-TTG of Prime Minister, River water warning level is divided into 3 main levels as level I, II, III correspond to possible flood condition, dangerous flood condition, and very dangerous flood condition, respectively.

retention basins and shallow lakes are filled) and improper exploitation of upstream forests in river basin. In addition, the lack and limited capacity of flood early warning systems, shortage of human resources and rescue facilities, preventive care equipment, solid houses and particularly the limited awareness of city residents - especially those who are the most vulnerable - strongly contribute to the level of flood damage (Institute for Social and Environmental Transition 2011).

**Table 8 Damage caused by severe typhoons and floods in Da Nang city from 1989-2011**

| Year | Natural disaster | Number of people | | Estimation economic damage (Billion VN Dong) |
|---|---|---|---|---|
| | | Death/Missing | Injured | |
| 1964 | Typhoon, historic flood | 32 | - | 182.3 |
| 1971 | Typhoon Hista | 50 | - | - |
| 1989 | Typhoon Cecil | 194 | 106 | 1000 |
| 1997 | Typhoon, Flood | 03 | 20 | 26.75 |
| 1998 | Typhoon, Flood | 32 | 27 | 182 |
| 1999 | Serious Flood | 37 | 61 | 611 |
| 2001 | Flood | 5 | - | 5.756 |
| 2002 | Typhoon | - | - | 6 |
| 2004 | Flood, Typhoon | 5 | 3 | 19.2 |
| 2005 | Typhoon, Flood | 1 | 11 | 41 |
| 2006 | Typhoon Chanchu<br>Typhoon Xangsane | 107 | 61 | 5,290 |
| 2007 | Flood | 3 | 3 | 1,524 |
| 2009 | Typhoon, Flood | 8 | 92 | 495 |
| 2011 | Flood 15/8 | 1 | - | 4.442 |
| | Flood 4-8/11 | 4 | 7 | 85 |
| | Total damage | 432 | 391 | 9,472.448 |

Source: (DNCFSC 2011)

# CHAPTER 4
# ANALYSIS OF URBAN EXPANSION AND FLOOD RISK CHANGE IN DA NANG CITY IN CENTRAL OF VIETNAM

## 4.1. Introduction

Flood is widely seen as the most hazardous, frequent, and widespread source of disaster risk throughout the world (Wisner, Blaikie et al. 2003, Taubenbock, Wurm et al. 2010). Located in the tropical monsoon, Vietnam is one of the most natural disaster such as typhoons and floods in the Asia Pacific Region in which floods are by far considered the most frequent and most devastating hazard causing significant economic, social and environmental damages, directly hindering the country from sustainable socio-economic development (CCSFS 2006, World Bank 2013). Particularly, the central area of Vietnam, which is a long, stretching, and narrow region that runs along the coastline, has a complex sloping terrain and suffers the most frequent influence of typhoons, tropical storms and floods (counting for 65%) (MARD 2012). Population growth, combined with rapid socio-economic development, unplanned urbanization, and pressures on natural resources, as well as climate change impacts, have accelerated the exposure and vulnerability of the Vietnamese population to flood hazards and consequent disaster risks (Bloschl G. 2010, Oanh, Thuy et al. 2011). Vietnam's 2007 "National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020" identified floods as one of the country's most important natural hazards and focused on how to take measures to reduce the risk as well as enhance the capacities for forecasting floods (Social Republic of Vietnam 2008). Therefore, flood delineation and risk assessment is crucial for identifying those areas having a high need for risk reduction management, due to effects of climate change and unpredictable natural hazards.

In recent years, urbanization has taken place rapidly in Da Nang city, a coastal city located in central Vietnam. The process of urbanization and economic development of the city has made better living conditions for people. However urbanization also has pushed Da Nang city more challenges to solve under the more impact of the potential hazards and climate change. The increase of human settlement, infrastructure development and industrial growth in flood zone areas has decreased the agriculture and aquaculture lands leading to the congestion of storm water drainage in rainy season. Urbanization has been creating more expansion of settlements in inappropriate areas that are most likely to expose to natural hazards such as coastal areas, low-lying river basin areas. According to the report on the State of Coping with Natural disaster of the People's Committee of Da Nang (2009), Da Nang city has suffered five great disasters (typhoons and floods) in the last decade, which killed nearly 200 people in the city and damaged houses, boats, infrastructure, transportation, irrigation canals, and agriculture products. The severity of the loss is estimated at approximately 5.902 billion VND (DNPC 2009).

Remote sensing and GIS technique have become essential tools for monitoring urban expansion as well as for mapping flood hazards and assessing flood risks. The objective of this paper is to exemplify the relationship between urbanization and flood risk using remote sensing and GIS techniques. Firstly we focused on determining land use/cover changes and then assessed potential hazard and flood risk. The findings of this study will serve as a good reference, providing the local authorities with basic information for flood risk mitigation.

## 4.2. Data Used for Analysis

In this study, time series satellite images, digital elevation model (DEM), demographic statistical data, and flood record data from field survey were collected for assessing the temporal and spatial characteristics of urban expansion from 1990 to 2010, the flood risk, and to determine a correlation between urbanization and flood risk. The detailed specifications about used data are shown in Table 9.

**Table 9 Data source characteristics**

| Data | Type of data | Date | Resolution (m) |
|---|---|---|---|
| Satellite image | LANDSAT TM | 1990/08/24 | 30 |
| | LANDSAT ETM+ | 2001/03/23 | 30 |
| | LANDSAT TM | 2007/03/16 | 30 |
| | ALOS AVINIR-2 | 2009/03/24<br>2010/05/16 | 10 |
| | ALOS PALSAR | 2007/12/16 | 6.5 |
| DEM | ASTER GDEM | - | 30 |
| GIS data | Boundary | 2010 | - |
| Flood depth | Flood pillar, flood mark | 2007 | - |
| Statistical data | Demographic data | 1990-2010 | - |

#### 4.2.1. Satellite Images

The urban expansion process and land use/land cover change were investigated by image classification of LANDSAT Thematic Mapper (LANDSAT TM), LANDSAT Enhanced Thematic Mapper (LANDSAT ETM+), and ALOS Avnir-2 images.

The LANDSAT Project is a joint initiative of the United States Geological Survey (USGS) and the Nation Aeronautics and Space Administration (NASA). LANDSAT TM is a multispectral scanning radiometer that was carried on board LANDSAT 4 and 5. The TM sensors have provided nearly continuous coverage from July 1982 to present. The LANDSAT ETM+ was introduced with LANDSAT 7. ETM data cover the visible, near-infrared, shortwave and thermal infrared spectral bands of the electromagnetic spectrum. The LANDSAT images were free obtained from website of Global Land Cover Facility (GLCF 2013). The data acquired on August 1990, March 2001 and March 2007 which has a spatial resolution of 30m with number of path and row is 124 and 49, respectively (Figure 13).

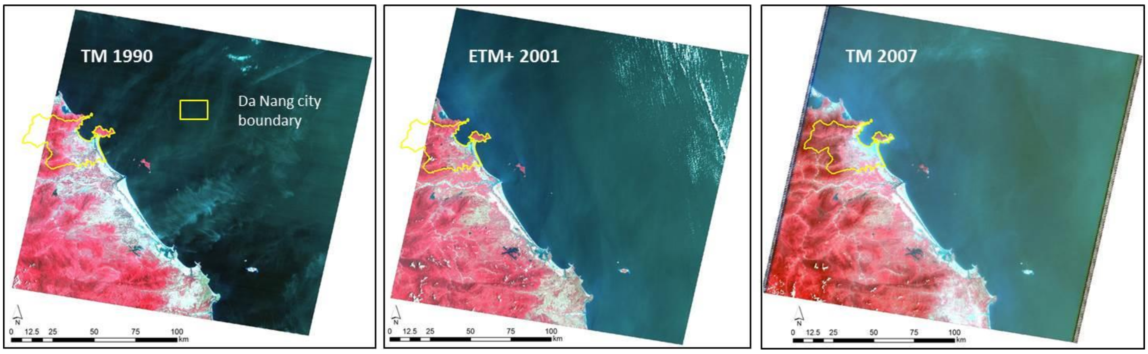


**Figure 13 Time series LANDSAT images of Da Nang city**

The Advanced Land Observing Satellite (ALOS) development and operation project is to contribute to cartography, regional observation, disaster monitoring, and resources surveying was realized as a joint project between the Japanese Ministry of Economy, Trade and Industry (METI) and the Japan Aerospace Exploration Agency (JAXA). The Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) is one of three remote sensing instruments of ALOS is used to observe what covers land surfaces (JAXA 2008). AVNIR-2 obtains high resolution image data in four bands of visible and near infrared. In this paper, multi season

ALOS AVNIR-2 images were ordered from JAXA including ALOS AVNIR-2 taken in March 2009 and May 2010 (Figure 14).

These LANDSAT and ALOS images created a temporal dataset that allowed analysis of the changes in urban expansion and land use/cover over a 20 year period.

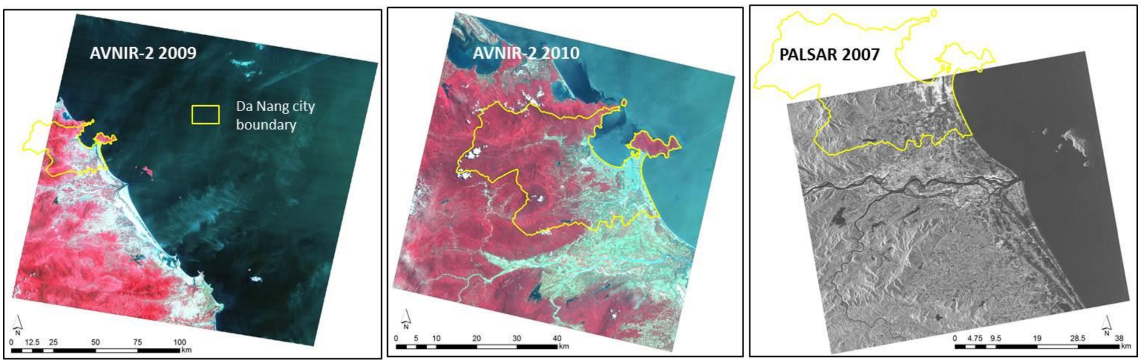


**Figure 14 Required ALOS images for analysis**

The ALOS Phased Array type L-band Synthetic Aperture Radar (PALSAR) image provides weather observation regardless of day or night and all-weather land observations, so its sensor has significant advantages for monitoring natural disasters, and especially for flood mapping (ERSDAC 2006). In this study, the ALOS PALSAR product level 1.5 images acquired on December 2007 were applied in order to extract the inundated areas from the historical flooding events of 2007.

### 4.2.2. GDEM ASTER image

The Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) is an achievement of an international joint project between the METI and the NASA. This is the only DEM that covers the entire land surface of the Earth at high resolution (30mx30m), generated from a stereo-pair of images acquired with nadir and backward angles over the same area (ASTER GDEM 2011a). A DEM of Da Nang obtained from the ASTER GDEM, was applied to analyze topographic characteristics for the flood hazards building progress. The GDEM version 2 was free obtained from ASTER GDEM website (ASTER GDEM 2011b) (Figure 15).

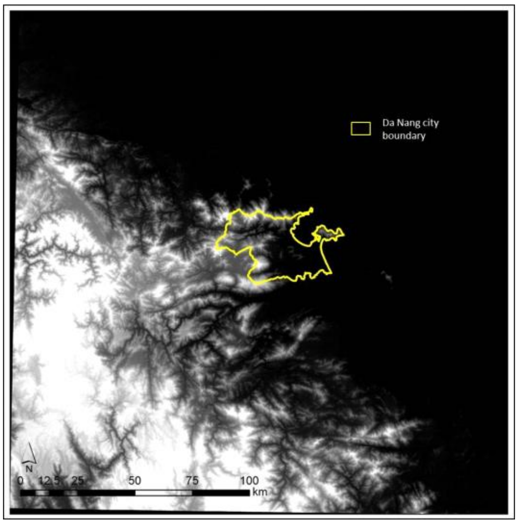


Figure 15 ASTER GDEM used for flow direction analysis

### 4.2.3. Statistical Data and GIS Data

Statistical data on demography was collected for analyzing the urbanization and demographic vulnerability. The indicators were gathered including population from 1990 to 2010, the percentage of children, elders, poverty households and women. The GIS data also was collected from administrative and topographic maps. The demographic data were integrated with GIS and remote sensing for assessing flood risk in study area.

### 4.2.4. Field Survey Data

In order to validate the analysis of the experienced inundation from ALOS PALSAR and ASTER GDEM, flood depth records were collected in field surveys. In Viet Nam, the flood depth value of some severe and historical floods is recorded on the pillar. The pillars almost locate in the paddy field, in the resident areas, or near the riverbank. We also can find the flood marks in the wall of residential houses. Flood depth value and theirs coordinate in 2007 flood event were measured and recorded by using meter tap measure and Global Position System (GPS) hand machine and GPS camera (Figure 16). A total of 47 flood depth points were used for this analysis. Besides, during the field survey we also captured some ground truth points for determining the training sample during land use classification as well as accuracy assessment.


**Figure 16 Flood depth value collected from flood pillar during field surveys**

(a) Measure flood depth value from flood pillar (b) Measure flood depth value from flood mark in wall of house (c) Flood pillar in riverbank (d) Flood pillar in paddy field
(e) Flood pillar in the resident areas

## 4.3. Methodology

### 4.3.1. Land Use/Cover Classification

#### 4.3.1.1. Land Use/Cover Scheme

A classification scheme effectively defines the legend that will be used for the final map. In this study, our classification scheme was based on referring land use/cover classification system given by Anderson et al., (1976) for interpretation of remote sensor data as well as the real major land use/cover types present in the study area (Anderson, Hardy et al. 1976). A total of 7 land use/cover classes were considered in this study as the table follows (Table 10).

**Table 10 Land use/cover classification scheme**

| Land use/ cover class | Description | Sample |
|---|---|---|
| Built - up area | Built-up area/land is comprised of areas of intensity use with much of the land covered by structures such as cities, towns, and villages, strip developments along highways, transportation, power, and communications facilities, industrial and commercial complexes, institutions, and tourist resorts. |  |
| Water body | Water body is defined as all areas within the land mass that persistently are water covered including streams and canals, lakes, reservoirs, and estuaries. |  |
| Paddy field | A paddy field is a flooded parcel of arable land used for growing semiaquatic rice |  |
| Upland field | Upland areas where annual crops plant represent the dominant cover type such as cereals, cotton, potatoes, vegetables, melons, etc. |  |
| Bare land | Bare land is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover including an area of thin soil, sand, or rocks; an area that vegetation is more widely spaced and scrubby than that in the Shrub and Brush category; or an area that land appear barren because of man's activities (preparation for new open areas/open land, or the transformation of land use to its former use) |  |

| Land use/ cover class | Description | Sample |
|---|---|---|
| Forest | Forest Lands have a tree-crown areal density (crown closure percentage) of 10 percent or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the climate or water regime. |  |
| Shrubs/Grass | Shrubs/Grass is land type forming on abandoned farmland or forest-exploitation or open land. They distribute mainly on the beaches and along rivers, streams and near the forest areas. |  |

Source: (Anderson, Hardy et al. 1976) and Field survey results of Authors

#### 4.3.1.2. Land Use/Cover Classification and Urban Expansion Analysis

Before conducting land use/cover classification, all satellite images were geo-metric correction with Universal Transverse Mercator (UTM) map projection for zone 49 and the datum of World Geodetic Systems 1984 (WGS84) and then masked by the study area boundary. All the data sources were re-sampled into a 30m resolution. ERDAS IMAGINE 2010 software was used for image processing. The study area boundary was digitized from the topographic map using ArcGIS 10.0 software.

The classification process involves translating the pixel values in a satellite image into meaningful categories. Land use/cover classification aims to label each pixel in a scene to specific land use/cover categories which comprise different types of land use/cover defined by the classification scheme that being implemented. The classification can be done by approaching traditional pixel - based image analysis and object-oriented image analysis. In this study we employed pixel - based image analysis for land use/cover classification.

Pixel-based image analysis automatically categorizes all pixels in an image into land use/cover classes based on conventional statistical techniques (Matinfar 2007). There are two methods of classification in pixel-based image analysis approach including unsupervised classification and supervised classification. In unsupervised classification, clustering algorithms were used to partition the feature space into a number of clusters (Janssen and Huurneman 2001). The

ISODATA algorithm is the most common unsupervised classification tool. In the preprocessing phase, ISODATA was used to create a total 20 clusters in order to discriminate the cloud/shadow from the other types of land use/cover. Then supervised classification got benefit from the result of unsupervised classification (Xu, Wang et al. 2000). This classification method uses the training sample data as a mean of estimating the average and variance of each land use/cover class, which is applied to estimate probabilities. Training samples are areas representing each known land use/cover that appear fairly homogenous on the image as determined by similarity in tone or color within shapes delineating the categories. Training data for supervised classification was collected from a variety of sources such as ground check points, aerial images, Google Earth map, digital topographic map, and knowledge of the data as well as visual interpretation of LANDSAT and ALOS satellite images. In addition cropping calendar was also taken into account during selection of the training sample. The Maximum Likelihood algorithm with decision tree rule was employed to detect the unique land use/cover type.

Maximum Likelihood method is based on Bayesian probability theory utilizing mean and variance of signatures to estimate the posterior probability that a pixel belongs to each class (ERDAS 1999). Decision trees have several advantages over traditional classification procedures used in remote sensing such as Maximum Likelihood classification. A decision tree is defined as a classification procedure that recursively partitions as a data set into smaller subdivisions on the basis of set of tests defined at each branch (or node) in the tree (Friedl and Brodleyf 1997). Finally, the supervised classification was carried out using the training areas recognized in the statistical procedures (Xu, Wang et al. 2000). The false color composite of band 4 (Near infrared), band 3 (Red), band 2 (Green) in ALOS Avnir-2 and band 5 (Mid-infrared), band 4 (Near infrared), band 3 (Red) in LANDSAT was used in training sample for land use/cover classification. Four time series land use/cover maps for 1990, 2001, 2007, and 2010 were produced with seven categories.

Following the classification of satellite image from the individual years, multi-data post classification comparison change detection was used to determine changes in land use/cover in three intervals, 1990-2001, 2001-2007, and 2007-2010 (Yuan F. 2005). Urban expansion can be detected by comparing two classified images, as 1990-2001, 2001-2007, and 2007-2010 (Figure 17).

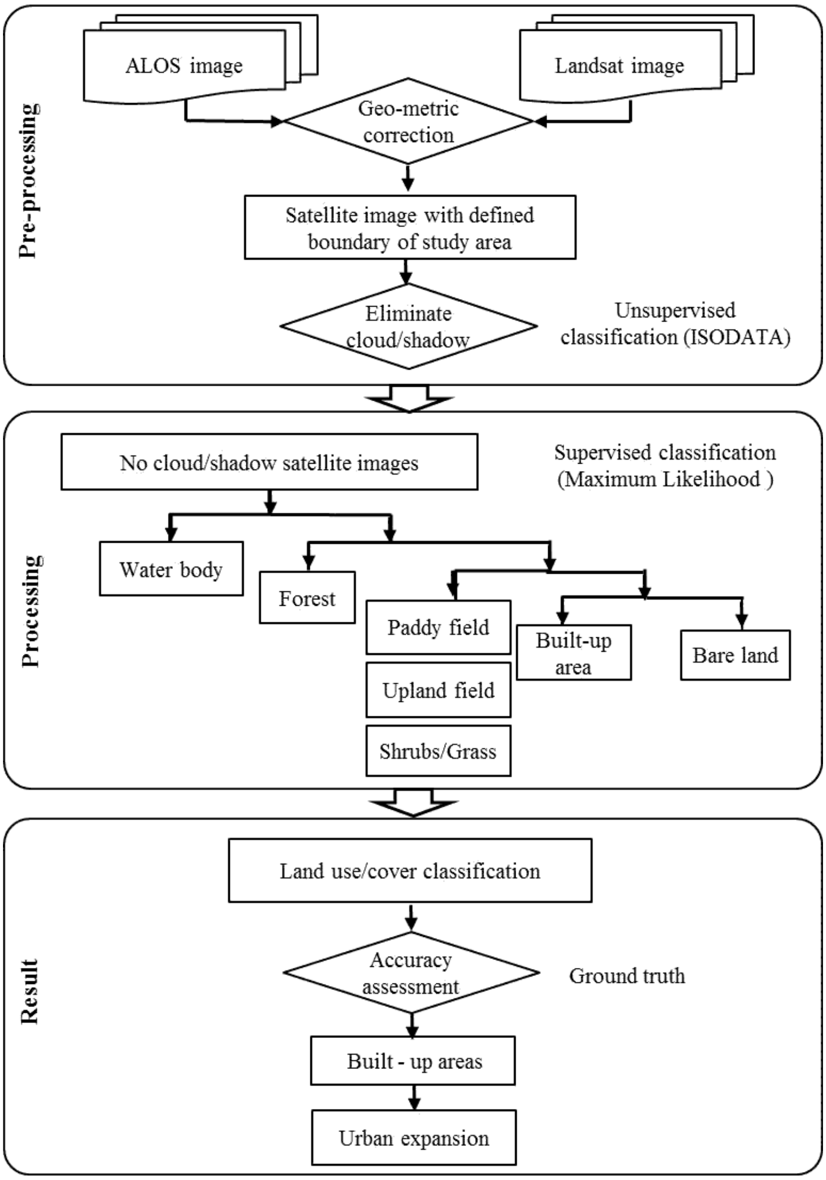


**Figure 17 Land use/cover classification and urban expansion analysis flow chart**

#### 4.3.1.3. Accuracy Assessment

Accuracy assessment is considered very necessary and available technique for assessing the accuracy of remote sensing data (Congalton 1991). The result of an accuracy assessment typically provides us with an overall accuracy of the map and the accuracy of each class in the map. A most common and typical method used by researchers to assess classification accuracy is with the use of an error matrix (Congalton 1991). An error matrix is a square array of numbers set out in rows and column which expresses the number of sample units (pixels) assigned to a particular category relative to the actual category as verified on the ground (Table 11). The columns usually represent the reference data (i.e. ground truth) while the rows indicate the classification generated from the remote sensed data (.i.e. LANDSAT data).

**Table 11 An example of Error Matrix**

| | | Reference data | | | | |
|---|---|---|---|---|---|---|
| | | D | C | BA | SB | Row total |
| **Classified data** | D | **65** | 4 | 22 | 24 | 115 |
| | C | 6 | **81** | 5 | 8 | 100 |
| | BA | 0 | 11 | **85** | 19 | 115 |
| | SB | 4 | 7 | 3 | **90** | 104 |
| | Column total | 75 | 103 | 115 | 141 | 434 |

| **Land Use/Cover categories** | **Producer's accuracy** | **User's accuracy** | **Overall accuracy** |
|---|---|---|---|
| D: deciduous, | D= 65/75= 87% | D= 65/115= 57% | = |
| C: confiner, | C=81/103=79% | C=81/100=81% | (65+81+85+90)/434=74% |
| BA: barren, | BA=85/115=74% | BA=85/115=74% | |
| SB: shrub | SB=90/141=64% | SB=90/104=87% | |

Source: (Congalton 1991).

The error matrix table produces many statistical measures of thematic accuracy including Overall classification accuracy (the sum of the diagonal elements divided by the total number in the sample), User's accuracy (represents the probability that a given pixel will appear on the ground as it is classed - the percentage correct for a given row divided by the total for that row), Producer's accuracy (represents the percentage of a given class that is correctly identified on the map-the percentage correct for a given column divided by the total for that column. Use's accuracy and Producer's accuracy can also be expressed in terms of Error of commission (indicates pixels that were placed in a given class when actually belong to another) and Error of omission (the percentage of pixels that should have been put into a given class but were not). In addition in being measure of accuracy, Kappa is also a powerful technique in its ability to provide information about a single matrix as well as to statistically compare matrices. Kappa coefficient is an index that relays the classification accuracy after adjustment for chance agreement (Congalton 1991). A kappa of 1 indicates perfect agreement, whereas a kappa of 0 indicates agreement equivalent to chance (Viera and Garrett 2005) (Table 12).

**Table 12 Interpretation of Kappa Coefficient**

| | Poor | Slight | Fair | Moderate | Substantial | Almost perfect |
|---|---|---|---|---|---|---|
| **Kappa** | 0.0 | .20 | .40 | .60 | .80 | 1.0 |

| Kappa | Agreement |
|---|---|
| <0 | Less than chance agreement |
| 0.01-0.20 | Slight agreement |
| 0.21-0.40 | Fair agreement |
| 0.41-0.60 | Moderate agreement |
| 0.61-0.80 | Substantial agreement |
| 0.81-0.99 | Almost agreement |

Source: (Viera and Garrett 2005)

In this research, for accuracy assessment, a total of 3,901 points derived from the intersection of 500m in size were collected from reference data. Reference data were developed for each of the four years for accuracy assessment including the ground truth delivered from Geo Eye image on Google Earth (year 2010), field survey observation records (2013), LANDSAT TM color composite conditions of land use (1990, 2007), and old topographic map (2002). Subsequently, each individual point was trained by visual interpretation of those reference data in order to compare the accuracy of each classification result. The results of the accuracy assessment were obtained from each confusion matrix table for 1990, 2001, 2007, and 2010 and examined the value of user's accuracy, producer's accuracy, overall accuracy, as well as kappa and overall Kappa statistics.

### 4.3.2. Flood Risk Analysis

Risk is defined as the probability of harmful consequences, or expected loss (death, injury, disruption of property, livelihood, economic activity, or environmental damage) resulting from interaction between natural or human induced hazards and vulnerable conditions. The definition emphasizes the relationship between the hazard and vulnerability, in which risk is expressed by the notation: Risk = Hazard x Vulnerability (UNISDR 2004). Hazard is referred to the physical events whereas vulnerability is referred to the social factors.

In this study, a flood risk map was developed using the basic ranking matrix in two-dimensional multiplication model of flood hazard and demographic vulnerability (Islam and Sado 2002). The extent of the area for risk analysis was set at less than 35 m in height and according to the administrative boundaries of 31 ward/commune levels. These areas correspond to the constantly flood-affected lowlands of the Hoa Vang, Cam Le, and Ngu Hanh Son districts and the wards along the Han River to the river mouth.

#### 4.3.2.1. Flood Hazard Assessment

A hazard is defined as a potentially damaging physical event, phenomenon, and/or human activity that may cause the loss of life or injury, property damage, social and economic disruption, or environmental degradation (UNISDR 2004). In the present study, the hazard was flood events in the context where a flood hazard is defined as the accelerated probability of potentially damaging flood situations in a given area and within a specific period of time (Thieken, Merz et al. 2006). A flood hazard map defines the area at risk and is considered the basic tool for flood preparedness and mitigation activities. The information indicated on the flood hazard map can be used to promote proper and prompt early warning evacuation actions for local residents (Suriya and Mudgal 2012).

Several methods for flood hazard mapping have been developed using various hydrological-hydraulic, geomorphology, and hydro geomorphological methods (Lastra, Fernandez et al. 2008, Spachinger, Dorner et al. 2008, Loan and Umitsu 2011), but no consensus currently exists with respect to a standardized method for producing flood maps or for assessing flood risks (Ashraf Mahmmood Dewan 2005, Giuseppe Tito Aronica 2011). Moreover, many of the well-developed methods usually require large amounts of hydrological observation data, but these data are often inadequate and scarce and may not be easily accessible in developing countries such as Vietnam due to lack of high resolution digital elevation models (DEMs) and digital data, as well as restricted access to disaster data. Remote sensing and GIS are increasingly considered as very useful and effective tools in disaster management (Vogt, Riitters et al. 2007, Vijayaraghavan, Thirumalaivasan et al. 2012), especially in flood hazard mapping, flood risk monitoring, and flood risk assessment (Sakamoto, Nguyen et al. 2007, Suriya and Mudgal 2012). These provide a broad range of tools for determining flood areas and assessing the extent of a flood hazard. Synthetic aperture radar remote sensing with its weather capability and its sensitivity towards smooth open water surface has been employed effectively in previous studies for delineation of flood prone areas (Townsend and J.Walsh 2001, Sakamoto, Nguyen et al. 2007). However, this type of research requires both pre- and post-flood radar images for assessment of flooding by investigating the changes in backscatter value. Unfortunately, in the present study, only one PALSAR image obtained near the flood event was available for analysis. Due to the difficulties in getting detail local data regarding hydrology and geomorphology as well as the limitation of satellite image in study area, a new approach on deriving a potential flood hazard map has been conducted. Our approach is to identify the areas that are prone to flood hazard. Flow direction analysis revealed the effectiveness of extracting these areas. In this study, flow direction characteristics delivered from ASTER GDEM and the past flood inundation experiences obtained from ALOS PALSAR images were integrated to analyze and rank the potential flood hazard zones. Flood records for the 2007 historical event from field surveys and land use/cover classification of 2007 from LANDSAT were then integrated to check the accuracy of these putatively identified flood affected areas (Figure 18).

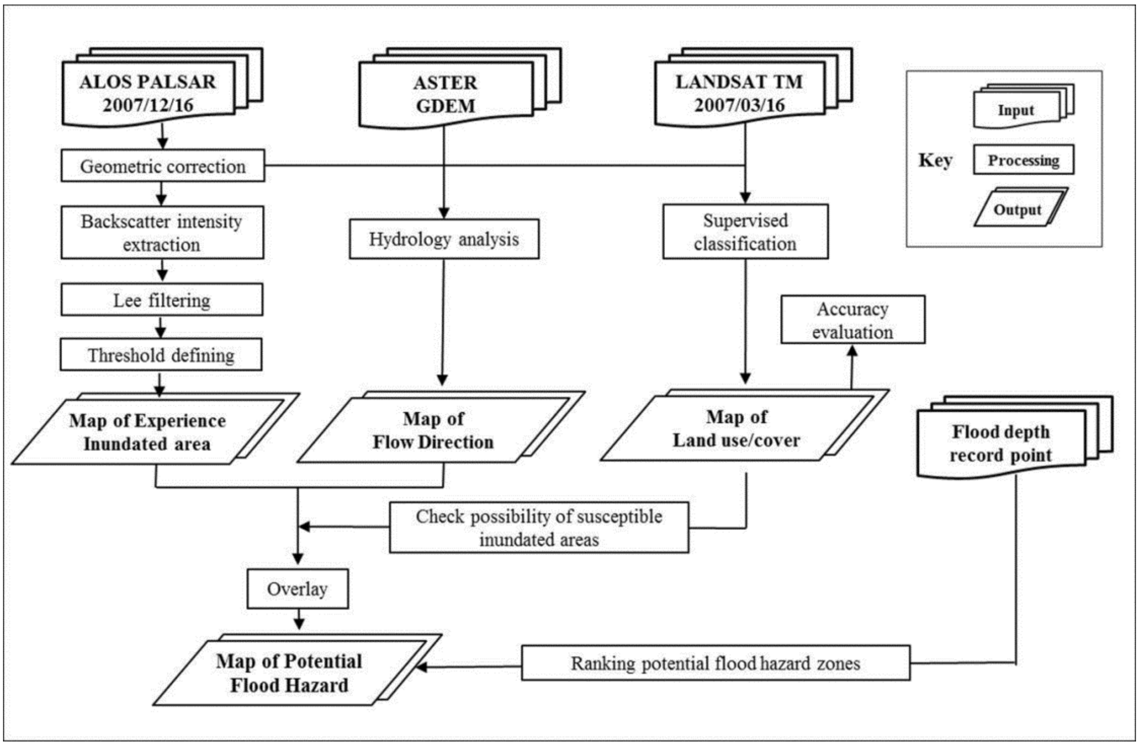


**Figure 18 Flowchart of potential flood hazard mapping**

**a. Inundation area Extraction from ALOS PALSAR**

Backscatter information obtained from PALSAR indicates the strength of microwave irradiation emitted from the antenna and returned after scattering on the surface or targeted substances. Analysis of the backscatter coefficients obtained from PALSAR image enabled the estimation of the volume of water contained on the surface. The backscatter coefficient is reflected in response to the differences in brightness, where a water surface appears dark because the backscatter coefficient is weak on the smooth surface of water (ERSDAC 2006). The inundated areas can be detected by defining the threshold value of backscatter coefficient based on the training samples' histogram for water and non-water classes.

The ALOS PALSAR image acquired on December 16, 2007 (about 1 month after the big flood) was used to extract the flood water inundation area by utilizing ERDAS Imagine (v.9.1). First, geometric correction was carried out using a geo-referenced LANDSAT TM image of the same area, until the Root Mean Square Errors (RMSE) were less than 1 pixel.

A second order polynomial fit was applied and resampled with the Nearest Neighbor method. Flood inundation mapping was based on water appearing darker in the image. The SAR image in the Digital Numbers (DN) value was converted to normalize backscattering coefficients ($\sigma^0$), expressed in decibels (dB) in order to determine the dynamic threshold. For PALSAR at the 1.5 product level, this conversion follows Eq. (1)

$$\sigma^0 = 10 * log_{10}(DN^2) - 83 \qquad (1)$$

where DN is the radar amplitude expressed as a digital number and -83 is the calibration coefficient for the PALSAR 1.5 level product (Shimada, Isoguchi et al. 2009). The speckle noise in the SAR image was also reduced using an LEE filter with a 3x3 window size. Based on that threshold in the training sample histogram, the image was classified into two discrete classes: water and nonwater areas. This inundation map was then derived by masking with the permanent water bodies. Suppose that one month after a flood, water partially flowed in an area, but no SAR images were taken close to that flood incident to check for this. To overcome this deficiency, a flow direction element was carried out to ascertain the potential flood hazard in this area. Those areas were then overlaid on the inundation map from the ALOS PALSAR image interpretation. A flow direction polygon with a high proportion of inundated sections indicated a more flood more prone and hazardous area. These results were validated using land use/cover map extracting from LANDSAT TM and flood depth point records from field surveys.

**b. Flow Direction from ASTER GDEM**

The flow direction was derived from the ASTER GDEM using the hydrologic analysis functions in ArcGIS ver.10 software. The flow direction for a cell is the direction water will flow out of that cell. The direction of flow is determined by the direction of steepest descent, or maximum drop, from each cell. Eight valid output directions are available, relating to the eight adjacent cells to which flow could travel (eight direction flow model). The flow is encoded to correspond to the orientation of one of the eight cells that surround the cell in the center as 1, 2, 4, 8, 16, 32, 64, and 128 (Jenson and Domingue 1988). In this study, the depressed surfaces into which water can accumulate at the time of flooding also need to be identified (Figure 19).

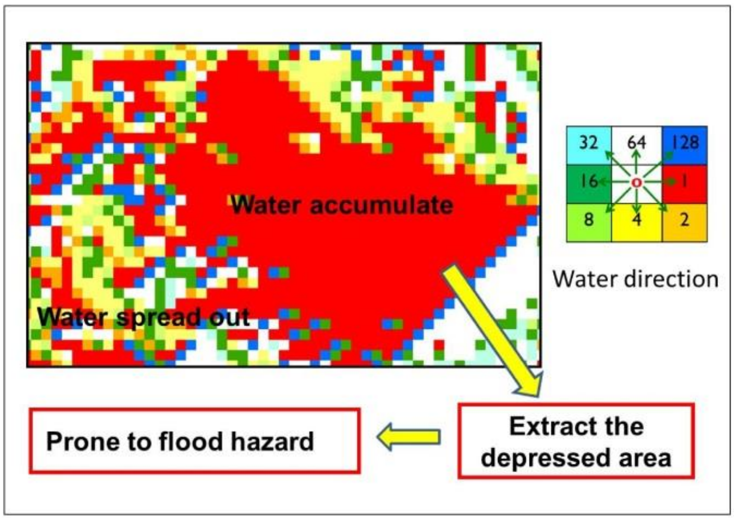


**Figure 19 Depressed surface extraction from flow direction**

From the flow direction grid, if the adjacent pixels have different values, it means that water cannot accumulate and will flow in many directions. In contrast, if the adjacent pixels have the same direction value, water will concentrate and that area will be prone to a flood hazard. From this point of view, extraction of the depressed surfaces from the large and smooth areas in the flow direction grid is relatively easy.

Before deriving the flow direction, a fill-DEM technique was done with a Fill tool in order to fill sinks that were considered most likely to be data errors/imperfections.

#### 4.3.2.2. Vulnerability Assessment

The concept of vulnerability has been defined using many different approaches by many researchers in various fields (Wisner, Blaikie et al. 2003, Fussel and Klein 2006). Vulnerability is understood as the characteristics of a person or group and their situation that influences their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard (Wisner, Blaikie et al. 2003). In this study, the degree of vulnerability can be defined by several indicators of socio-economic status, such as poverty, ethnicity, gender, disability, age, occupation, and immigration status. The vulnerable groups, which included children, the elderly, impoverished households, and females, were utilized for analysis. Based on the degree of susceptibility to flood hazard, a particular vulnerable group is managed by the weighting ($W_i$), in which the high value of the percentage of people who are under 5 years old and above 65 years old corresponds to a higher weight, as showed on Table 13.

**Table 13 Weight assignment for each vulnerability group**

| No | Vulnerability group variable (Pi) | Weights (Wi) |
|---|---|---|
| 1 | Percentage of children <5 years | 3 |
| 2 | Percentage of elder >65 years | 3 |
| 3 | Percentage of poverty household | 2 |
| 4 | Percentage of female | 1 |

The Demographic Vulnerability Index (DVI) score was calculated for each ward/commune level by the following Eq. 2:

$$DVI = \sum_{i=1}^{n} PiWi \qquad (2)$$

Where: DVI: Demographic Vulnerability Index;

$P_i$: Value of vulnerable group variable;

$W_i$: Weighting of each vulnerable group.

The demographic census data in 2009 was used for assessing the demographic vulnerability of prone flood hazard areas.

## 4.4. Results and Discussion

### 4.4.1. Land Use/Cover Mapping and Accuracy Assessment

The time series land use/cover classification maps over the past 20 years were shown in Figure 20 and the individual class area and change statistics for the for years area were summarized in Table 14.

**Table 14 Summary of statistical land use/cover classification area for 1990, 2001, 2007, and 2010**

| Categories | 1990 | | 2001 | | 2007 | | 2007 | |
|---|---|---|---|---|---|---|---|---|
| | Area (ha) | Occupancy (%) | Area (ha) | Occupancy (%) | Area (ha) | Occupancy (%) | Area (ha) | Occupancy (%) |
| Build - up area | 5091.75 | 5.21 | 7144.2 | 7.31 | 9495.81 | 9.71 | 11208.87 | 11.5 |
| Water body | 2190.60 | 2.24 | 3079.35 | 3.15 | 2832.75 | 2.90 | 2099.12 | 2.15 |
| Paddy field | 8164.53 | 8.36 | 6367.77 | 6.25 | 4796.19 | 4.90 | 4030.62 | 4.13 |
| Upland field | 1956.15 | 2.00 | 1568.97 | 1.61 | 737.10 | 0.75 | 711.80 | 0.73 |
| Bare land | 7123.32 | 7.29 | 6323.31 | 6.47 | 3469.77 | 3.55 | 3129.10 | 3.21 |
| Forest | 69773.40 | 71.40 | 68776.11 | 70.37 | 68655.78 | 70.19 | 67931.64 | 69.67 |
| Shrubs and Grass | 3419.73 | 3.50 | 4478.85 | 4.58 | 7822.35 | 8.00 | 8397.01 | 8.61 |
| Total | 97719.48 | | 97738.56 | | 97809.75 | | 97508.16 | |

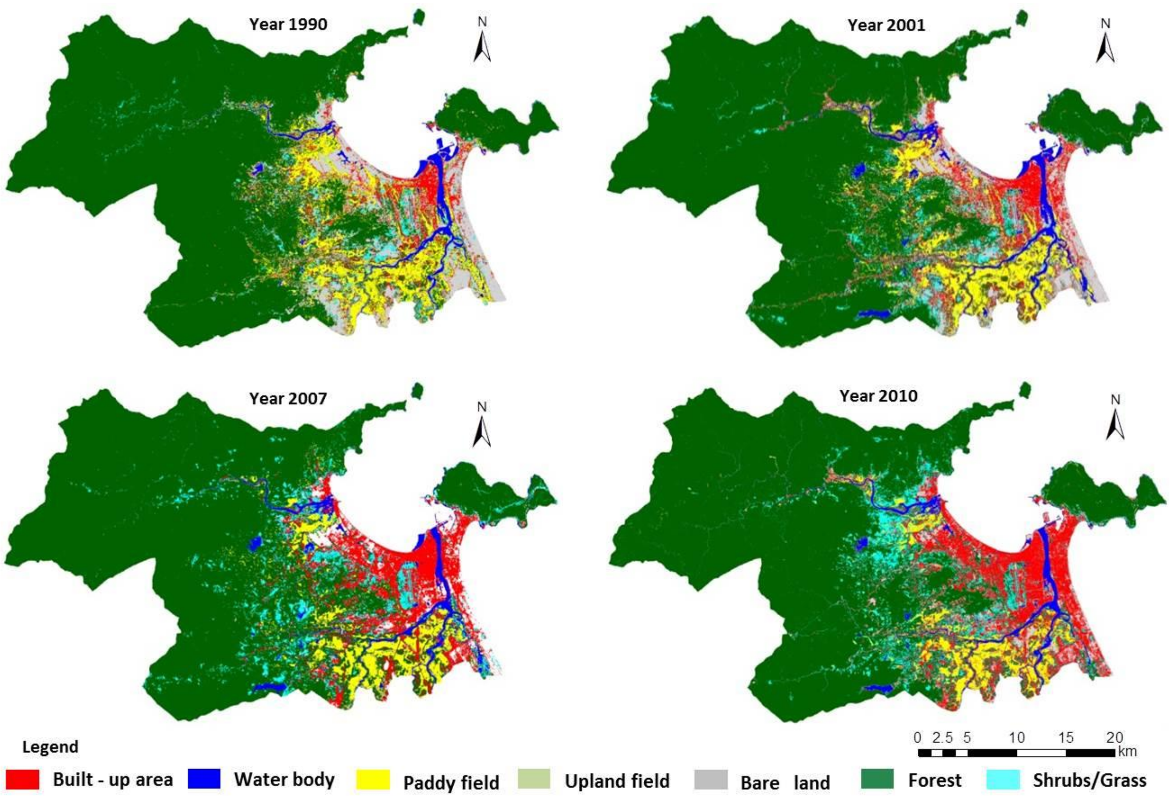


**Figure 20 Land use/cover maps in 1990, 2001, 2007 and 2010**

The general structure of the land use/cover in this study area was agglomerated significantly for four major land use/cover types: built-up area, agricultural field, bare land, and shrubs/grass. From 1990 to 2010, built-up area increase approximately 6,117 ha (6.29%), shrubs and grass increased approximately 4,977 ha (5.11%) while paddy field area decreased 4,133 ha (4.23%), bare land decreased 3994 ha (4.08%). The proportion of built-up areas increased steadily from 1990 to 2001, 2007, and 2010, at 5.2, 7.3, 9.7, and 11.5%, respectively. Since 1990, the built-up area has expanded beyond the Hai Chau and Thanh Khe districts to the districts along the coastal line. In contrast, the proportion of paddy fields from 1990 to 2001, 2007, and 2010 has continuously decreased from 8.4% to 6.5, 4.9, and 4.1%, respectively. As the similar trend, the proportion of upland fields also decreased approximately from 2% to 1.61%, 0.75% and 0.73% from 1990 to 2001, 2007, and 2010 respectively. The decline in agricultural fields during this period agrees with the development strategy of Da Nang city, which follows "Service, Industry and Agriculture", in which the density of service and industry is increasing and agriculture is decreasing.

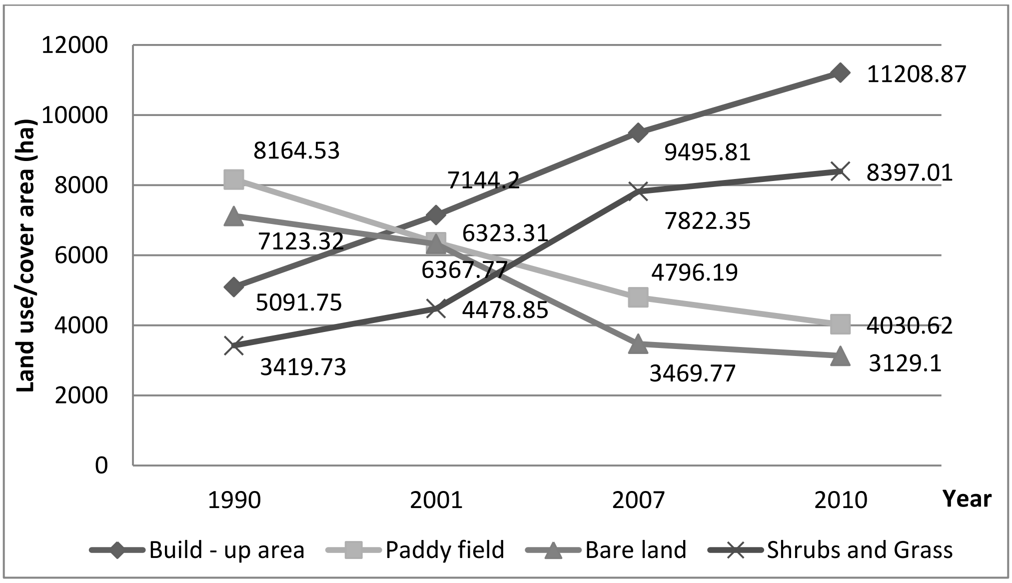


**Figure 21 Area of major land use/cover categories**

The city authorities invested actively in building Da Nang into a modern city, with strong industrialization, modernization, and high services. Therefore, most bare land areas were reclaimed and covered with industrial zone, infrastructure, and newly built-up areas, which showed a rate of decline from 7.3% to 3.2% in 1990 and 2010, respectively (Figure 21). In particular, a total of 2,853 ha of bare land disappeared during the period of 2001-2007. The sharp decrease observed over these 6 years may have resulted from the dramatic economic development beginning in 2003, when more infrastructure, industrial real estate, and residential structures were built. The tendency was also marked in forests, which showed a slight decline in area. The forest areas decreased gradually from 69,773ha to 67,931ha in 1990 and 2010, respectively. During this time, shrubs/grass increased, probably due to this deforestation. However, from 2001 to 2007, the increase in shrubs/grass area accelerated to cover 3,343 ha which showed a high disparity compared with the 120 ha area of deforestation. This is because of the limits of reflectance spectra during the classification. The difference between young offshoot forests and shrubs sometimes was not discriminated; therefore, there were some inter-conversion between the forest and the shrubs/grass categories. Accuracy assessment is an important step in the classification as it permits quantitative determination of how correctly the pixels were grouped into the feature classes in the area under investigation (Wisner, Blaikie et al. 2003). Error matrix was used to assess classification accuracy and is summarized for all four years in Table 15.

**Table 15 Summary of accuracy assessment for each land use/cover category in 1990, 2001, 2007, and 2010**

| Year | 1990 | | | 2001 | | | 2007 | | | 2010 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PA (%) | UA (%) | K | PA (%) | UA (%) | K | PA (%) | UA (%) | K | PA (%) | UA (%) | K |
| Built-up | 67.92 | 76.17 | 0.75 | 73.82 | 84.59 | 0.82 | 76.84 | 87.01 | 0.85 | 82.6 | 67.8 | 0.64 |
| Water body | 84.88 | 85.88 | 0.86 | 92.11 | 87.50 | 0.87 | 78.81 | 86.92 | 0.87 | 62.30 | 90.48 | 0.90 |
| Paddy | 76.42 | 72.32 | 0.70 | 89.67 | 83.14 | 0.82 | 74.55 | 89.78 | 0.89 | 75.47 | 79.21 | 0.78 |
| Upland field | 46.75 | 59.02 | 0.58 | 47.27 | 59.09 | 0.59 | 46.67 | 60.87 | 0.61 | 36.67 | 41.51 | 0.41 |
| Bare land | 69.57 | 71.91 | 0.70 | 84.83 | 63.40 | 0.62 | 76.04 | 61.34 | 0.60 | 34.64 | 55.21 | 0.53 |
| Forest | 96.04 | 93.40 | 0.78 | 97.26 | 96.66 | 0.89 | 95.74 | 95.33 | 0.84 | 98.14 | 92.03 | 0.75 |
| Shrubs/Grass | 36.24 | 55.10 | 0.4 | 53.25 | 68.33 | 0.67 | 63.82 | 47.92 | 0.45 | 16.86 | 45.36 | 0.41 |
| Overall Kappa Statistic | 0.73 | | | 0.81 | | | 0.77 | | | 0.69 | | |
| Overall Classification Accuracy (%) | 87.34 | | | 91.19 | | | 89.26 | | | 85.29 | | |

The overall accuracies for 1990, 2001, 2007, and 2010 were, respectively 87.34%, 91.19%, 89.26%, and 85.29%, and the corresponding overall Kappa statistics of 0.73, 0.81, 0.77 and 0.69 which was considered to indicate acceptable or good agreement with the optical data. User's and producer's accuracies of individual classes were also extracted. Among these, the use's and producer's accuracy for the 2001 classification were high. For the built-up areas, the Kappa coefficient was extracted with substantial agreement, ranging from 0.64 to 0.85. Therefore, these results allowed us to perform a temporal changes analysis for the urban expansion process.

### 4.4.2. Urban Expansion Process in Da Nang City

Da Nang is recognized as a new economic hub in Vietnam; i.e., a rapidly developing city in recent years. From our analysis of its land use/cover changes, Da Nang city has clearly undergone a rapid urban expansion. Tremendous urban development has taken place over the past two decades, amounting to 11,208ha in 2010 as compared to only 5,091ha in 1990. The built-up area grew by 6,117ha between 1990 and 2010, or nearly 300ha per year on average. The rate of increase in built-up area was 140.3% between 1990 and 2001, 132.9% between 2001 and 2007, and 118% between 2007 and 2010. Visual examination of the four land use/cover maps shows vast differences in built-up areas.

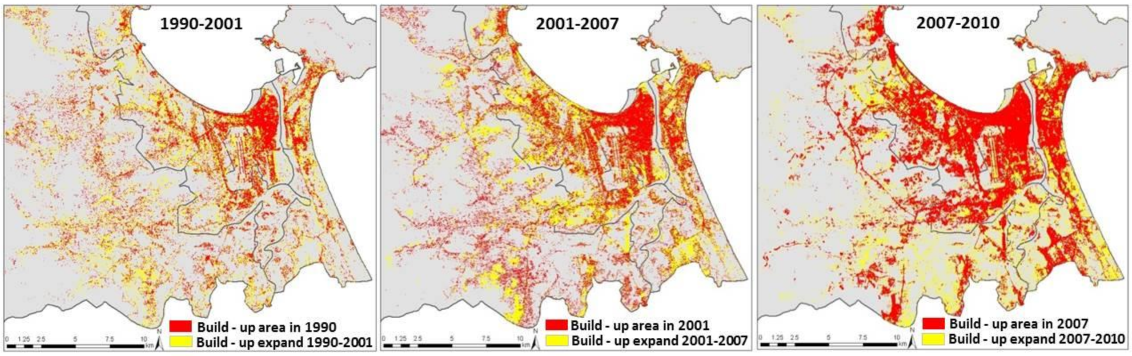


**Figure 22 Urban expansion in Da Nang city from 1990 to 2010**

The extent of expansion of built-up areas indicates that the core of the city (Hai Chau, Thanh Khe district) has been well developed since 1990. With the substantial development of the emerging industry parks and major infrastructure as well as roads and bridge networks from 2003, this has led to connection with other districts (Lien Chieu, Son Tra, and Cam Le). After 2007, the city authority has accelerated the development of sea park and tourism zones/resorts along the Son Tra - Dien Ngoc coastal road that connects Hoi An city in the Southeast. The urban area has largely expanded beyond the central city to connect Ngu Hanh Son and Cam Le, demonstrating a complete interconnection of urban areas. The urbanization appeared to a slight increasing after 2007 as it reached the mature stage of development. These developments resulted in the pattern of spatial expansion observed in this study area. Thus, the main direction of urbanization was to the West, Northwest, South, and Southeast, and along the coastal line (Figure 22).

During the 20 year period covered by this study, urbanization speech appeared highest in the Lien Chieu urban district, followed by the Ngu Hanh Son and Cam Le urban districts. In contrast, the center of Da Nang city, Hai Chau, and Thanh Khe showed a lower rate of expansion because they were already completely urbanized by 1997. During this time, most of built-up areas were reclaimed from agriculture land and bare lands for the construction, industrial park, and tourism sectors (Figure 23). This can be seen especially in the areas West, Northwest, and Southeast areas of the city, where a large area of bare land was transformed into residential sectors between 1990 and 2010.

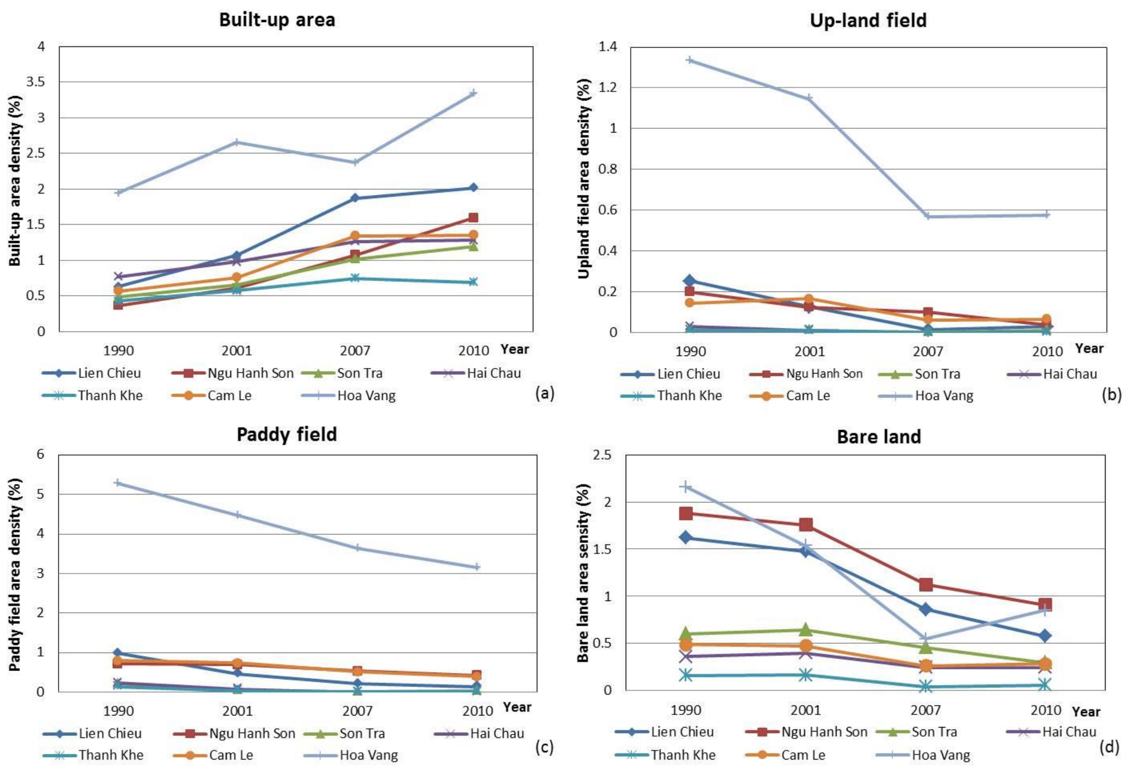


**Figure 23 The expansion of (a) Built-up area and the reduction of (b) Up-land field (c) Paddy field (d) Bare land in each district of Da Nang city from 1990 to 2010**

Together with the high rate of urbanization and industrialization, Da Nang city is further faced with the pressure of a greatly increasing population. The relationship between population growth and built-up area expansion was also examined. According to the results of a population census, just within 20 years, the population of the city has increased by 1.7 fold, from 537,509 to 926,018 in 1990 and 2010, respectively (Figure 24). The annual population growth rate is approximately 3.07% from 1990 to 2010. Within 20 years the annual growth in built-up area of approximately 6.01%, approximately two times the rate of population increase.

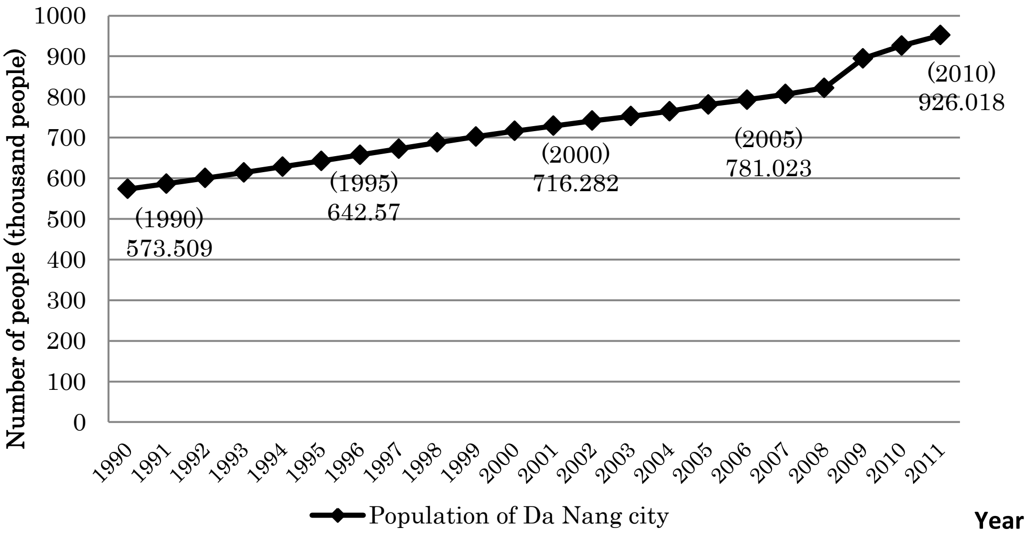


**Figure 24 Population growth in Da Nang city between 1990 and 2010**

The population growth and urban expansion rate were also tabularized at district level (Table 16). All the districts with significant population growth also had extremely expanding in built-up area. During 20 years (1990-2010), Lien Chieu is the leading urban district with population growth rate and urban expansion rate of 219.19% and 218.47%, respectively, followed by Ngu Hanh Son and Cam Le districts, which are the urban fringes. In contrast, Hai Chau, which is the center district, has the lowest rate of population growth rate, at only 23.97% correspond with the urban expansion rate of 65.96% from 1990 to 2010. These facts clearly demonstrate that rapid urbanization has occurred, together with increases in population in the urban districts.

**Table 16 Population growth and urban expansion rate in each district of Da Nang city from 1990 to 2010**

| District | Total area (ha) | 1989 Population (people) | 2010 Population (people) | Population growth rate (%) | 1990 Built-up area (ha) | 2010 Built-up area (ha) | Urban expansion rate (%) |
|---|---|---|---|---|---|---|---|
| Hai Chau | 2328 | 158186 | 196098 | 23.97 | 752.04 | 1248.09 | 65.96 |
| Thanh Khe | 944 | 117358 | 178447 | 52.05 | 419.31 | 675.56 | 61.11 |
| Son Tra | 5932 | 76321 | 132944 | 74.19 | 473.94 | 1162.55 | 145.29 |
| Ngu Hanh Son | 3912 | 25016 | 68270 | 172.91 | 360.09 | 1558.03 | 332.68 |
| Lien Chieu | 7913 | 42839 | 136737 | 219.19 | 617.76 | 1967.38 | 218.47 |
| Cam le | 3525 | 42407 | 92824 | 118.89 | 557.37 | 1317.71 | 136.42 |
| Hoa Vang | 73489 | 82926 | 120698 | 45.55 | 1901.16 | 3255.58 | 71.24 |

## 4.4.3. Flood Risk Assessment

### 4.4.3.1. Flood Hazard Map

Based on the values of backscatter (dB values) in the ALOS PALSAR image, a threshold value is determined by checking the histogram between water and non-water with backscatter values at -13 dB (Figure 25).

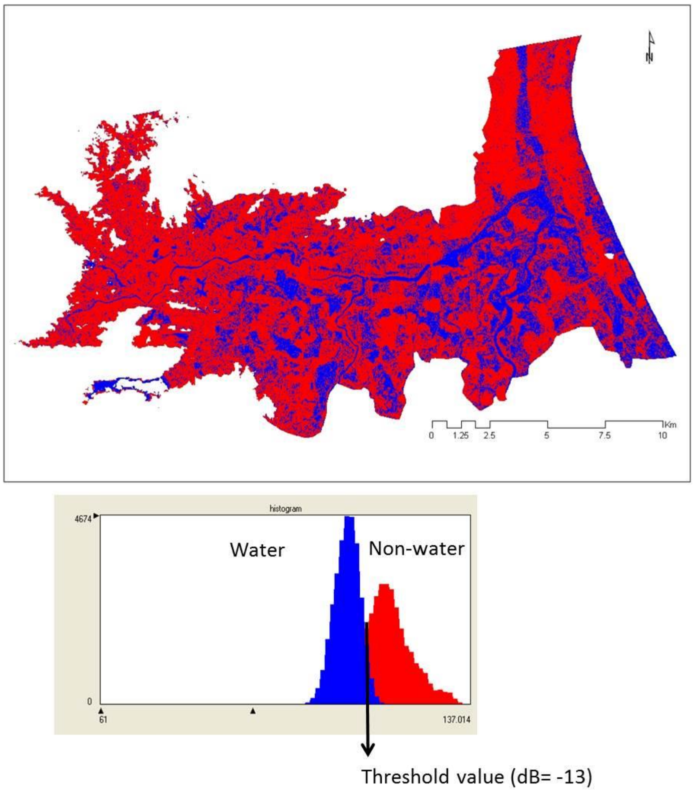


**Figure 25 Discrimination of threshold value between water and nonwater from ALOS PALSAR image**

The inundated areas extracted from ALOS/PALSAR showed that even one month after the flood, the inundated areas still remained, and the percentage of the inundated areas for some land use types still remained relatively high, such as paddy fields (58%), bare land (36%), upland fields (29%), and built-up areas (19%), so these could be used for further analysis. The potential flood hazard was mapped by overlaying the inundation and flow direction maps, to evaluate the percentage of inundated area per flow direction with respect to the flood depth point records for the 2007 historical flood. A total of 47 flood depth points collected from field surveys were used for this analysis (Figure 26).

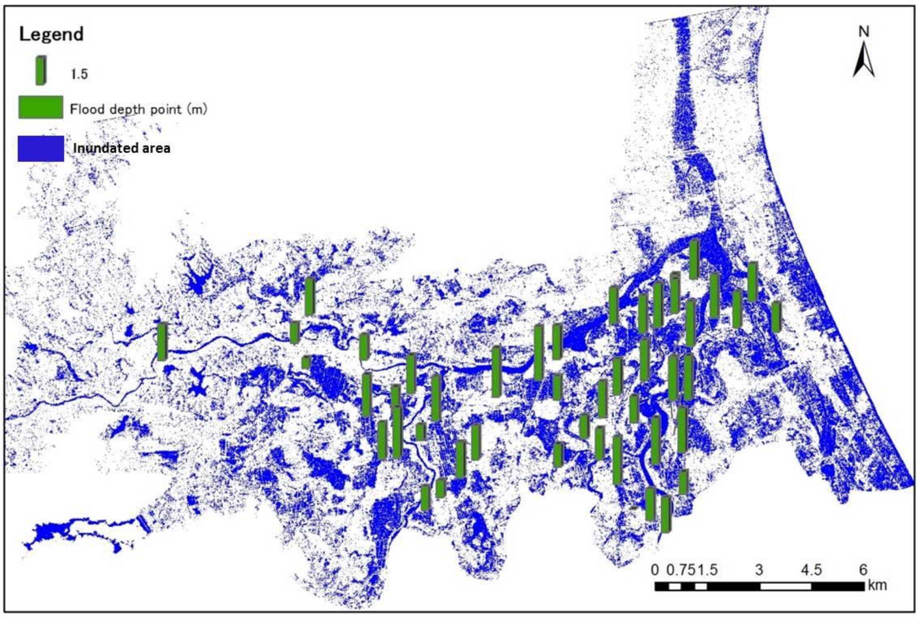


**Figure 26 Utilization of flood depth points collecting from field surveys for ranking flood hazard map**

Almost all of the flood depth points less than 1 m (5/5 points) fall within 4-23% of the inundated flow direction, 77.3% (17/23 points) of the flood depth points from 1-2m fall in the range of 26-49%, while 90% (18/19 points) of the flood depth points above 2m fall in the range of 50-70%. Therefore, a threshold value was set for classifying the hazard rankings shown in Table 17. A smaller hazard rank index was used to assign a low flood depth or low percentage of flow direction (P), while a larger hazard rank index was used to express a high hazard.

Table 17 Flood Hazard Rank Index

| Percentage of inundated per flow direction (P %) | Hazard category | Hazard Rank Index |
|---|---|---|
| No flood | No hazard | 0 |
| 0<P≤25 | Low | 1 |
| 25< P ≤50 | Medium | 2 |
| P>50 | High | 3 |

Most of the flood hazard areas were clearly concentrated around the Cau Do and Tuy Loan Rivers. The highest flood hazard was in the Hoa Xuan ward, followed by the Hoa Phong, Hoa Hai, Hoa Quy, Hoa Chau, and Hoa Khuong wards (Figure 27). These areas are located in a sunken region and along the Tuy Loan, Cau Do, and Vinh Dien Rivers, which are frequently inundated in flood times. In contrast, most of the wards along the Han River to river mouth area are under low flood hazard due to relatively high elevations and water can easily pour out from them to the sea.

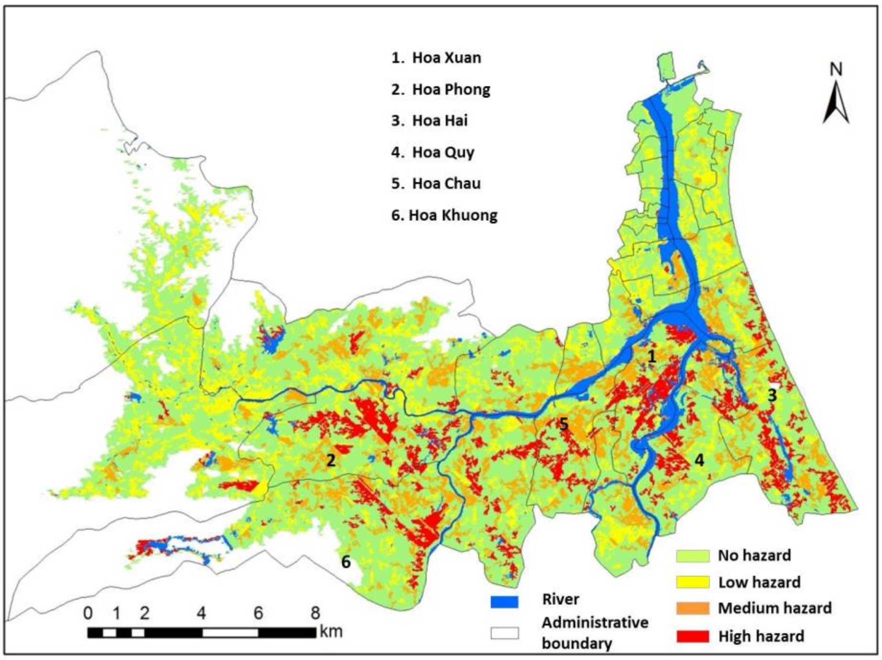


Figure 27 Flood Hazard map

### 4.4.3.2. Vulnerability Map

The demographic vulnerability formulation was used to obtain the weighted scores of Demographic Vulnerability Index (DVI), which ranged from 99.07 to

187.01. These were subsequently standardized on a scale from zero to one, in which a higher rank index value indicated a higher demographic vulnerability (Table 18).

**Table 18 Demographic Vulnerability Rank Index**

| No | Vulnerability score rescale | Vulnerability category | Vulnerability Rank Index |
|---|---|---|---|
| 1 | 0-0.33 | Low | 1 |
| 2 | 0.34-0.66 | Moderate | 2 |
| 3 | 0.67-1 | High | 3 |

Many wards/communes were vulnerable to flood hazard within the demographic vulnerability context. In total, 6 and 10 wards/communes fell into the high and moderate demographic vulnerability classes, respectively. As shown in Figure 28, almost all of the high demographic vulnerability areas fell within the communes located in the upstream areas.

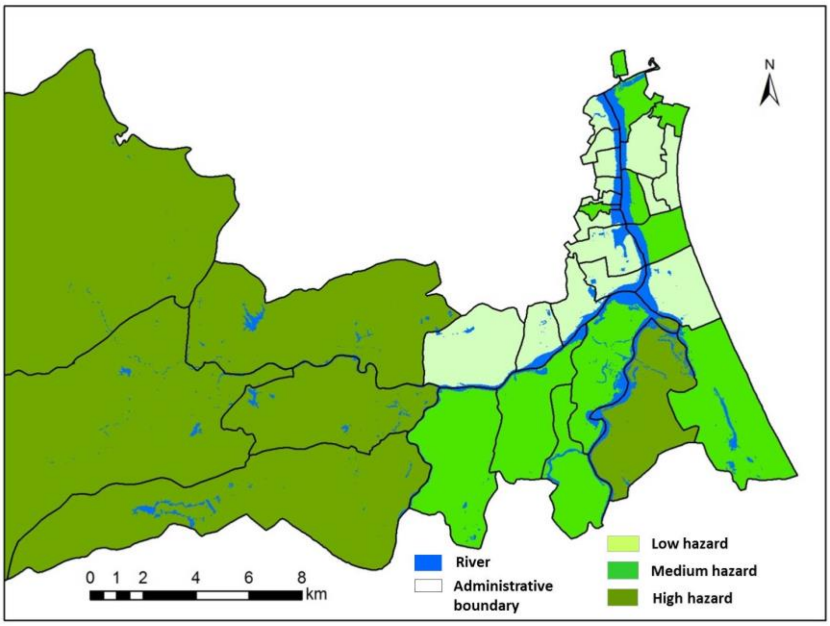


**Figure 28 Demographic Vulnerability map**

Those communes located in the rural areas and had a high percentage of children and elderly, as well as high rates of poverty, which considered greater susceptibility to flood hazards. In contrast, most of the wards in the center urban district are under low and moderate demographic vulnerability. It seems that the probability of exposure to the demographic vulnerability is higher in rural areas than in the urban centers.

#### 4.4.3.3. Flood Risk Map

A risk map was derived by 2D Multiplication Model of the flood hazard and the demographic vulnerability component shown in Table 19.

**Table 19 2D multiplication for Flood Risk Index**

| Flood risk index | | Flood Hazard Index | | |
|---|---|---|---|---|
| | | 1 (Low) | 2 (Moderate) | 3 (High) |
| Demographic Vulnerability index | 1 (Low) | 1 | 2 | 3 |
| | 2 (Moderate) | 2 | 4 | 6 |
| | 3 (High) | 3 | 6 | 9 |

The flood risk map has a rank of index order from 1 to 9, in which the rank 1-3 was set as low risk, 4-6 as medium risk, and 7-9 as high risk. The flood risk analysis revealed that an area of approximately 933 ha is under high risk, while 2,958ha and 3,588ha areas are under moderate and low risk, respectively (Figure 29).

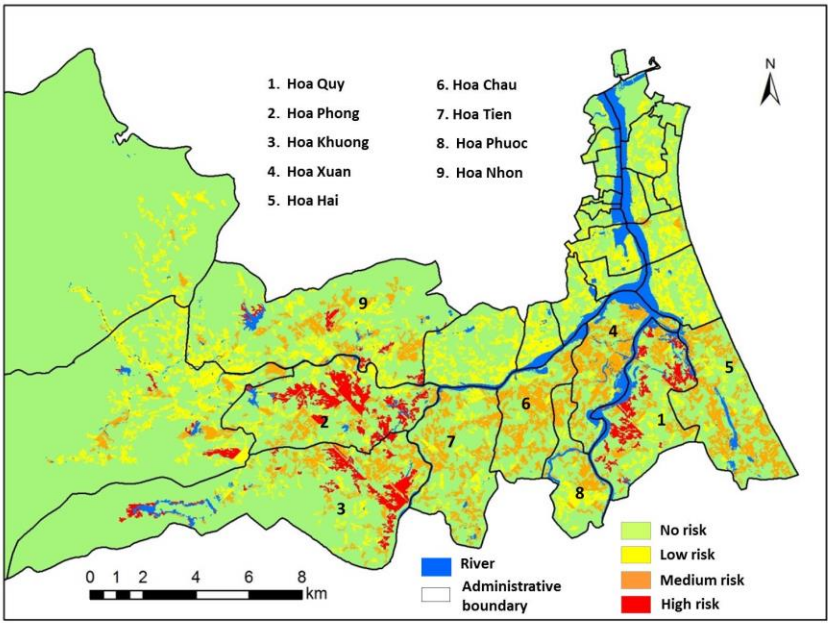


**Figure 29 Flood Risk map**

The high risk area is represented by a combination of both high flood hazard and high demographic vulnerability. Three wards/communes, namely Hoa Quy, Hoa Phong, and Hoa Khuong, fall into the high risk category, while 6 wards/communes, namely Hoa Xuan, Hoa Hai, Hoa Nhon, Hoa Tien, Hoa Chau, and Hoa Phuoc, fall into the moderate risk category. Most of the major high and moderate risk areas are situated in the lowlands of the Hoa Vang and Ngu Hanh Son districts, as well as along the banks of the Tuy Loan, Cau Do, and Vinh Dien River systems and other small rivers. These areas are the urban fringes, situated in the low-lying areas that are particularly exposed to extensive riverine floods. Although the result shows that the ratio of the relatively highest risk is not particularly large, it is necessary to identify and address this by providing strategies for mitigation because the damage to the lives and livelihoods of local people here have been relatively high in previous historical floods.

### 4.4.4. Urbanization and Flood Risk Changes

Da Nang city showed a high rate of urbanization during the 20 years from 1990 to 2010. By overlaying expanded settlements during 20 years with the flood risk map, we identified that some urbanized areas have clearly invaded into flood risk areas. The settlement areas exposed to flood risk increased from 31.6% to 31.8% and 36.7% in the urbanization periods of 1990-2001, 2001-2007, and 2007-2010, respectively (Figure 30).

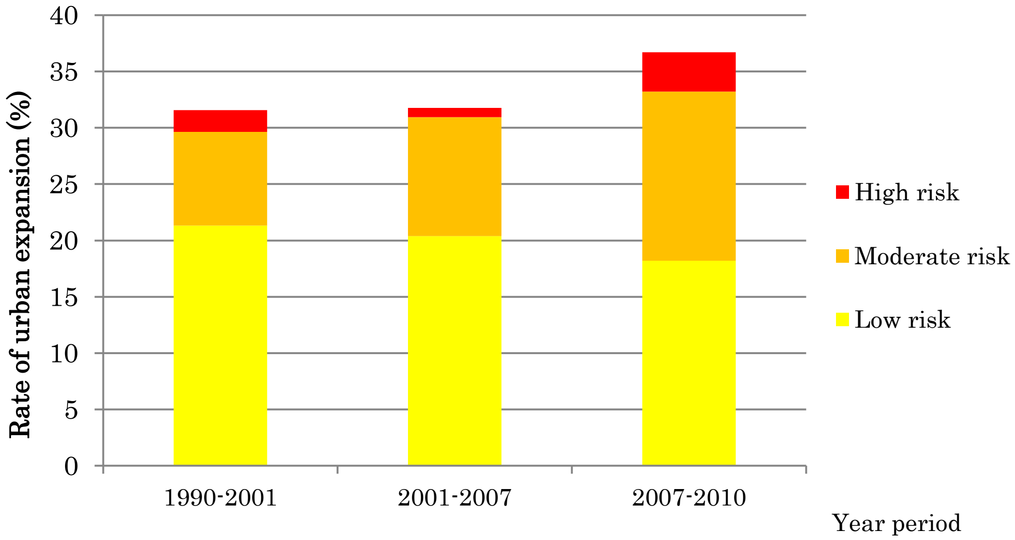


**Figure 30 Occupancy of settlements exposed to Flood Risk in periods of 1990 - 2010**

The occupation of settlements in areas with no or low flood risk decreased slightly, while the occupation of settlements in areas with moderate and high flood risk increased nearly twofold from the 1990-2001 to the 2007-2010 urbanization periods. The settlement expansion into the moderate flood risk areas increased from 8.3% in 1990 to 15% in 2010 (312ha) and expansion into the high flood risk areas increased from 1.9% to 3.5% in 2010 (74ha). In contrast, the settlement expansion into the no flood areas decreased from 68.4% in 1990 to 63.3% in 2010 and expansion to the low flood areas decreased from 21.3% to 18.2% in 2010. In essence, the urbanization process increases population density, with the result that space for resettlement becomes rare and expensive. Consequently, the urban poor people or migrants from rural areas tend to settle in the outskirts of the city, which are prone to floods or other hazards and where the wealthier do not want to live (World Meteorological Organization 2008). Urban expansion has been increasing in the present study area into regions where settlements are subject to significant flood risk.

## 4.5. Conclusion

In this study, remote sensing and GIS have been applied to analyze the urbanization process and flood risk changes in Da Nang city. The time series LANDSAT and multi-seasonal ALOS images were interpreted to create temporal land use/cover maps (for 1990, 2001, 2007, and 2010), which were then used to analyze the urban expansion process. The proposed methodology was successfully applied to produce a flood risk map by combining the flood hazard and demographic vulnerability maps. Flow direction extracted from GDEM was integrated with ALOS PALSAR images to produce the flood hazard map. This method is effective when hydrological and meteorological data are inadequate and remote sensing images taken during flood times are not available or are insufficient. The flood risk map was developed using a ranking matrix of flood hazard index and the demographic vulnerability index. This was then overlaid with the urbanization map for three periods to identify the rate of settlement exposure to flood risk.

The study revealed a high rate of urbanization during the 20 year period (the approximate rate of increase in built-up areas was 220%). Analysis of the detected land use/cover changes showed that the built-up area increased at a rate of 140.3% between 1990 and 2001, and at 132.9% and 118.0% between 2001 and 2007, and 2007 and 2010, respectively. The flood risk analysis represents that approximately 933 ha is classified as high risk, while 2,958 ha and 3,588 ha are classified as moderate and low flood risk, respectively.

The urban/settlements exposed to flood risk show a tendency toward a relative increase in moderate and high risk areas and a slight decrease in the low and no flood risk areas. However, the degree of risk to flood hazard does not only depend on the susceptibility to exposure to flood and demographic vulnerability, but also depends on social factors like the susceptibility and resilience of the community. In further studies, the response of the community to flood hazards, as well as the urban landscape changes before and after a flood disaster, must be considered in detail at the village level.

# CHAPTER 5
# COMMUNITY RESILIENCE ASSESSMENT TO FLOOD DISASTER IN RURAL DISTRICT OF DA NANG CITY, CENTRAL OF VIETNAM

## 5.1. Introduction

Resilience and vulnerability have been increasingly considered as vital components of disaster risk reduction since the adoption of the Hyogo Framework for Action 2005-2015 at the World Conference on Disaster Reduction in Kobe, Japan (UNISDR 2005, Cutter, Barnes et al. 2008). The vulnerability and what disaster analysts call "risk burdens" of communities and countries are progressing on a global scale, leading national and local governments, donors and many others evaluate the necessity of minimizing the associated natural disaster impacts by implementing disaster management principles and practices (UNISDR 2004, Ainuddin 2012). A great number of studies on vulnerability have referred to a negative term that focused on the susceptibility of persons or groups to harmful experiences due to exposure to a hazard, disturbance, or stress (Turner, Kasperson et al. 2003, Wisner, Blaikie et al. 2003). Vulnerability, on the other hand, pertains to the resilience of the system experiencing the hazards that encompass elements such as "adaptive capacity", "coping", "resistance", or "recovery" (Turner, Kasperson et al. 2003, Wisner, Blaikie et al. 2003, Paton 2005, Cutter, Barnes et al. 2008). In theory, resilience is used in the sense of the capacity of households and communities to bounce back, reorganize, and recover after a shock or disaster and are in part the opposite of vulnerability (Adger 2000). From a social perspective, resilience/vulnerability has been imbedded in the notion of communities with "good resilience" or "bad vulnerability" and appears as a simple spectrum where the extreme end is clearly recognized as resilience/vulnerability (Wilson 2012). The "good resilience" refers to the ability of a human system to absorb disturbance and to reorganize to become fully functional - a "positive" quality. In contrast, "bad resilience" is associated with the exposure and sensitivity of a human system that is unable to cope with risks, hazards, and slow or catastrophic change - a "negative quality" (Cutter, Barnes et al. 2008, Wilson 2012).

Recent models have shifted away from post disaster relief or "loss reduction", "reducing vulnerability" models to more comprehensive models of "building community resilience", which shift people's attitudes and behaviors towards coping with natural disasters, analyzing vulnerability, and building community resilience (UNISDR 2004, Mayunga 2007, Cutter, Barnes et al. 2008). Therefore, community resilience to disaster is crucial in reducing vulnerability and disaster risk and for achieving sustainable development in recent years.

Community resilience refers to community capacities to establish emergency plans and be ready for change whilst retaining the ability to be flexible and responsive to the uniqueness of the presenting situation (Wickes 2010). The studies on community resilience to disasters have been emerged since communities and people are becoming increasingly more vulnerable to natural hazards (floods, hurricanes, typhoons, tsunami…) due to worldwide climate change and environment issues (Indian Ocean Tsunami Warning System Program 2007, Mayunaga 2007; ACCCRN 2009, Shaw and Sharma 2011, Wilson 2012). Wilson (2012) and Mayunaga (2007) have investigated the community disaster resilience by utilizing the capital - based approach such as social, economic, human, physical, environment and natural capital of community, whereas ACCCRN (2009) approached community resilience assessment to flood and storm disasters focusing on urban cities by examining four elements of urban resilience including redundancy, flexibility, capacity to reorganize, and capacity to learn. Shaw and Sharma, 2011 also paid more attention to mapping climate and disaster resilience in urban areas based on Climate Disaster Resilience Index (CDRI) encompassing physical, social, economic, institutional, and natural dimensions. The Tohoku Earthquake (Great East Japan Earthquake) which occurred on 11$^{th}$ March 2011 was the most powerful known earthquake ever hit to Japan causing approximately 19,500 dead and missing people, 115,000 building totally destroyed and 162,000 half destroyed (Japan ICOMOS National Committee). Inotaga (2012) had discussed the related community resilience issues in his study on the resilience of rural community through emigration and return who experienced this catastrophe earthquake. Three month later, Thailand suffered the worst floods in more than half a century causing prolonged, widespread flooding and affecting more than 13 million people from July to December. The Royal Thai Government had collaborated with World Bank in conducting the rapid assessment for resilient recovery and reconstruction planning. Although researches on community resilience to disaster are still in its infancy, they have contributed the foundation for reducing vulnerability and disaster risk and for achieving sustainable development in recent years.

Vietnam is located in the tropical monsoon region of South East Asia, one of the most hazard-prone areas in the Asia Pacific Region. An estimated 70 percent of the Vietnamese people are exposed to risks from natural hazards (typhoons, tropical storms, floods, landslides, and droughts) - especially in rural communities, where livelihoods are most threatened (World Bank 2013). The Central Region of Vietnam, which is a long, narrow region with a complex sloping terrain stretching along the coastline, in particular suffers the most frequent and devastating effects of flood hazards. The present study examines the Hoa Vang rural district, located in Da Nang city in Central of Vietnam, as a case study location that experienced severe natural disasters in 1964, 1999, 2006, 2007, 2009 and 2011 caused by complex meteorological phenomena including storms, typhoons, and tropical low pressures. According to the report on the State of Coping with Natural Disaster of the People's Committee of Da Nang (2009), Hoa Vang is considered one of the major areas affected by natural disasters (inundation, flash flooding) causing damage to life, houses, infrastructure, and agriculture products during the last 10 years. The livelihood conditions of the local residents in this area are still substandard with an estimated 3,783 households at the poverty level (HVSO 2012). In addition, the weather events are likely to become less predictable and so more intense in future due to climate change.

There has been an apparent increase the awareness of the importance of prevention and mitigation of natural disasters in rural sustainable development in recent years. The Vietnam Government in general and the Da Nang Authority in particular have issued a number of policies related to natural disaster management. For instance, in 2007, the Vietnam Government issued the National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020 (Decision No.158/200/QĐ-TTg on November 2nd 2008), and the Da Nang city authority also subsequently approved the Action Plan of Responding to Climate Change and Sea Level Rise to 2020 (Decision No.6901/QĐ-UBND on August 24th 2012) (Socialist

Republic of Vietnam 2007, DNPC 2012). Since then, many projects in Nation and International level have been done focusing on mitigation flood disaster risk for vulnerability community as well as on building resilience community in a changing climate and environment (Centre for International Studies and Cooperation, 2008; Razafindrabe, 2009; Challenge to change and Hue University, 2009; ACCCRN, 2009). In 2008, the Centre for International Studies and Cooperation (CECI) conducted the Hydro - Meteorological Disaster Mitigation project in Da Nang city focusing on reducing vulnerability of urban communities through enhanced preparedness and mitigation of hydro-meteorological disasters. Subsequently, Razafindrabe and colleagues in 2009 also studied the resilience of urban communities in a changing climate and environment. Their results have been clarified and characterized the resilience of the new urban and coastal districts and theirs community with a special attention to water - related issues (mainly flood) in order to enhance resilience and adaptive capacity of urban government and community to these changes. The Asian Cities Climate Change Resilience Network which is a network of ten core cities in India, Indonesia, Thailand and Vietnam, has selected Da Nang as one of the study sites in Asian for building awareness and capacity on climate vulnerability and resilience (ACCCRN, 2009). This project has been implemented to study the hazard capacity and vulnerability assessment that facilitate community-based Disaster Risk Management and resilience planning focusing in some selected urban districts of Da Nang city. From 2007-2011, the Save the Children of Vietnam organization and Holland Kingdom Government also conducted projects of Mitigation Natural disaster risk in the core center of Da Nang city. In 2010, the Mantester International has been supported for raising capacity natural disaster prevention in 11 poor communes commonly subjected to flood in Hoa Vang district by providing equipment facilities in case of emergency and improving the early flood warning. The above reviewing projects have highlighted their primary research focus on building mitigation flood disaster risk as well as resilience community mainly in Da Nang urban districts, with a lack of ample attention to rural districts which are occasionally exposed to flood disaster at a great level.

In 2010, the Vietnam Government promulgated Decision No 800/QĐ-TTg of the National Target Program on New Rural Development for entire communities until

2020. The goal is to undertake comprehensive rural development including economic, social, environmental, and political fields that concern climate change responses as well as natural disaster prevention and mitigation (Son, Phung et al. 2011). However, most of these policies are often developed on a general scale (e.g., Nationwide, North region, Central region, and South region) and little attention has been paid to a detailed regional scale based on specific geographic features, especially at village level. Hoa Vang district now is on progress of rural planning it therefore needs to integrate natural disaster prevention and mitigation into each village for New Rural sustainable development. In this study, our aim was to conduct a community resilience assessment in Hoa Vang rural district based on the potential vulnerability typology of flood affected villages and subsequently to measure the resilience of the community via a capital-based approach by using questionnaire survey. The findings of this study will serve a good reference and a scientific foundation for local authorities in flood disaster mitigation as well as sustainable development in rural area.

## 5.2. Community Resilience Assessment Framework to Flood Disaster

Conceptually, the relationship between Risk, Vulnerability, and Hazards has been described as the following function: Risk = Hazard x Vulnerability, as given by the International Strategy Disaster Reduction committee (UNISDR 2004). Here, risk is defined as the probability of harmful consequences resulting from interactions between natural or human-induced hazards and vulnerable conditions within a social or community system. Vulnerability is defined as the characteristic of a person or group and their situation that influences their capacity to anticipate, copy with, resist, and recover from the impact of a natural hazards that threaten their life, well - being and livelihood (Wisner, Blaikie et al. 2003). Resilience is in part the opposite of vulnerability, but both resilience and vulnerability notions have common components of interest - the shocks and stresses, the response of the system, and the capacity for adaptive action (Adger 2000, Adger, Hughes et al. 2005, Wilson 2012). Risk can be minimized through reducing the degree of vulnerability or heightening the resilience of community to natural disasters. In this research domain, we focus on community resilience to disaster, which was defined as the ability of a group or community to respond to and recover from disaster and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-events, and adaptive processes that facilitate the ability of the social systems to re-organize, change, and learn in response to a threat (Adger 2000, Cutter, Barnes et al. 2008). Community here is defined as an entity with geographic boundaries (e.g., a village) where people or a group of people have similar characteristics, relate to each other as a community and share a common physical, environmental, economic, relational, political or social ways (Kumar 2005).

The concept of community resilience is increasingly being embraced as a framework for enhancing disaster readiness and response capability (Kathleen Sherrieb 2012). However, assessing community resilience is a complicated process due to the dynamic interaction of populations, communities, and societies as well as the environment (Mayunga 2007). A number of models and frameworks have been developed in order to assess community resilience (Mayunga 2007, Cutter, Barnes et al. 2008, Norris, Stevens et al. 2008, Wilson 2012). Cutter et al. (2008) employed six dimensions for assessing community resilience including ecological, social, economic, institutional, infrastructure, and community competence whereas Norris and colleagues (2008) identified four primary sets of capacities for community resilience: Economic Development, Social Capital, Information, and Communication Competence (with 19 indicators). Mayunaga (2007) utilized five major forms of capital which can contribute to reducing vulnerability and increasing community disaster resilience, i.e., social capital, economic capital, human capital, physical capital, natural capital encompassing 15 indicators. In investigating the impacts of globalization processes on community resilience, Wilson (2012) proposed a framework focusing on a social resilience approach for understanding community resilience as a conceptual space as the intersection between economic, social, and environmental capital including 36 indicators. Through those researches, it can be seen that various dimensions can be used for assessing resilience community and there was a high agree on conceptualizing community resilience linked with social, economic and environmental capital that could reduce vulnerability and enhance community resilience to natural disaster (Bourdieu 1987, Adger 2000, Stimon, Western et al. 2003, Cutter, Barnes et al. 2008, Magis 2010, Wilson 2010).

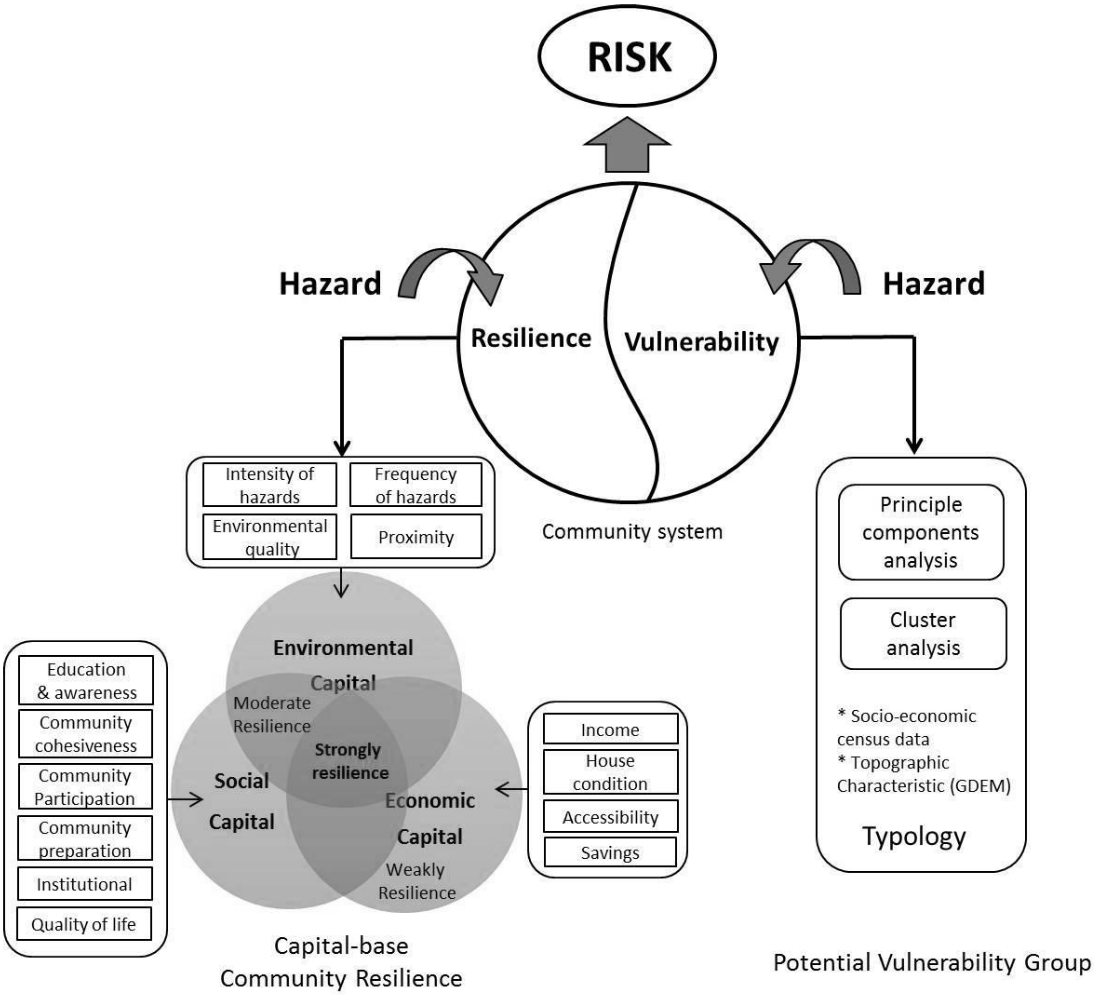


**Figure 31 Conceptual framework of Community Resilience Assessment**

This paper utilized the community resilience framework given by Wilson (2012) as its conceptual basis for assessment community resilience since it applies to natural disasters, particularly flood disasters. This framework enables any studies to apply its various indicators (36 indicators) as well as loose questions list (154 questions) in investigating socio, economic, and environmental capital. The advantage of this framework is that there is no prescription about how many indicators and questions are needed to assess each of the three capitals. The number of indicators and questions for addressing each capital will vary depending on research questions, types of disturbance, specific resilience issues under investigation as well as the complexity of community structure (Wilson, 2012).

The conceptual framework of Community Resilience Assessment is depicted in Figure 31 through the relationship between Risk, Hazard, Vulnerability, and

Resilience. Community resilience was measured based on the capital-based community resilience, which represented an interaction between the three capital pillars of resilience: economic capital, social capital, and environmental capital. Each capital has several corresponding variables that are used to measure the degree of resilience of a given community. The strongest form of community resilience can be found at the intersection between strong economic, social, and environmental capital. A community where only two of these capitals are well developed can be characterized as only moderately resilient, or indeed as moderately vulnerable, while a community that has only one (or no) well-developed capital is generally characterized as weakly resilient/highly vulnerable (Wilson, 2012). The community resilience assessment was conducted based on typology and a questionnaire survey, which will be clearly explained in the following methodology section.

## 5.3. Flood Disaster and Policies on Prevention and Mitigation Natural Disaster in Hoa Vang Rural District, Da Nang City

### 5.3.1. Flood Disaster in Hoa Vang Rural District

Hoa Vang is a rural district located in the western of Da Nang city. The district has an area of 736.9km$^2$ with a population of 123,024 people (2011). It consists of 11 communes, in which there are 3 plain communes (Hoa Chau, Hoa Tien, and Hoa Phuoc); 4 midland communes (Hoa Khuong, Hoa Phong, Hoa Nhon, and Hoa Son), and 4 mountainous communes (Hoa Lien, Hoa Bac, Hoa Ninh, and Hoa Phu). The topography here is complicated encompassing plains, hills and mountains. The mountain region occupies a large area of district (79.84%) with peaks of 700-1500m height, and steep slope (>40 degree). The hill areas are mainly low hills with average height of 50-100m occupying 15.75% of the whole district. The plain region is made up of narrow plain with average height of 2-10m.

With its characteristic of topography and the frequency of natural hazards, Hoa Vang has suffered many types of natural hazards such as typhoon, flood, flash flood, inundation, drought, and whirlwind (HVPC 2010a) (Table 20).

**Table 20 Natural hazard types affected to Hoa Vang district**

| STT | Name of hazards | Affected communes |
|---|---|---|
| 1 | Typhoons/Storm | 11 communes (Hoa Chau, Hoa Tien, Hoa Phuoc, Hoa Khuong, Hoa Phong, Hoa Nhon, Hoa Son, Hoa Lien, Hoa Bac, Hoa Ninh, Hoa Phu) |
| 2 | Riverine flood | 11 communes (Hoa Chau, Hoa Tien, Hoa Phuoc, Hoa Khuong, Hoa Phong, Hoa Nhon, Hoa Son, Hoa Lien, Hoa Bac, Hoa Ninh, Hoa Phu) |
| 3 | Flash flood | Hoa Bac, Hoa Phu, Hoa Phong, Hoa Nhon |
| 4 | Local flood | Hoa Chau, Hoa Lien, Hoa Nhon, Hoa Phong, Hoa Tien, Hoa Khuong |
| 5 | Drought | Hoa Bac, Hoa Phong, Hoa Nhon, Hoa Son |
| 6 | Whirlwind | Hoa Lien, Hoa Khuong |

Sources : (HVPC 2010a)

Severe natural disasters have caused loss of life, damaged livelihoods and infrastructure of local people in Hoa Vang district (Table 21).

**Table 21 Damage by some severe natural disasters in Hoa Vang district**

| Year | Disaster | Affected village | Damage |
|---|---|---|---|
| 11/1999 | Flash flood | Hoa Bac, Hoa Ninh, Hoa Phong, Hoa Phu | 5 people died |
| 10/2006 | Storm (Xangsane) | 11 communes | 11 people died<br>212 people injured<br>5276 houses collapsed completely<br>7350 houses lost roofs |
| 11/2007 | Riverine flood | Hoa Chau, Hoa Tien, Hoa Phuoc, Hoa Khuong, Hoa Phong, Hoa Nhon, Hoa Son, Hoa Lien, Hoa Bac | 1 person died<br>5 people injured<br>2 houses collapsed |
| 9/2009 | Storm and flood (Ketsana) | 11 communes | 2 people died<br>27 people injured<br>793 houses collapsed completely<br>691 houses lost roofs |

Especially the big floods in 1999, 2007 and the serious typhoons in 2006 and 2009 killed 19 people, injured 444 people and collapsed thousands houses in the whole district. 11 communes/11 communes have been affected by floods, flash floods including 89 villages /118 villages with a total of 20,114 households. Up to now, approximately 85,424 people have been influenced by this type of natural disaster (HVPC 2010a).

## 5.3.2. Policies for Natural Disaster Prevention, Response and Mitigation in Hoa Vang District

### 5.3.2.1. Organizational Structure of Steering Committee for Flood and Storm Control, Rescue and Relief Steering Committee in Hoa Vang District

The Steering Committee for Flood and Storm Control, Rescue and Relief (SCFSC) are established at the levels of Nation, Province, District and Commune and theirs operation are close in coordinate with each other. The SCFSC at national level undertakes activities that cover the complete spectrum of disaster management; from preparedness, response, and minimization of damages and losses, to recovery and rehabilitation from a disaster and mitigation of negative effects on the economy and environment. Under the administrative of the Central Committee, SCFSC at the province and district levels are set up by their People's Committee. These committees are headed by the Chairmen of People's Committee, with the Director of the Department of Agriculture and Rural Development (DARD) serving as Standing Deputy Head. Directors and Deputy Directors of relevant departments involved in local flood and storm control activities compose the membership. The Department of Agriculture and Rural Development is the standing agency for flood and storm control at the province level. At the district level (districts, towns and cities under provincial management), the district DARD is the standing office and advises the District SCFSC in the implementation of state management functions regarding local flood and storm control and disaster mitigation. At the commune level, the Commune People's Committee assigns a full-time staff member to work on flood and storm control and disaster mitigation as a standing position. Under the administration of Commune People's Committee, the team of sub-committee for flood and storm control at the village level is set up by the local community (MRC, 2006). The organizational structure of SCFSC in Hoa Vang district level is clear summarized as follows (Figure 32).

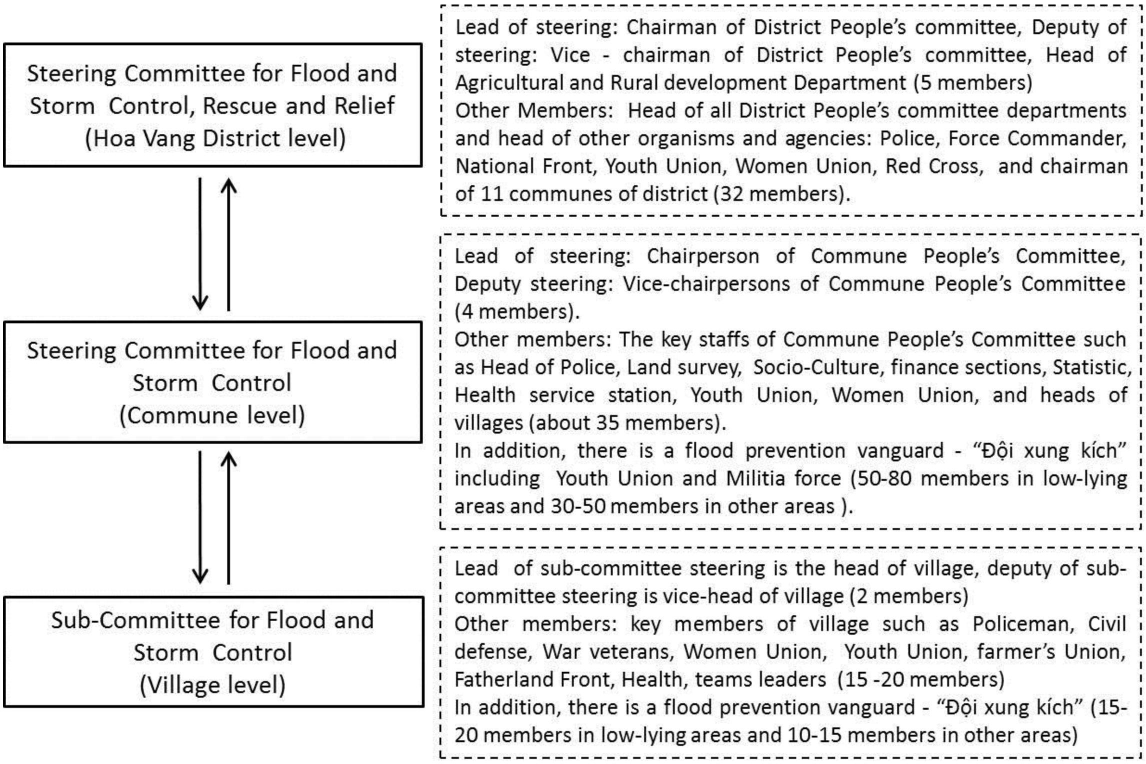


**Figure 32 Structure of Flood and Storm Control, Rescue and Relief Steering Committee in Hoa Vang district**

Source: (HVPC 2010a, HVPC 2010b).

### 5.3.2.2. Functions and Task of the Committee for Flood and Storm Control at District, Commune and Village Level

The district, commune, village CFSC assist People Committees in state management functions relating to flood and storm control and disaster mitigation within their administrative areas. Such functions include: to plan and oversee the implementation of disaster preparedness operations, dyke maintenance, disaster response, protection of economic activities and residential areas and also in recovery and rehabilitation of the disaster-affected communities before, during and after natural disaster occur. The detail tasks process of SCFSC are showed in Table 22.

**Table 22 Functions and tasks of Authorities and SCFSC on prevention and mitigation natural disasters in Hoa Vang district**

| Actions | Tasks of SCFSC at district and commune level |
| --- | --- |
| Before hazards (Direct) | Report on total assessment damages, coping experiences to natural disasters in the previous year and develop plans for FSCDM for this year.<br>Consolidate issues and enforce legal documents on forecasting, early warning, disaster response in district, commune and village level.<br>Disseminate and transfer knowledge, experience and legislation relating to flood and storm control and disaster mitigation within the areas of their administration (district, commune, village, and hamlet).<br>Inspect and assess frequently the safety of flood mitigation structures (dams, dykes reservoirs, etc…); construct, upgrade, manage and protect disaster preparedness and mitigation facilities and infrastructure.<br>Develop plans for flood and storm control and disaster mitigation for the entire area and for every focal point (in district level, commune level and village level); Monitor and evaluate periodically the implementation of disaster preparedness plans.<br>Prepare and provide rescue facilities and equipment; organize and train emergency response and volunteer groups, evacuate rout when flooding occurs;<br>Ensure adequate storage of food, medicines and other necessities at selected locations in flood-prone areas;<br>Develop the district annual planning for FSCDM based on the specific plan of commune and village and report to the city People's Committee. |
| During hazards (Response) | Receive information on flood and storm (24h/24h) and promptly report direct to the commune, village authorities and local residents for responding natural disaster.<br>Broadcast flood/storm information, develop and disseminate of warning messages, carry out urgent mobilization of resources and other measures.<br>Ensure regular, timely and smooth communication and instruction in district, commune and village level<br>Deploy emergency response teams (in district, commune and village level) to ensure a timely response to floods<br>Protect and reactivate disaster preparedness works for the local communities, evacuate people out of dangerous areas and protect the properties of individuals and of the village, commune.<br>Ensure both social and economic security and safety in the affected areas. |
| After hazards (Recovery) | Mobilize emergency response forces and resources to save people and property.<br>Relief and support to local people ensure security and enable a return to their normal lives as soon as possible.<br>Implement necessary measures for recovery of the local economy.<br>Organize environmental cleaning and disease prevention in local areas.<br>Repair the damaged flood mitigation structures (dykes, levees…), damaged infrastructure, transportation, irrigation system, medical, electric systems, radio station.<br>Conduct assessment on losses and damage.<br>Distribute rice seeds, agriculture material to support serious damaged households. |

Source: (FMMP and MRC 2006, HVPC 2010a)

## 5.4. Methodology

### 5.4.1. Typology Potential Vulnerability Flood Affected Villages

#### 5.4.1.1. Concept of Typology

A typology is defined as a classification of individual units into a series of categories that are useful for a particular objectives and purpose (Blunden, Pryce et al. 1998). Typology is widely used to describe pattern variance associated with social, economic and environmental or ecological processes (Meredith and SakasOlmedo 2012). Typology has been used broadly in various fields such as socio-economic typology of regions, counties, provinces, districts (Spilton, Solomon et al. 1981, Thinh and Duc 2005, Tsutsui 2005), rural - urban characteristic regions typology in Europe (Blunden, Pryce et al. 1998, Ballas, Kalogeresis et al. 2003, Bengs and Schmidt-Thomé 2006), farm system typologies (Madry, Mena et al. 2013, El-Osta 2014), coastal typology (Tym and Partners 2011), and crop-drought vulnerability typologies (Simelton, Fraser et al. 2009). The development of typologies can be linked to the very foundation of geography as a discipline whereupon the focus was on the interrelation between physical environments and human activity (Meredith and SakasOlmedo 2012).

The classification functions of typologies determine to which "type" a case can be characterized as belonging. Due to the complexity and large amounts of the variables and geographic units utilizing in typology, some attempts have been made in recent years to use multivariate data analytic techniques to reduce such data sets to manageable and comprehensible proportions involved factor analysis technique or principle component analysis (PCA) and cluster analysis (CA) technique. Principle component analysis was used to reduce the rank of the data matrix to a smaller set of basic composite variables whereas cluster analysis was used to identify geographic units with similar profiles in terms of scores on conceptually selected variables (Spilton, Solomon et al. 1981). Geographic units (e.g. regions, villages) in specific cluster share many characteristics but are very dissimilar to objects not belonging to that cluster (Mooi and Sarstedt 2011). Principle components analysis is a method for transforming the variables in a multivariate data set into new variables which are uncorrelated with each other and which account for decreasing proportions of the total variance of the original variables. Cluster analysis technique are concerned with exploring data sets to assess whether or not they can be summarized meaningfully in terms of a relatively small number of groups or clusters of objects or individuals which resemble each other and which are difference in some respect from individuals in other clusters. In a clustering context, PCA provides a means of projecting the data into a lower dimensional space, so as to make visual inspection hopefully more informative (Mooi and Sarstedt 2011).

In this study, typology was used for grouping flood affected villages in the Hoa Vang rural district according to indicators relevant to socio-economic and physical characteristics under perspective of potential vulnerable to flood disaster. Thereby the result of potential vulnerability of flood affected villages typology would provide the background for assessing community resilience to flood disaster.

#### 5.4.1.2. Selection of Variable for Typology

##### a. Pilot Areas and Selected Villages

Hoa Vang is a suburban of Da Nang city, which includes 11 communes and 118 villages. The topography here is very diverse, combining mountains, hill and plain areas, where the mountainous area dominates (79.84%) (Figure 33).

As already mentioned, Hoa Vang is a rural district and annually exposed to natural disasters, especially flood disasters including riverine flood and flash flood. According to Natural disaster report of Da Nang's Committee for Flood and Storm Control (2008), a total of 11/11 communes and 87/118 villages in Hoa Vang were affected in historical flood of 2007. Those villages located along rivers near the mountainous areas (Northwest of Hoa Vang) are highly exposed to flash flood, whereas the villages located in plain areas are highly exposed to riverine flood. In order to enhance the effectiveness of emergency disaster warnings contributing to reducing and preventing flood disasters, Vietnam's Ministry of Natural Resources and Environment has issued regulations of building flood pillar in local areas of the country. Flood pillar is a concrete landmark which provides some vital flood information such as the place name of flood area, code number of pillar, water warning level (I, II or III correspond to level of dangerous flood condition) as well as flood depth level of some historical flood events (Figure 34).

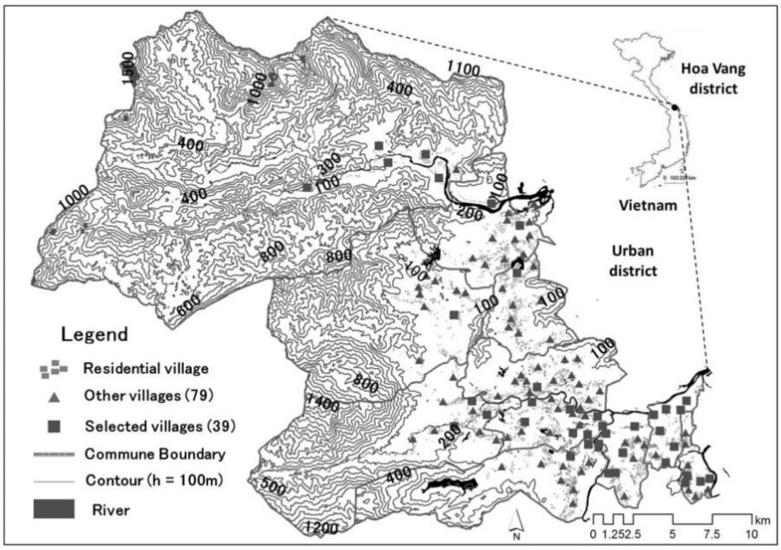


**Figure 33 Location of pilot areas and selected villages**


**Figure 34 Flood pillars from field survey**

a. Flood pillar structure in Thai Lai village, Hoa Nhon commune, Hoa Vang district
b. Measure flood depth and co-ordinate of flood pillar

Flood pillar is almost located in areas of high frequency and magnitude damage of flood and have high density of residence and of easy identification. From 1999 to 2013, 39 villages of Hoa Vang district which were severely affected by flood hazards have been built with flood pillars by the local government for emergency flood disaster warnings. Based on the data from Da Nang's Committee for Flood and Storm Control and field survey results, we selected those 39 villages for cluster analysis the potential vulnerability of flood affected villages (Table 24). The authors have surveyed and checked a total of 18 flood pillars within 39 flood pillars in the study areas.

### b. Variables Selection

Social indicators such as population, employees per economy sector, and households at the poverty level, as well livelihood conditions are the significant factors that identify vulnerability (S. Kienberger , Fekete 2009). The socio-economic data in village level of Hoa Vang district was collected basing on the Agriculture - Aquaculture Rural Census of Hoa Vang in 2011 and Population and Housing Census of Da Nang city in 2009. The physical characteristic of villages was collected by extracting topographic characteristic from ASTER GDEM of Da Nang city.

**Table 23 Variables used for potential vulnerability typology of flood affected villages**

| Parameter | Variables | Description | Unit | Year |
|---|---|---|---|---|
| Demography | Pop | Population | Person | 2011 |
| | Num_ho | Number of household | Household | 2011 |
| | Scale_ho | Scale of household | People/ Household | 2009 |
| | Depedent_ho | Rate of dependent population | % | 2009 |
| Labor and employment | Pop_WAge | Rate of population in working age | % | 2011 |
| | AgrForAqu_ho | Rate of Agriculture Forestry Aquaculture household | % | 2011 |
| | IndCon_ho | Rate of Industry - Construction household | % | 2011 |
| | BusSer_ho | Rate of Business - Service household | % | 2011 |
| Livelihood conditions | Poverty_ho | Rate of poverty household | % | 2009 |
| | SanLa_ho | Rate of household using sanitary latrines | % | 2009 |
| | NonLa_ho | Rate of household have no latrines | % | 2009 |
| | Se_Perma_ho | Rate of permanent house and semi-permanent house | % | 2009 |
| | Other_ho | Rate of other house | % | 2009 |
| | RuWater_ho | Rate of household using running water | % | 2009 |
| | WeWater_ho | Rate of household using well water | % | 2009 |
| | TV_ho | Rate of household using TV | % | 2009 |
| | Moto_ho | Rate of household having motorcycle | % | 2009 |
| | Tel_ho | Rate of household having table telephone | % | 2009 |
| | Ra_ho | Rate of household having radio | % | 2009 |
| Topographic | Ave_Elevation | Average elevation | m | GDEM |

Source: (DNSO 2010c, HVSO 2012)

Therefore, typology in this research is based on the analysis of 19 variables obtained from census data of the Hoa Vang District (DNSO 2010c, HVSO 2012) including characteristics of demography (4 variables), labor and employment (4 variables), and living condition (11 variables); 1 variable of topographic characteristic extracting from GDEM for classifying the potential vulnerability groups of flood affected villages (Table 23).

#### 5.4.1.3. Procedure of Potential Vulnerability Flood Affected Village Typology

Flood affected villages typology was constructed by using two multivariate statistical techniques, respectively Principle Component Analysis (PCA) and Cluster Analysis (CA). Initially, individual geography unit (village) profiles were developed with component scores derived from a general principle component analysis. Then these profiles were clustered to identify the groups of geography units with maximally similar profiles. The average profiles of the geographic units falling into each cluster were considered to represent geographic "type".

**Table 24 List of selected villages for typology**

| No | Village | Commune | No | Village | Commune | No | Village | Commune |
|---|---|---|---|---|---|---|---|---|
| 1 | Pho Nam | Hoa Bac | 14 | Tuy Loan Dong 2 | Hoa Phong | 27 | Qua Giang 2 | Hòa Phước |
| 2 | Nam Yen | Hoa Bac | 15 | Bo Ban 2 | Hoa Phong | 28 | Ngon Tho 1 | Hoa Phuoc |
| 3 | Nam My | Hoa Bac | 16 | Thach Bo - HP | Hoa Phong | 29 | Nhon Tho 2 | Hoa Phuoc |
| 4 | Loc My | Hoa Bac | 17 | Cam Toai Dong | Hoa Phong | 30 | Giang Nam 1 | Hoa Phuoc |
| 5 | Ta Lang | Hoa Bac | 18 | Cam Toai Trung | Hoa Phong | 31 | Cam Nam | Hoa Chau |
| 6 | Quan Nam 2 | Hoa Lien | 19 | An Tan | Hoa Phong | 32 | Bau Cau | Hoa Chau |
| 7 | Truong Dinh | Hoa Lien | 20 | Duong Lam 2 | Hoa Phong | 33 | Dong Hoa | Hoa Chau |
| 8 | Dong Son | Hoa Ninh | 21 | Cam Ne | Hoa Tien | 34 | Tay An | Hoa Chau |
| 9 | An Ngai Tay 2 | Hoa Son | 22 | Thach Bo - HT | Hoa Tien | 35 | Phong Nam | Hoa Chau |
| 10 | Thai Lai | Hoa Nhon | 23 | Bac An | Hoa Tien | 36 | Quang Chau | Hoa Chau |
| 11 | Dong Lam | Hoa Phu | 24 | An Trach | Hoa Tien | 37 | Giang Dong | Hoa Chau |
| 12 | Hoa Phuoc | Hoa Phu | 25 | Le Son 2 | Hoa Tien | 38 | Thon 4 | Hoa Khuong |
| 13 | Hoi Phuoc | Hoa Phu | 26 | La Bong | Hoa Tien | 39 | La Chau | Hoa Khuong |

Prior to the analysis with PCA, it was necessary to check whether the data set is appropriate to be factored. A Kaiser-Meyer-Olkin Measure of Sampling (KMO) and Bartlett's test of sphericity was conducted to check the appropriateness of factor analysis for further analysis. The value of KMO should be greater than 0.5 if the sample is adequate (Field 2005). The KMO and Bartlett's test has been performed for 20 selected variables (Table 25) with the value of 0.641 which satisfies the requirement.

**Table 25 Statistical description and summary of the variables used in PCA**

| Variables | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Pop | 39 | 242 | 2330 | 1009.77 | 544.032 |
| Num_ho | 39 | 63 | 653 | 269.03 | 143.657 |
| Scale_ho | 39 | 3.2 | 4.2 | 3.726 | .2342 |
| Depedent_ho | 39 | .53 | .85 | .6618 | .06545 |
| Pop_WAge | 39 | 42.52 | 63.26 | 56.4721 | 5.14118 |
| AgrForAqu_ho | 39 | .00 | 90.48 | 45.1613 | 22.57208 |
| IndCon_ho | 39 | 1.82 | 40.74 | 20.6144 | 12.15877 |
| BusSer_ho | 39 | 1.59 | 59.29 | 26.3010 | 14.94183 |
| Poverty_ho | 39 | 8.1 | 73.2 | 27.896 | 14.6773 |
| SanLa_ho | 39 | 6.45 | 99.63 | 72.8221 | 24.70305 |
| NonLa_ho | 39 | .00 | 75.61 | 13.1354 | 19.83535 |
| Se_Perma_ho | 39 | 64.52 | 100.00 | 96.6164 | 6.20765 |
| Other_ho | 39 | .00 | 35.48 | 3.3856 | 6.20590 |
| RuWater_ho | 39 | 0 | 100 | 26.52 | 33.633 |
| WeWater_ho | 39 | .00 | 100.00 | 64.1969 | 37.16091 |
| TV_ho | 39 | 62.20 | 96.87 | 85.9215 | 7.60620 |
| Moto_ho | 39 | 35.37 | 91.44 | 74.6308 | 10.50034 |
| Tel_ho | 39 | 19.09 | 90.21 | 47.2900 | 13.16028 |
| Ra_ho | 39 | .0 | 59.7 | 11.903 | 15.7430 |
| Ave_Elevation | 39 | 6.55 | 30.20 | 9.9151 | 4.18612 |
| Valid N (list wise) | 39 | | | | |

Analyzed by IBM SPSS StatisticsVerson 21.

The number of villages employed for analyzing was 39. The Standard Deviation (Std.) is a measure of how spread out numbers is. Within 20 variables used for analyze, the pop and num_ho variables showed the high value of Std. due to the distribution characteristics of population in the rural areas. The number of components has been retained by using PCA method and varimax rotation with eigenvalues greater than 1 (Field 2005). Then components extracted from PCA were used in CA by Ward's method. The hierarchical classifications produced by either the agglomerative or divisive route may be represented by a two-dimensional diagram known as a dendrogram, which illustrates the fusions or divisions made at each stage of the analysis (Everitt B.S 2011).

## 5.4.2. Questionnaire Survey and Community Resilience Assessment

### 5.4.2.1. Community Data Collection

A variety of qualitative and quantitative research methods were used for community data collection. Firstly, secondary data collection and literature/archival documents as well as the pre-result in typology of potential vulnerability villages in Hoa Vang were conducted in 2012 in order to define the pilot site and indicators in questionnaires for assessing community resilience to flood disasters. Secondary, first field survey in Hoa Vang rural district was conducted in March, 2013 with individuals interviews to key informants including government officials, chiefs of mass organization, public officers, and village leaders. Flexibly interviews were used to elicit information about caused of flooding, flood experiences, historical socio-economic and political enhancing resilience, as well as coping strategies of local authorities and local people. Based on the results above, the questionnaire were designed and pre-tested in Hoa Phong communes by consultants and the authors in the final week of May, 2013. Finally, the household questionnaires were accomplished for final questionnaire survey in target villages.

The sample of households was limited using a simplified formula of Yamane (1967) to calculate the sample size

$$n = \frac{N}{1 + NE^2} \quad (3)$$

Where: n: sample size/number of sample; N: Total number of household size;

E: margin of error desired/error tolerance (Yamane 1967)

Then the divisions in the target villages in Hoa Vang district were compared before using simple random sampling to collect the data. Questionnaires were carried out by the authors with the assistance of Hoa Vang Statistical Office's staffs experienced in survey technique (groups of 6 members), who were also involved in the piloting and final drafting of the questionnaire. In each household, the male household head or his wife was interviewed or, if both were absent, the eldest member of the household present. The length of each household interview was around 1 hour including face to face interview with the respondent's household and capturing the location and image of household by GPS camera or handheld GPS device. Interviews were conducted during the day to fit around the community's livelihood activities and they took nearly three week (June 2013) for completion.

In additional, GIS technology also was utilized in accomplishing the community resilience assessment. GIS has captured, organized and managed conventional data sets such as road network, river and channel network, land use, elevation, flood emergency response facility, and socio-economic data, community resilience indicators which were collected through the household survey. The proximity analysis was then populated with households to identify some environmental capital contributing to community resilience to flood disasters. Firstly, images captured by handheld GPS device or GPS camera in interviewed households were imported to map database in ArcGIS. A buffer analysis was then utilized to calculate the environment capital variables such as proximity to river, proximity to safe shelter and proximity to main road for conduct community resilience assessment in the target villages.

#### 5.4.2.2. Dimension and Variables for Measuring Community Resilience

Based on the conceptual framework of Community Resilience Assessment as defined above, a structure questionnaire used a multiple - choice format which focused on the parameters of 3 dimensions defined as: (i) Economic capital, (ii) Social Capital, and (iii) Environmental Capital. Additional variables were included in the questionnaire such as geographic location, age, and gender of the respondents. Each type of capital corresponded to various variables: 11 variables were used to investigate economic capital, 26 to explore social capital, and 10 to assess environmental capital (Table 26). A combination of quantitative and qualitative approaches was used to analyze community resilience. The quantification of resilience for each community was based on a subjective ranking score of 1, 2, or 3 corresponding to low, medium and high resilience, respectively, referring to the community resilience and global indicators of strong and weak economic, social, and environmental capital (Razafindrabe, Parvin et al. 2009, Wilson 2012).

**Table 26 Variables used in Community Resilience Assessment**

| Capital | Variables | Description |
|---|---|---|
| Economic capital (11 variables) | Personal income | <1 million VND = 1; 1-2 million VND=2; >2 million VND =3 |
| | Diverse income | 1 source=1; 2 source = 2, >2 source = 3 |
| | Storey | 1 storey = 1; 1 storey + mezzanine=2; >1 storeys = 3 |
| | House construction | Old (>10 years) = 1; Recent (5-10 years) = 2; New (<5 years) = 3 |
| | House level | <0.5m = 1; 0.5-1m = 2; >1m=3 |
| | Transport interruption | High = 1; Medium = 2; Low = 3 |
| | Clean water access | Low = 1; Medium = 2; High = 3 |
| | Health service access | Low = 1; Medium = 2; High = 3 |
| | Education access | Low = 1; Medium = 2; High = 3 |
| | Internet access | Low = 1; Medium = 2; High = 3 |
| | Savings | Don't have = 1; Maybe have = 2; Certainty have = 3 |
| Social capital (26 variables) | Education | Illiterate =1, Under High school =2, Higher = 3 |
| | Awareness | No important = 1; Normal = 2, Important = 3 |
| | Local knowledge | No important = 1; Normal = 2, Important = 3 |
| | Get help | Don't have = 1; Maybe have = 2; Certainty have = 3 |
| | Strong cohesiveness | Low = 1; Medium =2; High = 3 |
| | Willing to help | Low = 1; Medium =2; High = 3 |
| | Community activities | Low = 1; Medium =2; High = 3 |
| | Discuss together | Low = 1; Medium =2; High = 3 |
| | Discuss leader | Low = 1; Medium =2; High = 3 |
| | Disaster mitigation effort | Low = 1; Medium =2; High = 3 |
| | Experience learning | Low = 1; Medium =2; High = 3 |
| | Community connectivity | Low = 1; Medium =2; High = 3 |
| | Trust and hope | Low = 1; Medium =2; High = 3 |
| | Committed to well-being | Low = 1; Medium =2; High = 3 |
| | Satisfy life | Low = 1; Medium =2; High = 3 |
| | Decision making | Low = 1; Medium =2; High = 3 |
| | Training participation | Low = 1; Medium =2; High = 3 |
| | Women participation | Low = 1; Medium =2; High = 3 |
| | Community Preparation | Less = 1; Moderate = 2, Good = 3 |
| | Hazards coping plan | Don't have = 1; Maybe have = 2; Certainty have = 3 |
| | Volunteer provision | Don't have = 1; Maybe have = 2; Certainty have = 3 |
| | Accuracy information | Low = 1; Medium =2; High = 3 |
| | Effective early warning | Low = 1; Medium =2; High = 3 |
| | Evacuation plan | Low = 1; Medium =2; High = 3 |
| | During disaster support | Low = 1; Medium =2; High = 3 |
| | Post disaster support | Low = 1; Medium =2; High = 3 |
| | Trust to local government | Low = 1; Medium =2; High = 3 |
| Environmental capital (10 variables) | Flood depth | > 2m = 1; 1-2m =2; <1m = 3 |
| | Flood damage | High = 1; Medium = 2; Low=3 |
| | Flood frequency | Frequently=1; Medium=2; Less frequently=3 |
| | Water quality | No ensure = 1; Normal = 2; Good = 3 |
| | Sanitation condition | No ensure = 1; Normal = 2; Good = 3 |
| | Solid waste | No ensure = 1; Normal = 2; Good = 3 |
| | Drainage system | No ensure = 1; Normal = 2; Good = 3 |
| | Proximity to river | <100m=1, 100-200m=2, >200m=3 |
| | Proximity to safe shelter | >100m=1, 50-100m=2, <50m=3 |
| | Proximity to main road | >100m=1, 50-100m=2, <50m=3 |

Source: Modified from Shaw and Sharma 2011, Pfefferbaum and Pfefferbaum et al 2011, Wilson 2012, Kathleen and Pfefferbaum et al. 2012.

For example, if the question 'What is the highest flood level in your house during last 20 year?' was answered '2.1m', then a score of '1' (indicators of high vulnerability or low environmental resilience) was allocated. Conversely, if the question 'what is your level of your household in participating in training course on enhancing awareness of local residential' was answered 'very high' a score of 3 was given (indicator of strong social capital (Table 25). An average score was calculated for each of the three capitals and then an overall average for the three capitals was established, enabling quantitative comparison of community resilience between the target communities.

## 5.5. Result and Discussion

### 5.5.1. Potential Vulnerability Group Classification

#### 5.5.1.1. Typology Model of Potential Vulnerability Flood Affected Villages

In order to avoid dealing with variables measures by different units, data standardization was performed before carrying out the PCA analysis. The PCA of the 20 variables resulted in extraction of five components with a cumulative percentage of the total variance of 73.74%, all of which had eigenvalues of over 1. The characteristics of each component are indicated in Table 27.

*Component 1:* The items with the highest loading on this component represent a combination of characteristics often associated with center towns, communes. This factor is therefore considered to represent *Level of living condition*. It shows high positive loadings for items representing living condition (Rate of household using sanitary latrines, Rate of permanent house and semi-permanent house, rate of household using TV, having motorcycle); scale of household; and Rate of Industry-Construction household. High negative loadings occur for rate of household have no latrine and rate of poverty household.

*Component 2:* This component clearly represents the *Scale of population*. It contains high positive loadings for items referring Population, Number of household, rate of population working ages. Only one negative loading occurs for average elevation.

*Component 3:* In this component some types of variables are included among the high loading (positive) items. The items with the high loadings from Rate of population working age and Rate of household using well water. Whereas negative loadings items occur for rate of dependent household and rate of household using running water. It can be interfered the term *Labor force and water sanitations condition* and for this component.

**Table 27 Contribution of each component (Varimax rotation) in PCA**

| | |
|---|---|
| **Component 1** | |
| % of Variance | 27.13 |
| % Cumulative | 27.13 |
| Scale of household | 0.715 |
| Rate of Industry - Constructions household | 0.66 |
| Rate of Poverty household | -0.55 |
| Rate of household using sanitary latrines | 0.88 |
| Rate of household have no latrines | -0.83 |
| Rate of permanent house and semi-permanent house | 0.58 |
| Rate of other house | -0.58 |
| Rate of household using TV | 0.79 |
| Rate of household having motorcycle | 0.80 |
| **Component 2** | |
| % of Variance | 13.77 |
| % Cumulative | 40.90 |
| Population | 0.91 |
| Number of household | 0.93 |
| Rate of population in working age | 0.60 |
| Average elevation | -0.50 |

| | |
|---|---|
| **Component 3** | |
| % of Variance | 12.05 |
| % Cumulative | 52.95 |
| Rate of dependent household | -0.72 |
| Rate of population in working age | 0.53 |
| Rate of household using running water | -0.81 |
| Rate of household using well water | 0.81 |
| **Component 4** | |
| % of Variance | 11.16 |
| % Cumulative | 64.11 |
| Rate of Agriculture Forestry Aquaculture household | -0.78 |
| Rate of Business-Service household | 0.89 |
| **Component 5** | |
| % of Variance | 9.63 |
| % Cumulative | 73.74 |
| Rate of permanent house and semi-permanent house | -0.64 |
| Rate of other house | 0.64 |
| Rate of household having radio | 0.77 |

Source: Analyzed by IBM SPSS StatisticsVerson 21.

*Component 4:* This is a bipolar component, containing one item with high positive for Rate of Business –Service household and one item with high negative for rate of Agriculture - Forestry - Aquaculture. This component is considered to represent *Condition of occupation and household economy*.

*Component 5:* The high loading items on house conditions represent of characteristics associate with the remote rural areas (temporary household rate, having radio household rate). In addition high negative loading occur for permanent and semi-permanent household rate. Therefore, the component as a whole is considered to represent *Low housing conditions*.

The five components retained were employed in cluster analysis (CA) with hierarchical methods to identify groupings of villages which had relatively similar components profiles for providing more information about socio-economic conditions. Based on the rescale distance cluster combine value in Dendrogam of Cluster analysis (with Ward's method), five groups of villages were delivered (Figure 35, Figure 36, Table 27, and Table 28). The characteristic of the five components allowed classification of 39 flood affected villages into five group type under perspective of potential vulnerable to flood disaster: (I) Very low potential vulnerability, (II) Low potential vulnerability, (III) Medium potential vulnerability, (IV) High potential vulnerability, and (V) Very high potential vulnerability.

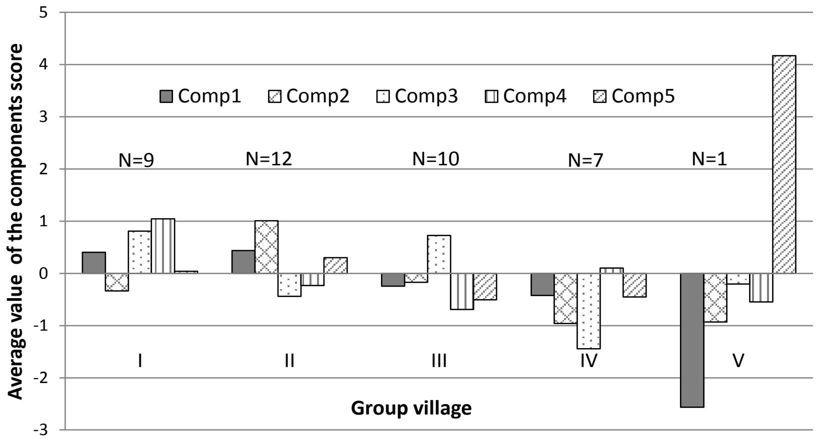


**Figure 35 The average characteristics of five groups of potential vulnerability villages**

*Group I - (Very low potential vulnerability):* The profile shows the villages in this group slightly urban. It has a high score (positive) in component 1 (*Level of living condition.*), component 3 (*Labor force and water sanitations condition),* component 4 *(Condition of occupation and household economy)*, and slightly positive value in component 5 *(Low housing conditions)*. There has only the component 2 (*Scale of population*) in negative value (relative low value). This can be interfered that this group of villages have good living conditions, economic development and abundant labor force.

*Group (II) - Low potential vulnerability*: The characteristic of the profile of this group is relative high score (positive) in component 1 (*Level of living condition*), component 2 (*Scale of population*), slightly positive in component 5 (*Low housing condition*), and relative high score (negative) in component 3 (*Labor force and water sanitations condition*), and component 4 (*Condition of occupation and household economy*). This combination of those components seems consistent with suburban communities.

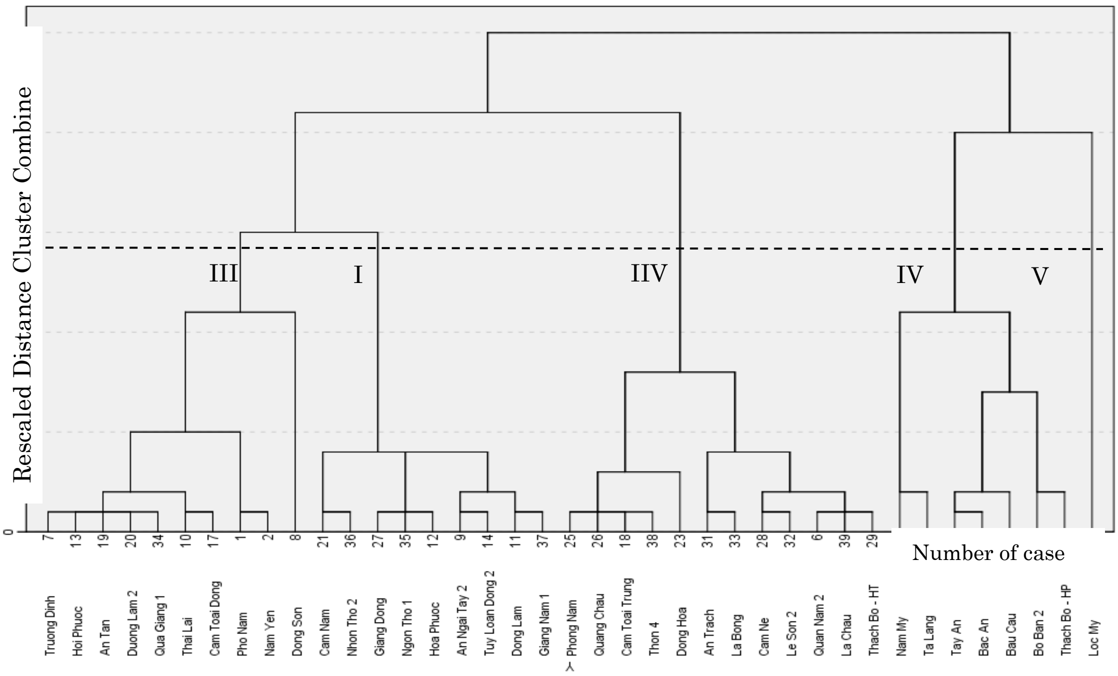


**Figure 36 Dendrogram producing from a cluster analysis (Ward methods)**

**Table 28 General typology resulting from the Wards' method using SPSS**

| Cluster | No. of villages | Villages |
|---|---|---|
| I | 9 | These villages primarily located in the center areas of communes, along highways, surrounding urban areas and on progress of urbanization. An Ngai Tay 2, Cam Nam, Dong Lam, Giang Dong, Giang Nam1, Hoa Phuoc, Nhon Tho 1, Nhon Tho 2. Tuy Loan Dong 2 |
| II | 12 | These villages primarily located in the plain areas of Hoa Vang district including An Trach, Cam Ne, Cam Toai Trung, Dong Hoa, La Bong, La Chau, Le Son 2, Phong Nam, Quang Nam 2, Quang Chau, Thach Bo (Hoa Tien commune), and Thon 4. |
| III | 10 | These villages located in the hill and mountainous areas of Hoa Vang district including An Tan, Cam Toai Dong, Dong Son, Duong Lam 2, Hoi Phuoc, Nam Yen, Pho Nam, Qua Giang 2, Thai Lai, Truong Dinh |
| IV | 7 | These villages mainly located in the remote areas of mountainous commune of Hoa Bac commune and riverine villages of Hoa Phong and Hoa Phuoc communes including Bac An, Bau Cau, Bo Ban 2, Nam My, Ta Lang, Tay An, and Thach Bo (Hoa Phong commune) |
| V | 1 | This village locate in the remote and mountainous area of Hoa Bac commune, Hoa Vang district Loc My |

*Group (III) - Medium potential vulnerability:* This group has relative low negative score in component 1 (*Level of living condition*) and 2 (*Scale of population*), relative medium in component 4 (*Condition of occupation and household economy),* component 5 (*Low housing condition*) and shows a relative high score (positive) in component 3 (*Labor force and water sanitations condition*). It can be interfered that this group has a medium living condition, representing to the typically rural communities.

*Group (IV) - High potential vulnerability:* This group has a more moderate negative score in component 1 (*Level of living condition*), component 2 (*Scale of population*), component 3 (*Labor force and water sanitations condition*), component 5 (*Low housing condition*), and slightly positive score in component 4 (*Condition of occupation and household economy*). These represent that villages in this group are remote rural areas with low socio-economic development condition.

*Group (V) - Very high potential vulnerability:* The most prominent characteristic of the profile of this group is a very high negative score in component 1 (*Level of living condition*), moderate negative score in Component 2 (*Scale of population),* slightly low negative score component 3 (*Labor force and water sanitations condition*) and component 4 (*Condition of occupation and household economy),* and very high score (positive) in component 5 (*Low housing condition*). This village has high rate of poverty household as well as very low living conditions.

#### 5.5.1.2. Selection Pilot Villages for Measuring Community Resilience

Based on the results of typology and the data on flood depth in each village, a selection of pilot villages for measuring community resilience was conducted. The flood depth pillar values from the field survey were used to select the villages which have the highest historical flood depth in each potential vulnerability group for community resilience assessment in the next process. In this study, we limited the study areas to four case study villages in four communes designated as group I to group IV: these were villages of Tuy Loan Dong 2 (Hoa Phong - a hilly and mountainous commune), Cam Ne (Hoa Tien - a flatland commune), Hoi Phuoc (Hoa Phu - a mountainous commune), and Tay An (Hoa Chau - a flatland commune), respectively. The village in group V (Loc My) was not selected because evaluation of the field survey showed that the flood pillar was far from the residential areas and the value of highest historical flood depth was lower (1.8 m flood depth value from the bottom of flood pillar) than those measured in the other villages (average flood depth value from 2.65-3.64m) (Figure 37).

### 5.5.2. Community Resilience Measurement

#### 5.5.2.1. Overall Sample

Applying a 5% error margin, household questionnaires were administered to 92, 130, 44, and 34 households of Tuy Loan Dong 2, Cam Ne, Hoi Phuoc, and Tay An villages, respectively (representing 27% of those villages' respective households), for a total of 300 households.

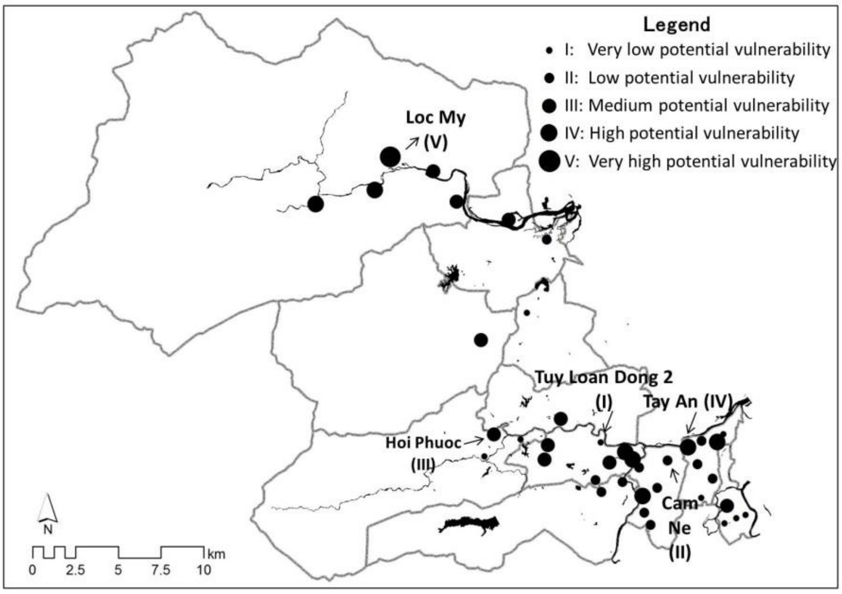


**Figure 37 Distribution of the five groups of potential vulnerability villages**

A randomly selected within each village is based on the household tabulation list which done by sorting in order of map location (following the main roads) for ensuring the highest representation. Thus the sampling applied in each village as follow: every fourth residential house was selected and within that, one house was chosen. Results from the overall sample of the household survey (Table 29) indicated that the sample is not particularly unequal in terms of gender, comprising 42% female and 58% male respondents.

**Table 29 Overall characteristic of households in Tay An, Hoi Phuoc, Tuy Loan Dong 2 and Cam Ne village**

| Key characteristic | Tay An (n=34) | Hoi Phuoc (n=44) | Tuy Loan Dong 2 (n=92) | Cam Ne (n=130 |
|---|---|---|---|---|
| Gender (%) | | | | |
| Male | 41.2 | 36.4 | 44.6 | 47.7 |
| Female | 58.8 | 63.6 | 55.4 | 52.3 |
| Age (%) | | | | |
| <25 | 5.8 | 6.8 | 7.6 | 2.3 |
| 25-65 | 55.8 | 68.2 | 78.3 | 64.6 |
| >65 | 38.2 | 25 | 14.1 | 33.1 |
| Marriage status (%) | | | | |
| Marriage | 67.6 | 63.6 | 76 | 66.9 |
| Single | 2.9 | 9.1 | 3.3 | 4.6 |
| Widower | 29.4 | 25 | 17.4 | 27.7 |
| Divorce | 0 | 2.3 | 3.3 | 0.8 |
| Education level (%) | | | | |
| Illiterate | 14.7 | 4.5 | 4.9 | 16.9 |
| Elementary school | 26.5 | 43.2 | 46.9 | 79.3 |
| Secondary school | 50 | 36.4 | 39.5 | 45.5 |
| High school | 5.9 | 6.8 | 7.4 | 19.5 |
| Higher | 2.9 | 9.1 | 9.9 | 7.8 |
| Occupation (%) | | | | |
| Self-organization business | 41.2 | 6.8 | 58.7 | 62.3 |
| Labor family | 2.9 | 47.7 | 7.6 | 28.5 |
| Wage | 26.5 | 22.7 | 25 | 0 |
| Unemployment/Retired | 29.4 | 22.7 | 8.7 | 9.2 |
| Household size (#) | | | | |
| Average # | 4.4 | 4.07 | 4.78 | 4.36 |
| Length of stay in village (%) | | | | |
| <15 years | 5.8 | 11.4 | 18.5 | 3 |
| >15 years | 94.2 | 88.6 | 81.5 | 97 |
| Experience past flood (%) | | | | |
| Yes | 100 | 59.1 | 98.9 | 96.9 |
| No | 0 | 40.9 | 1.1 | 3.1 |

Source: Analyzed by IBM SPSS StatisticsVerson 21.

On average, 43% of the sample respondents had a secondary level of education, varying from 36% in Hoi Phuoc village to 50% in Tay An village. The majority of the sample (67%) was aged between 25 and 65 years old, while those fewer than 25 and above 65 years old accounted for 5% and 28%, respectively. In terms of experience of a flood disaster, more than 96% of all respondents in Tay An, Tuy Loan Dong 2, and Cam Ne was affected households, ranging from 96.9% in Cam Ne to 100% in Tay An. These villages are located in a low altitude area, near the vicinity of water bodies, and are considered to be more susceptible to flooding than the whole villages (chronic flooding areas). However, in Hoi Phuoc village, only 59% of respondents claimed to have experienced a flood disaster. The reason for this is two-fold: on one hand, they live in a mountainous area with high elevation; on the other hand, this area experienced a serious flash flood in 1999, which affected only a portion of the residents in this village. The results also point out that the highest flood depth experience was in the range of 1.5-2m, comprising 57.7%, 41.2%, 37.0%, and 18.2% in Cam Ne, Tay An, Tuy Loan Dong 2, and Hoi Phuoc villages, respectively. This sample size is large enough and reasonably represented the flood disaster experience of the residents to analyze the resilience of rural people to flood disasters.

In order to facilitate the analysis of resilience community, we also appreciated/took account the spatial distribution of survey households and their level of experienced flood depth in concerning with the height of house floor.

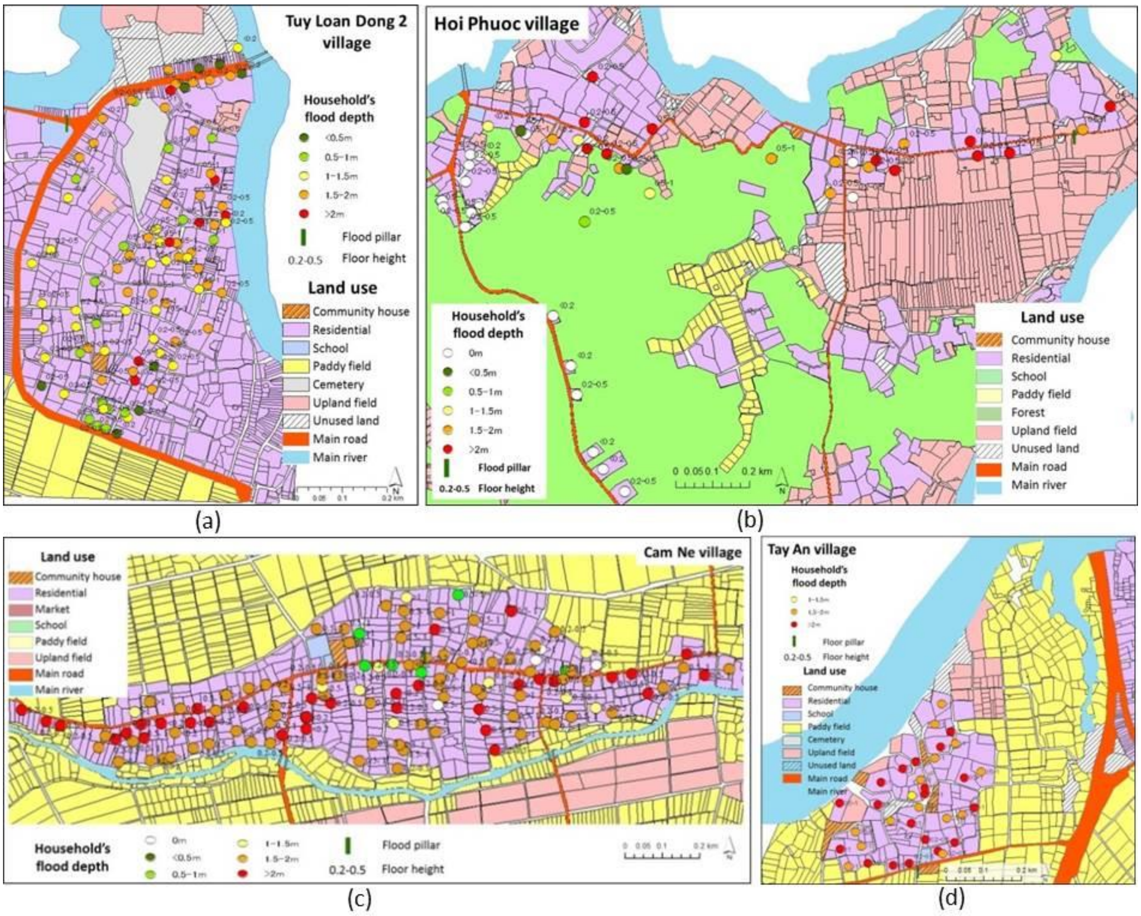


**Figure 38 Spatial distribution and flood disaster experience of household survey in targeted villages**

(a) Tuy Loan Dong 2 village (b) Hoi Phuoc village (c) Cam Ne Village (d) Tay An Village

The result shows that the residents locating near the main river and canal are more susceptible to high level of flood depth in compared to residents living in the inner parts. Those households have high level of house background seemed have low rate of exposing to high flood depth. From the Figure 38 it can be seen that the residents in Tay An village more exposed to high level of flood depth (>2m), comprising 55.9% in compare with the other villages. The obvious here can see that its location is contiguous with the main river and is one of the most depressed areas in Hoang Vang district. In contrast Hoi Phuoc mountainous village showed the low rate of exposing to high flood depth correspond with 45.4% of household experienced the level of flood depth under 0.5m. By looking at the initial results, difference spatial distribution/location of each village showed difference rate of exposure to flood hazards. Examining whether these villages are becoming resilience to flood disaster is needed to address for the second research question.

#### 5.5.2.2. Analysis of Community Resilience

The overall community resilience was mapped by calculating each capital (economic, social, and environmental) for the four target villages. A detailed radar diagram of each capital dimension of community resilience and overall community resilience is presented in Figure 39.

The economic capital points out the considerable difference in the range of scores between the variables. For instance, accessibility variables appeared to differ among the villages, where Hoi Phuoc had the highest score, followed by Tuy Loan Dong 2 and Cam Ne, whereas the savings variable seemed to have a relatively low and equivalent level for most of them. Almost all of the respondents stated that they have to earn and save money for their daily lives and it was not necessary to save money for coping with disaster. Variables of house conditions and income seemed to decline the economic capital of resilience. This is likely due to the limited capacity of rural residents to generate income (dependent on agricultural activities, low opportunities for employment), which leads to low level of housing conditions. However, only Tuy Loan Dong 2 showed the highest capital in the income per capital variable because it is located near the administrative center of Hoa Vang district and has a high number of households that work in the nonagriculture section. In brief, households in Hoi Phuoc are more resilient to flood disasters in terms of economic capital when compared to the other villages.

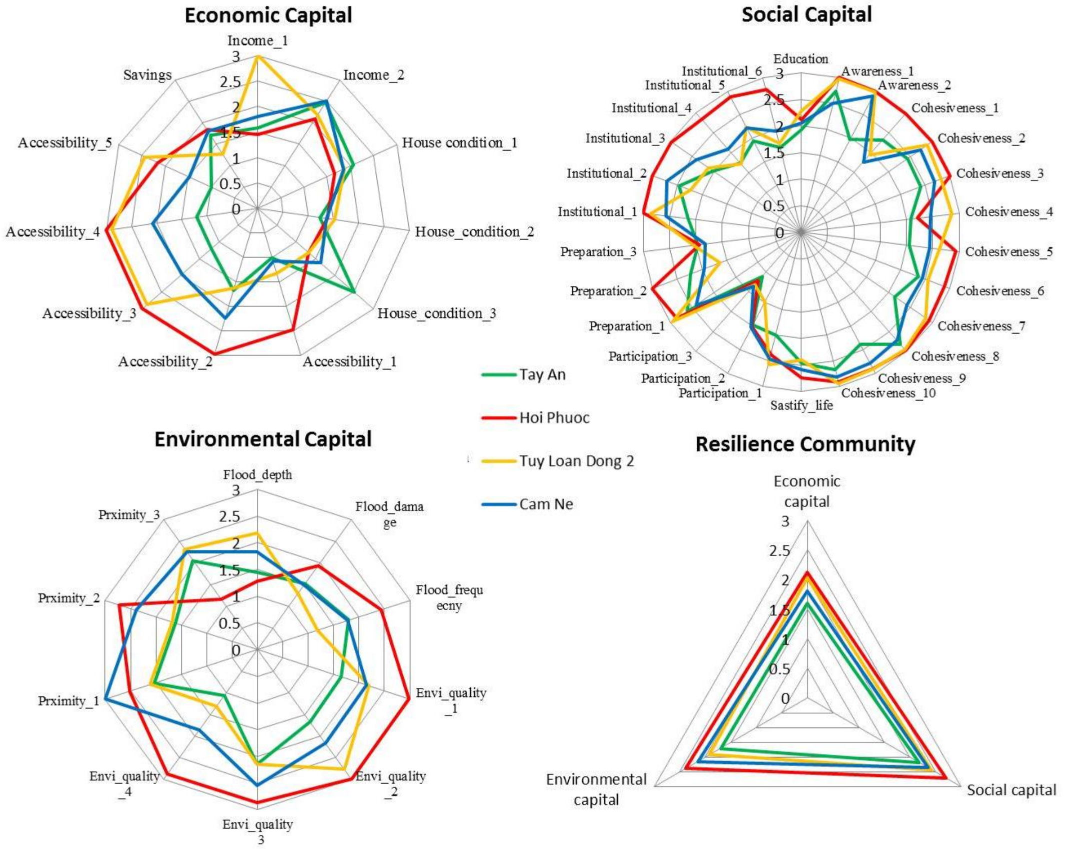


**Figure 39 Resilience Community for Tay An, Hoi Phuoc, Tuy Loan Dong 2 and Cam Ne village**

The social capital of the villages, as indicated by the household survey results, had more variables that appeared to show a relatively auspicious level. Community cohesiveness variables showed a relatively high score (average of 2.6) but a difference was still apparent among the four villages. Tay An residents formed a less cohesive community, especially in terms of attendance at community activities as well as joint discussions to solve community issues. The variables of community cohesiveness indicated that all villages have made an effort to take action to prevent and mitigate natural disasters and that the villages have a high belief in having a prosperous community in the future. Likewise, looking at institutional aspects shows a large variation between Hoi Phuoc and the other villages, ranging from 2.9 (in Hoi Phuoc) to 1.9 (in Tay An) on average. This strength in Hoi Phuoc village may be due to its experiences learned from the serious damage due to the flash flood in 1999 and good community collaboration as well as residents' awareness followed by well-functioning institutional activity in forming a development plan that addresses natural disaster issues. Aspects of education, satisfying life, community preparation, and community participation in disaster-related activities were not significantly different among the villages and had low scores, contributing to a decline in the social capital of resilience. Community participation in particular seemed to be fragile in most of the villages. However, in general, the form of the radar diagram for social capital was homologous in most villages and revealed the highest score when compared with the other capitals.

The environmental capital showed a significant variation in each variable between the villages. Tay An village highlighted a low score in most of variables of environmental capital, especially in drainage system, water quality, and sanitation conditions. Conversely, Hoi Phuoc showed an advanced score in those variables of environmental quality, with an average of 2.9. The shape of the radar diagram clearly shows that the level of flood depth does not closely relate to the flood damage degree in most of the villages. The reason for this could that the damage to residents by flood hazards was not only due to the flood depth but also to other factors such as the living conditions as well as the level of preparation to cope with flood hazards. The proximity variables reveal differences between the villages due to their dissimilar spatial distribution.

Overall, community resilience shows higher values for social capital, followed by environmental capital. This reflects the characteristics of rural residents, who still maintain their social networks and community cohesiveness, as well as a willingness to provide support to other people during disaster events. The results indicated the highest score of community resilience to flood disaster in Hoi Phuoc, followed by Cam Ne and Tuy Loan Dong 2.

### 5.5.3. Community Resilience Assessment

Investigating the typology based on the socio-economic and topographic characteristics of the flood affected villages allowed extraction of the potential vulnerability of villages and was used for analyzing the community resilience. Examining the relationship between potential vulnerability typology and community resilience with respect to the actual condition of flood disaster related issues in the four villages yielded the assessment of community resilience shown in Table 30.

**Table 30 Community Resilience Assessment in Tay An, Hoi Phuoc, Tuy Loan Dong 2 and Cam Ne village**

| No | Village | Potential Vulnerability | Community Resilience | Problems relate to flood disaster |
|---|---|---|---|---|
| 1 | Tay An | High | Moderate | Much trouble |
| 2 | Tuy Loan Dong 2 | Very low | Moderate | Less trouble |
| 3 | Cam Ne | Low | Moderate | Less trouble |
| 4 | Hoi Phuoc | Medium | High | No trouble |

In terms of potential vulnerability, Tay An village was classified into group IV (High potential vulnerability), characterized by a negative value in most components such as “Level of living conditions”, “Scale of population”, “Level of labor force”, and “Housing conditions” (Figure 35 and Table 27). The questionnaire survey showed that Tay An formation could be classified as showing medium community resilience but with a lower score than Tuy Loan Dong 2 and Cam Ne. Geographically, Tay An is located in the most low-lying region of the Hoa Vang district, and it suffers high flood damage to livelihood and life, as well as infrastructure. About 20 riverine households are exposed to a high frequency of river landslides and are always must prepare to relocate when floods occur. In addition, the progression of urbanization has enabled the formation of new urban areas as well as widening highways surrounding Tay An village but these are at different elevations. This had led to Tay An becoming an island separated from the surrounding areas time of heavy flooding. The assessment results as well as the actual situation show that Tay An will have significant trouble in its response and recovery when faced with a flood disaster. Therefore, the local government as well as residents urgently needs to develop solutions to reduce social vulnerability and simultaneously enhance the resilience of community to a higher level to meet the requirements of a new rural development program.

Tuy Loan Dong 2 and Cam Ne show relatively equivalent results in assessment of community resilience. Although Cam Ne and Tuy Loan Dong 2 village are evaluated with respectively low and very low potential vulnerability in social aspects, both had a medium score among the four villages when evaluated as resilient communities. This result infers that these villages will have less trouble in response and recovery when faced with a flood disaster. However, with the relatively low topographic features, combined with frequent flood hazards, Tuy Loan Dong 2 and Cam Ne need to further enhance their community resilience.

Hoi Phuoc is considered to have a relatively high capacity for resisting flood disasters, with a high level of community resilience potential and a medium level of potential vulnerability. This may be due to its high level of environmental capital - which is defined as the crucial component for a strongly resilient community that is inextricably linked to the condition of the environment and natural disaster, combined with the positive aspect of socio and economic capital that increases the level of resilience of the community to a natural disaster. In addition, this village has not been exposed to high flood hazards in recent years. From these results, Hoi Phuoc was assessed as being in "no trouble" in its response and recovery when faced with a flood disaster. However, its complex topography, being located in the lower section of upstream (Lo Dong and An Loi River), Hoi Phuoc shows a high potential for flash floods. Therefore, the local government needs to pay attention to maintain the high degree of resilience to flood disasters.

## 5.6. Conclusion

The findings in this study show that examining community resilience in relation to vulnerability is essential in order to understand how communities respond and adapt to natural disasters. Quantitative and qualitative analysis of community resilience via a capital-based approach can facilitate comparisons between different villages as well as determine how strengths and weakness of the each capital contributes to ensure community resilience.

The use of typology in zoning rural flood affected villages as a background for community resilience assessment is an effective and novel approach to flood disaster related research in rural Vietnam. Based on the case study results, this approach can provide fundamental science for authorities to base their policy decisions for building reasonable policies and solutions for prevention, response, and mitigation of natural disasters in specific regions. Specifically for the implementation period of the New Rural Development in Hoa Vang district, identifying these issues will support the decision to have the correct orientation in new rural planning integrated with mitigation and adaptation to climate change. The outcomes of this assessment reveal the current capacities of communities to initiate contextualized community - led planning and implementation of household responses in form of actions to enhance the community resilience to flood disaster. In this study, a number of solutions for improving rural community resilience for each village were identified, as follows:

* Tay An village:

- In terms of minimizing potential vulnerability, some policies should focus on enhancing housing conditions and livelihood quality, as well as diversifying the income of the local residents.

- In terms of enhance the community resilience: First, the village needs to provide investment support to improve the structural risk reduction measures for riverine embankments and evacuation routes, as well as enhance environmental quality. As a long term strategy, the local government should increase awareness and participation of the local residents and establish detailed natural disaster prevention plans for households in the village.

* Tuy Loan Dong 2 and Cam Ne villages: In implementing the new rural planning, disaster risk management should be integrated into the community's socio-economic development plans, such as by improving the quality of the rural environment and enhancing household preparedness strategies to ensure the village's sustainable development.

* Hoi Phuoc village: Strengthening the watershed forest growth and protection to improve water control when floods occur will help to prevent and limit flash floods in the upstream regions.

The results will serve as a good reference for policy decision-makers as well as local authorities in order to carry out solutions and policies that can enhance the resilience of rural community in specific regions and meet the objectives of the new rural development program to withstand the effects of climate change and unpredictable natural hazards.

# CHAPTER 6
# GENERAL DISCUSSIONS AND CONCLUSION

## 6.1. Discussions and Conclusion

The goal of study was to contribute to the theory of flood risk assessment in concerning with urbanization and addressed the dimensions that affect community resilience to flood disaster in Da Nang city. The research sought a conceptual framework on risk in relation with hazard, vulnerability and community resilience. The dissertation research employed a GIS and remote sensing to analyze urbanization expansion and flood risks change in Da Nang city. The new approach in establishing flood hazard based on the utilization of inundation extracting from ALOS PALSAR and flow direction from ASTER GDEM, subsequently was utilized for conducting the flood risk assessment. A typology technique and households questionnaire survey method were employed to assess the community resilience in case study of Hoa Vang rural district, Da Nang city that illustrated how differential flood community resilience in the context of socio-economic conditions, historical flood disaster as well as the political of the local authorities. This chapter provides a summary of the main research findings and provides overall conclusions.

There were two main objectives of the research.

(1) To contribute the ongoing development of flood risk assessment and analyze the relationship between flood risk and urban expansion by applying remote sensing and GIS technique.

(2) To appraise how differential community resilience to flood disaster in the context of socio-economic conditions, historical flood disaster as well as the political of the local authorities

In the first objective, the first question was *identifying the risk concept and the related concepts (hazard, vulnerability and resilience) in context of flood risk management*. The definition of risk and the related concepts were inundated in many literatures and research and often makes confused. Therefore the identification of the framework and its concepts of dissertation is necessary for implementation the flood risk assessment as well as the future process. The risk concept requires a specific view on the context of flood risk management as well as the relationship between risk and important related concepts such as hazard, vulnerability, and community resilience (Chapter 2). In this dissertation research, we approved the risk definition given by UNISDR, 2004, in which flood risk is a product of hazard and vulnerability and was represented as a formula: Risk=Hazard x Vulnerability. A circumstance of flood risk is on account of/due to the incompatibility between hazard levels and vulnerability levels for the same location.

- Flood hazard is defined as the exceeding probability of the occurrence of potential damaging flood situation in a given area and within a given area and within a specified period of time.
- Vulnerability is defined as the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard.
- Risk is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.
- Vulnerability and resilience are widely used in flood risk assessment and management in recently years. However resilience is often confused with vulnerability, it needs to explained and clear defined. We have approved the definition given by Adger 2000; Cutter et al., 2008; and ISDR 2004, in which community resilience is defined as the ability of a groups or communities to respond and recover from disaster and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social systems to re-organize, change, and learn in response to a threat for better future protection and to improve risk reduction measures. Building community resilience is considered an effective way for community preparedness, awareness, coping and recovery from hazards and disaster.

The second question was *demonstrating how remote sensing and GIS is applicable to flood risk assessment*. In chapter 4 we developed a method for flood risk assessment based on remote sensing and GIS techniques. Flood risk was obtained by evaluating the flood hazard and demographic vulnerability with a ranking matrix in two - dimensional multiplication model. Due to the lack of high resolution DEM, digital maps, as well as the restriction in accessing to disaster data of the study area, we attempted to conduct a novel approach for delineating the potential flood hazard by integrating ALOS PALSAR and ASTER GDEM. The achievement of this analysis is the potential flood hazard was successful derived by integrating the inundation extracting from ALOS PALSAR and flow direction extracting from ASTER GDEM. The ALOS PALSAR image is obtained one month after the flooding; therefore the result of extraction inundated areas was not the "real flood zone". That why we have to integrate the flow direction extracting from ASTER GDEM. The depressed surfaced (susceptible to be flooded) into which water can accumulate was extracted relative clear in Flow direction as described in chapter 4. The flow direction then overlaid with inundated areas for mapping the potential flood hazard. It is believed that the high proportion of inundated per flow direction indicated a more flood more. The land use/cover map extracted from LANDSAT TM and flood depth point records from field surveys were utilized to check the possibility of susceptible inundated areas extracting from ALOS PALSAR and ranking the potential flood hazard. The demographic vulnerability was derived based on analyzing the degree of susceptibility to flood of a particular vulnerability groups which included children, elder, impoverished households, and females. The flood risk analysis represented that the most of the major high and moderate risk areas were located in the depression lowlands as well as along the banks or river channels. This method is effective when hydrological and meteorological data are inadequate and the remote sensing images taken during flood times are not available or insufficient. The findings of this research contributes to develop the methodology of applying remote sensing and GIS in flood risk assessment for natural disaster management in the study sites.

The third question have to solve in the first objective of dissertation is *identifying where are exposed to high flood risks during 20 years in Da Nang city*. Time series LANDSAT TM/ETM+ images and multi seasonal ALOS images were analyzed to generate temporal land use/cover maps (for 1990, 2001, 2007 and 2010), which was then utilized to analyze the urban expansion process. During 20 years, Da Nang city experienced a high rate of urbanization, the approximate rate of increasing built-up in the area was 220%. The main directions of urbanization were seen in the

West, Northwest, South and Southeast and long the coastal line. By overlaying expanded urban/settlement expansion during 20 years (from 1990 to 2010) with those extracted flood risk areas, the rate of settlement exposure to flood risk was clarified. The result shows that some areas of urbanization have clearly invaded into the higher risk areas of flood. The potential risk revealed by such urban/settlement expansion into the relatively high flood risk areas increased from 1.9 to 3.5% (nearly twofold) in the urbanization periods of 1990-2001 and 2007-2010, respectively.

In implementation of community resilience assessment for the case study of the rural district of Da Nang city, the fourth question examine *which framework and methods can be useful for assessing community resilience?* (Chapter 2 and Chapter 5). In the chapter 2, we have reviewed the resilience concepts as well as the frameworks of community resilience assessment from many literatures. Here we adopted the community assessment framework given by Wilson (2012) as it conceptual basic for assessment community since it applies to natural disasters, particular flood disasters. The model presented the interaction between three pillars of resilience including economic capital, social capital and environmental capital. The community resilience assessment was conduct based on typology technique and a questionnaire survey. Flood affected villages typology was constructed by using two multivariate statistical techniques, respectively Principle Component Analysis (PCA) and Cluster Analysis (CA). Typology was used for grouping flood affected villages in the Hoa Vang rural district according to indicators relevant to socio-economic and physical characteristics under perspective of potential vulnerable to flood disaster. Thereby the result of potential vulnerability of flood affected villages typology would provide the background for assessing community resilience to flood disaster. The use of typology in zoning flood affected villages as a background for community resilience assessment is an effective and novel approach to flood disaster rerated in Vietnam. Household questionnaires were carried out by the authors with the assistance of Hoa Vang Statistical Office's staffs including face to face interview with the respondent's household and capturing the location and image of household by GPS camera/handheld GPS device. A total of 300 households were administered in four plot site villages of Hoa Vang rural district by using simplified sample formula of

Yamane (1967). A combination of quantitative and qualitative approaches was employed to analyzed community resilience via a capital-based approach that can facilitate comparison between villages and determine how strengths and weakness of the each capital contributes to ensure community resilience. The linking typology potential vulnerability flood affected villages and capital-based approach in community resilience measurement (including economic capital, socio capital and environmental capital) has showed an effective and unique methodology/conceptual framework for representing and assessment community resilience to flood disaster.

Applying the community resilience concept by calculating the value of the difference capital dimensions for community resilience assessment in context of flood risk is studied. The fifth question *examined the critical indicators could be used to assess the community resilience*. In chapter 5 it was found that a clear indication of a system is received by quantifying the dimensions of a community resilience framework that characterize the response of the system to flood disturbances including economic capital, social capital and environmental capital. Indicators then were defined for each capital, in which 11 indicators were employed to investigate economic capital, 26 to explore social capital and 10 to assess environmental capital. An average score was calculated for each three capital and then an overall average for the three capitals was obtained. The application of the 47 indicators to the case study of Tay An, Cam Ne, Tuy Loan Dong 2, Hoi Phuoc villages showed that those indicators are applicable, duplicable, and effective for better describe how resilience of community to flood disaster in the study area sites.

Finally, based on the results of typology and community resilience questionnaire, it enables to answer *how resilient of the studied communities*. The findings of this study showed that various types of resilience community were found for each target village. Based on those differences, some solutions, recommendations can provide for the authorities to base their policy decisions for the enhancement of community resilience as well as meet the objectives of the new rural development program in the face of flood disaster and other climate related disasters.

Despites the contributions of this dissertation, it still remains the limitations of knowledge gaps in the analysis. In our discussion of establishment the potential flood hazard, DEM and the sensitivity analysis associated with the potential errors of the ASTER DEM play a vital role and affect the accurate of flood hazard maps. Due to the limitation in obtaining detail elevation data in Vietnam, especially to the rural areas where often shortage of map database, a medium resolution 30mx30m ASTER GDEM was attempted to use for analyzing. In further study, care must be taken in increasing the resolution of DEM as well as the potential error of this analysis for comprehension the risk assessment

## 6.2. Recommendations

This thesis provided the new approach for delineating the potential flood hazard by integrating ALOS PALSAR and ASTER GDEM that subsequently was used for conducting the flood risk assessment. It demonstrates the applicable of utilizing remote sensing and GIS in flood risk assessment for natural disaster management in the study sites. It is therefore the recommended to integrated RS and GIS in some action phases of disaster management in general and in flood risk management in particular.

Further research is recommended that it needs more attention the knowledge on the hydraulic system, the micro-land form when assessing the current flood risk and resilience of the system.

This thesis proposed the applicable capability of typology techniques in conducting community resilience assessment. It provided resilience indicators within three dimensions of economic capital, socio capital and environmental capital and demonstrated that applying those indicators results facilitates the development of comprehensive strategies for flood risk management in some plot sites. Therefore it is recommended to apply the typology and the resilience indicators to the whole districts for better understand the difference community resilience in the context of recent authority's flood risk management strategies. In advanced, also those analysis techniques and indicators can be applied for the other systems, the other areas such as the coastal areas and the urban areas.

# References


ACCCRN (2009). Asian Cities climate change resilience network (ACCCRN): Responding to urban climate challenge. ISET, Boulder, CO, 60 p.

ADB (2008). Natural Disaster and Damage Caused by Disaster in Vietnam - Water Sector Review Project.

Adger, W. N. (2000). "Social and ecological resilience: are they related?" Progress in Human Geography **24**(3): 347-364.

Adger, W. N., et al. (2005). "Social-Ecological Resilience to Coastal Disasters." Science **309**: 1036-1039.

Afeku, K. (2005). Urbanization and flooding in Accra, Ghana, Miami University. Master of Art - Geography.

Ainuddin, S. (2012). "Community resilience framework for an earthquake prone area in Baluchistan." International Journal of Disaster Risk Reduction **2**: 25-36.

Aldrich, N. and W. F. Benson (2008). "Disaster Preparedness and the Chronic Disease Needs for Vulnerability Older Adults " Preventing Chronic Disease - Public health Research, Practice, and Policy **5**(1): 1-7.

Alliance, R. (2010). Assessing resilience in social-ecological systems. Workbook for Practotioners.

Anderson, J. R., et al. (1976). "A Land Use And Land Cover Classification System For Use With Remote Sensor Data." Geological Survey Professional Paper 964 **964**: 138-145.

Ashraf Mahmmood Dewan, K. K.-Y. a. M. N. (2005). "Assessing Flood Hazard in Greater Dhaka, Bangladesh Using SAR Imageries with GIS." Journal of Applied Sciences **5**(4): 702-707.

ASTER GDEM (2011a). "ASTER Global Digital Elevation Model (ASTER GDEM) ". from http://gdem.ersdac.jspacesystems.or.jp/.

ASTER GDEM (2011b). "ASTER GDEM Version 2." from http://www.jspacesystems.or.jp/ersdac/GDEM/E/4.html.

Ballas, D., et al. (2003). A comparative study of typologies for rural in Europe 43rd European Congress of the Regional Science Association, Jyvaskyla, Finland.

Banasik, K. and N. Pham (2010). "Modeling of the effects of land use changes on flood hydrograph in a small catchment of the Plaskowicka, southern part of Waesaw, Poland." Land Reclamation **42**(2): 229-240.

Bardhan, P. (2006). "Globalization and Rural Poverty." World Development **34**(8): 1393-1404.

Beierle, T. C. and J. Cayford (2002). Democracy in Practice: Publish Participation in Environmental Decisions. London, Earthscan.

Bengs, C. and K. Schmidt-Thomé (2006). Urban-rural relations in Europe - Epson 1.1.2 Final Report, Center for Urban and Regional Studies, Helsinki University of Technology.

Bhandari, H. and K. Yasunobu (2009). Human Values, Social Capital and Sustainable Development: A cross-country Analysis from Asia. J. W. Report. Japan. **62**: 107.

Birkmann, J. (2006). "Measuring vulnerability to promote disaster-resilient societies: Comeptual frameworks abd definitions." Measuring vulnerability to natural disaster hazards: Towards disaster resilient societies: 7-54.

Bloschl G., M. A. (2010). "Climate change impacts - throwing the dice." Hydrological Processes **24**: 374-381.

Blunden, J. R., et al. (1998). "The Classification of Rural Areas in the European Context: An Exploration of A Typology Using Neural Network Applications." Regional Studies **32**(2): 149-160.

Bourdieu, P. (1987). "What makes a social class? On the theoretical and practical existence of groups." Berkeley Journal of Sociology **32**: 1-17.

Brand, F. S. and K. Jax (2007). "Focusing the Meaning(s) of Resilience: Resilience as a Descriptive Concept and a Boundary Object." Ecology and Society **12**(1): 23.

Brooks, N. (2003). "Vulnerability, risk and adaptation: A conceptual framework." Tyndall Centre Working Paper(38): 20.

Bruijin, K. d. (2005). Resilience and flood risk management - A system approach applied to lowland rivers, Netherland.

Buika, J., et al. (2003). Natural hazard Risk and Vulnerability assessment and Mitigation Plan for the territory of American Samoa. American Samoa Hazard Mitigation Plan, Pacific Disaster Center.

Business Dictionary (2013). From http://www.businessdictionary.com/definition/fundamentalrisk.html#ixzz2oYmlSLkw.

CCSFS (2006). "Disaster Database."

CCSFS (2013). "Disaster Database." from http://www.ccfsc.gov.vn/KW6F2B34/CatId/G986H8324D/Summary-of-amages.aspx.

Centre for International Studies and Cooperation (CECI). (2008). Program for Hydro-Meteorological Disaster Mitigation in Secondary Cities in Asia - Vietnam - Final Report. Asian Disaster Preparedness Center.

Challenge to challenge and Hue University. (2009). Hazard Capacity and Vulnerability Assessment in Da Nang Report, Asian Cities Climate Change Resilience Network.

Chaskin, R. J. (2007). "Resilience, Community, and Resilient Communities: Conditioning Contexts and Collective Action." Child Care in Practice **14**(1): 65-74.

Clark, G. E., et al. (1998). "Assessing the vulnerability of coastal communities to extreme storms: The case of revere, Mam, USA." Mitigation and Adapation Strategies for Global Change **3**: 59-82.

Coastanza, R. and J. Farley (2007). "Ecological economics of coastal disasters: Introduction to the special issue." Ecological Economics **63**: 249-253.

Coleman, J. S. (1988). "Social Capital in the Creation of Human Capital." The American Journal of Sociology **94**: 95-120.

Congalton, R. G. (1991). "A Review of Assessing the Accuracy of Classifications of remotely Sensed Data." Remote sens. Environ **37**: 35-46.

Costanza, R., et al. (1997). "The value of the world's ecosystem services and natural capital." Natural **387**: 253-260.

Cutter, S. L. (1996). "Vulnerability to environemtal hazards." Progress in Human Geography **20**(4): 529-539.

Cutter, S. L., et al. (2008). "A place-based model for understanding community resilience to natural disaster." Global Environmental Change **18**: 598-606.

Cutter, S. L., et al. (2010). "Disaster Resilience Indicators for Benchmarking Baseline Conditions." Journal of Homeland Security and Emergency Management **7**(1): 1-22.

Davidson, D. J. (2010). "The Applicability of the Concept of Resilience to Social Systems: Some Sources of Optimism and Nagging Doubts." Society & Natural Resources: An International Journal **23**(12): 1135-1149.

Department of Regional Development and Environment Executive of American States (1991). "Primer on Natural Hazard Management in Integrated Regional Development Planning." Retrieved 15 December 2013, from http://www.oas.org/dsd/publications/Unit/oea66e/begin.htm#Contents.

DNCFSC (2011). Report Status of Natural disaster in Da Nang city. Da Nang Committee for Flood and Storm Control. (In Vietnamese). Da Nang city.

DNDONRE (2004). Report of environmental state in 2004 of Da Nang city. (In Vietnamese). Da Nang Department of Natural Resources and Environment.

DNPC (2009). Report on State of preventing and remedying the Storm Xangsane (No.6) Da Nang, Vietnam. Da Nang People Committee. (In Vietnamese).

DNPC (2012). Action Plan of Responding to Climate Change ans Sea Level Rise. Decision No.6901/QĐ-UBND. I. Vietnameses.

DNSO (1998). Da Nang statistical yearbook 1997. Da Nang Statistical Office,. (In Vietnamese). Statistical Publishing House, Da Nang city.

DNSO (2000). Result of the 1999 Da Nang Population and Housing Census. (In Vietnamese) Statistical Publishing House, Da Nang city.

DNSO (2005). Da Nang city - 30 year building and development 1975-2005. (In Vietnamese). Statistical Publishing House, Da Nang city.

DNSO (2006). Da Nang statistical yearbook 2005. Da Nang Statistical Office, (In Vietnamese). Statistical Publishing House, Da Nang City.

DNSO (2007). Da Nang statistical yearbook 2006. (In Vietnamese). Statistical Publishing House, Da Nang city.

DNSO (2010a). Da Nang statistical yearbook 2009. (In Vietnamese). Da Nang Statistical Office. Statistical Publishing House - Da Nang city, VN.

DNSO (2010b). "Da Nang Population growth from past to present." Da Nang Statistical Office. (In Vietnamese). From http://ctk.danang.gov.vn/TabID/59/CID/26/ItemID/146/default.aspx.

DNSO (2010c). Result of the 2009 Da Nang Population and Housing Census. (In Vietnamese). Statistical Publishing House, Da Nang city.

DNSO (2011). Da Nang statistical yearbook 2010. (In Vietnamese). Statistical Publishing House, Da Nang city.

DNSO (2012). Da Nang statistical yearbook 2011. Da Nang Statistical Office,. (In Vietnamese). Statistical Publishing House, Da Nang city.

Douglas Paton, L. S., and John Violanti (2000). "Disaster response: Risk, Vulnerability and Resilience." Disaster Prevention and Management **9**(3): 173-179.

Ekins, P., et al. (2003). "A framework for the practical application of the conceots of critical natural capital and strong sustainability." Ecological Economics **44**: 165-185.

El-Osta, H. (2014). "A Typology of Socioeconomic Disadvantage among Farm Operator Households: Assessment of Contributing Factors Using Evidence from a National Survey." Applied Research Quality Life **9**: 15-44.

Eleitério, J. (2012). Flood risk analysis: impact of uncertainty in hazard modelling and vulnerability assessments on damage estmations Civil Engineering. Water Science & Environmental economics University of Strasbourg, France. Doctor of Philosophy: 243.

EM-DAT (2013). from http://www.emdat.be/.

Enason, E., et al. (2004). Gender and Disaster: Foundations and Directions - Chapter 8.

ERDAS (1999). Erdas Field Guide - Fifth Edition, Revised and Expanded.

ERSDAC (2006). PALSAR Reference Guide. Japan.

Everitt B.S, L. S., Leese M., Stahl D. (2011). Cluster Analysis. King's Collge London, UK.

Fedeski, M. and J. Gwilliam (2007). "Urban sustainability in the present of flood and geological hazards: The development of a GIS-based vulnerability and risk assessment methodology." Landscape and Urban planning **83**(1): 50-61.

Fekete, A. (2009). "Validation of a social vulnerability index in context to river-floods in Germany." Natural Hazards and Earth System Sciences **9**: 393-403.

Field, A. P. (2005). Discovering statistics using SPSS. Sage, London.

Flynn, J., et al. (1994). "Gender, Race, and Perception of Environmental Health Risks." Risk analysis **14**(6): 1101-1108.

FMMP and MRC (2006). Manual on Flood Preparedness Program for Provincial and District Lvel Authorities in the Lower Mekong Basin Countries. F. M. A. M. Program and M. R. Commission. **2**.

Folke, C. (2006). "Resilience: The emergence of a perspective for social-ecological systems analyses." Global Environmental Change **16**: 253-267.

Folke, C., et al. (2002). "Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations." A Journal of the Human Environment **31**(5): 437-440.

Force, J. E. and G. E. Machlis (1997). "The human ecosystem Part II: Social indicators in ecosystem management." Society & Natural Resources: An International Journal **10**(4): 369-382.

Fothergill, A. and L. A. Peek (2004). "Poverty and Disaster in the United States: A Review of Recent Sociological Findings." Natural Hazards **32**: 89-110.

Friedl, M. A. and C. E. Brodleyf (1997). "Decision tree classification of land cover for remote sended data." Remote Sensing Environment **61**: 399-409.

Fussel, H.M. and R. J. T. Klein (2006). "Climate change vulnerability assessments: An evolution of conceptual thinking." Climate change **75**: 301-329.

Giuseppe Tito Aronica, A. C., Pamela Fabio, Mario Santoro (2011). "Estimation of flood inundation probabilities using global hazard indexes based on hydrodynamic variables." Physics and Chemistry of the Earth **42-44**: 119-129.

GLCF (2013). "Welcome to the Earth Science Data Interface (ESDI) at the Global Land Cover Facility." Earth Science Data Interface, From http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp.

Goodwin, N. R. (2003). "Five Kinds of Capital: Useful Concepts for Sustainable Development." Global development and environment institute working paper No. **03-07**: 1-13.

Gouldby, B. and P. Samuels (2005). Language of Risk. Intergrated Flood Risk Analysis and Mangament Methodologies. P. D. I. P. Floodsite: 56.

Groot, R. D. (1992). Function of nature: Evaluation of Nature in Environmental Planning , Management and Dicision Making, Wolters-Noordhoff Groningen, Netherlands.

Guha-Sapir, et al. (2013). Annual Disaster Statistical Review 2012: The Numbers and Trends. Brussels: CRED.

Hoffman, S. (2009). "Preparing for Disaster: Protecting the Most Vulnerability in Emergencies." Law review **42**(5): 1491-1547.

Holling, C. S. (1973). "Resilience and stability of ecological systems." Annual Review of Ecology ans Systematics **4**: 1-23.

Hsieh, C. H., et al. (2011). "Disaster Risk Analysis of Highway Bridges from Vulnerability Perspective." Journal of the Eastern Asia Society for Transportation Studies **9**: 1-15.

Huong, H. T. L. and A. Pathirana (2011). "Urbanization and climate change impacts for future urban flood risk in Can Tho city, Vietnam." Hydrology and Earth System Sciences Discussion **8**: 10781-10824.

Huttenlau, M. and J. Stotter (2011). "The struture vulnerability in the framework of natural hazard risk analyese and the exemplary application for storm los modelling in Tyrol (Austria)." Natural Hazards **58**: 705-729.

HVPC (2010a). Summatation conference material for flood - storm control, rescue and relief year 2010 and implementation the orientation and tak for year 2011. Hoa Vang District People Committee. (In Vietnamese). Hoa Vang district, Da Nang city.

HVPC (2010b). "Plan of community -based prevention and mitigation natural disaster in Hoa Vang district, Da Nang city. " (In Vietnamese) Hoa Vang District People Committee.

HVSO (2012). Hoa Vang statistical yearbook 2011. (In Vietnamese). Hoa Vang district, Da Nang city.

Indian Ocean Tsunami Warning Program (2007). How resilience is your Coastal Community? A guide for Evaulating Coastal Community Resilience to tsunami and other coastal Hazards., U.S. Indian Ocean Tsunami Warning System Program supported by the United States Agency for International Development and partners, Bankok, Thailand.

Institute for Social and Environmental Transition (2011). Da Nang Climate Change Resilience Strategy, Vietnam.

IPCC (2007). Summary for Policymakers - In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth

Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, Cambridge University Press: 7-22.

Islam, M. M. and K. Sado (2002). "Development Priority Map for Flood Countermeasures by Remote Sensing Data with Geographic Information System." Journal of Hydrologic Engineering **7**(5): 346-355.

Itonaga, K. (2012). "Resilience of Rural Community through Emigration and Return." Journal of Rural Planning **30**(4): 563-566.

Japan ICOMOS National Committee, 2011, The Great East Japan Earthquake - Report on the Damage to the Cultural Heritage, 32pp. In http://www.icomos.org/publications/ICOMOS%20Japanearthquake_report_20111120.pdf , Accessed on January 23rd 2014.

Janssen, L. L. F. and G. C. Huurneman (2001). Principles of Remote Sensing - An introductory textbook. ITC, Enschede, The Netherlands.

JAXA (2008). ALOS Data Users Handbook. Japan.

Jenson, S. K. and J. O. Domingue (1988). "Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis." Photogrametric engineering and remote sensing **54**(11): 1593-1600.

Kathleen Sherrieb, A. L. C., R. L. Pfefferbaum, Betty Pfefferbaum J.D, Eamon Diab, Fan H. Nonrris (2012). "Assessing community resilience on the US coast using school principals as key informants." International Journal of Disaster Risk Reduction **2**: 6-15.

Kelman, I. (2002). Physical Flood Vulnerability of Residential Properties in Coastal, Eastern England, University of Cambridge, U.K.

Klein R.J.T, N. R. J., Thomalla F. (2003). "Resilience to natural hazards: How useful is this concept?" Environmental Hazards **5**: 35-45.

Kron, W. (2005). "Flood Risk = Hazard * Value * Vulnerability." Water International **30**(1): 58-68.

Kumar, C. (2005). "Revisisting 'community' in community-based natural resource managment." Community Development Journal **40**(3): 275-285.

Lastra, J., et al. (2008). "Flood hazard delineation combining geomorphological and hydrological methods: an example in the Northern Iberian Peninsula." Natural Hazards **45**: 277-293.

Lawler, J. (2011). Children's Vulnerability to CLimate Change and Disaster Impacts in East Asia ans the Pacific. Children and Climate Change. UK, UNICEP.

Lewis, S. (2013). "Remote sensing for natural disaster: facts and figures." From http://www.scidev.net/global/earth-science/feature/remote-sensing-for-natural-disasters-facts-and-figures.html.

Liu, Y. B., et al. (2004). "Assessing land use impacts on flood processes in complex terrain by using GIS and modeling approach." Environmental Modeling and Assessment **9**: 227-235.

Loan, T. K. H. and M. Umitsu (2011). "Micro-landform classification and flood hazard assessment of the Thu Bon alluvial plain, central Vietnam via an integrated method utilizing remotely sensed data." Applied Geography **31**: 1082-1093.

Madry, W., et al. (2013). "An overview of farming system typology methodologies and its use in the study of pasture-based farming systems: a review." Spanish Journal of Agricultural Research **11**(2): 316-326.

Magis, K. (2010). "Community Resilience: An Indicator of Social Sustainability." Society and Natural Resources **23**: 401-416.

MARD (2012). Resetlement policy framework (RPF) Vietnam. Managing Natural hazard project (VN-HAZ),. Ministry of Agriculture and Rural Development Vietnam. Ha Noi: 55.

Mason D.C, H. J. T., Dall' Amico J.T, Scott T.R and bates P.D. (2007). "Improving River Flood Extent Delineation From Synthetic Aperture Radar Using Airborn Laser Altimetry." IEEE Transactions On Geosicences and Remote Sensing **45**(12): 3932-3943.

Matinfar, S., Panah, Heck (2007). "Comparision of Object-Oriented and Pixel-Based Classification of Land Use/Land Cover Type Based on LANDSAT 7, ETM+ Spectral Bands (Case Study: Arid Region of Iran)." American Eurasian J.Agric & Environ Sci **2**(4): 448-456.

Mayunga, J. S. (2007). Understanding and Applying the Concept of Community Disaster Resilience: A Capital-based approach: 16 p.

Meredith, D. and M. SakasOlmedo (2012). Understanding the potential role od spatial typologies in responding to the Ruragri Call. Ruralgri Era-Net. Ashtown, Dublin 15, Ireland.

Mooi, E. and M. Sarstedt (2011). A Concise Guide to Market Research - The Process, Data, and Methods Using IBM SPSS Statistics. Springer Heidelberg Dordrecht London New York.

Morrow, B. H. (1999). "Identifying and Mapping Community Vulnerability." Disasters **23**(1): 1-18.

Nirupama (2002). Role of remote sensing in disaster management. Institute for Catastrophic Loss Reduction, Western Ontario. Post doctoral.

Nirupama, N. and S. P. Simonovic (2007). "Increase of Flood Risk due to Urbanization: A Canadian Example." Natural Hazard and Earth System Sciences **40**: 25-41.

Norris, F. H., et al. (2008). "Community Resilicen as a Metaphor, Theory, Set of Capacities, and Straegy for Disaster Readiness." Am J Community Psychol **41**: 127-150.

Oanh, L. N., et al. (2011). A preliminary analysis of flood and storm disaster data in Vietnam. Global Assessment Report on Disaster Risk Reduction. GAR.

Ostrom, E. (2009). "A General Framework for Analyzing Sustainability of Social-Ecological Systems." Science **325**: 419-422.

Oudenhoven, F. J. W. v., et al. (2010). "Social-ecological indicators of resilience in agrarian and natural landscapes." Management of Environmental Quality: An International Journal **22**(2): 154-173.

Paton, D. (2005). Community Resilience: Integrating Hazard Management and Community Engagement. International Conference on Engaging Communities, Brisbance Convention & Exhibition Center, Queensland, Australia.

Pfefferbaum R.L., Pfefferbaum B., and Van Horn R.L. (2011), The CART Integrated System. Oklahoma City, OK: Terrorism and Disaster Center at the University of Oklahoma Health Science Center.

Pretty, J. and H. Ward (2001). "Social Capital and the Environmental." World Development **29**(2): 209-227.

QNDNSO (1990). Quang Nam Da Nang statistical yearbook 1989. Quang Nam - Da Nang Statistical Office. (In Vietnamese). Quang Nam - Da nang Province.

Razafindrabe, B. H. N., et al. (2009). "Climate Disaster Resilience: Focus on Coastal Urban Cities in Asia." Asian Journal of Environment and Disaster Management (AJEDM) **1**(1): 101-116.

Robert Stimson, J. W., Scott Baum and Yolanda Van Gellecum, (2005). "Measuring community strength and social capital." Regional Studies **39**(8): 1095-1109.

Rygel, L., et al. (2006). "A method for constructing a social vulnerability index: An application to hurrican storm surges in a developed country." Mitigation and Adapation Strategies for Global Change **11**: 741-764.

S. Kienberger, F. A. J., P. Zeil, C. Hutton,S. Lang, M. Mark Modelling socio-economic vulnerability to floods: Comparision of methods developed for European and Asian case studies Research and Innovation.

S.B.Manyena (2006). "The concept of resilience revisisted." Disaster **30**(4): 433-450.

Sakamoto, T., et al. (2007). "Detecting temporal changes in the extent of annual flooding within the Cambodia and the Vietnamese Mekong Delta from MODIS time-series imagery." Remote Sensing of Environment **109**: 295-313.

Samarasinghea, S. M. J. S., et al. (2010). "Application of remote sensing and GIS for flood risk analysis: A case study at Kalu- Ganga River, Sri lanka." International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science **38**(8): 110-115.

Sanyal, J. and X. X. Lu (2005). "Remote sensing and GIS-based flood vulnerability assessment of human settlements: a case study of Gangetic West Bengal, India." Hydrological Processes **19**(3699-3716).

Schanze, J., et al. (2004). Flood risk management: Hazards, Vulnerability and Mitigation. Ostrov, Czech Republic, Springer.

Schumann, G., et al. (2007). "Deriving distributed roughness values from satellite radar data for flood inundation modelling." Journal of Hydrology **344**: 96-111.

Shimada, M., et al. (2009). "PALSAR Radiometric and Geometric Calibration" IEEE transactions on Geoscience and Remote sensing." 47 **12**(3915-3932).

Shaw, R., and Sharme, A. (2011). Climate change and disaster resilience in cities. Volume 6 of Community, Environment and Disaster Risk Managament. ISSN 2040-7262. Emerald Group Publishing. 287 p.

Simelton, E., et al. (2009). "Typologies of crop-drought vulnerability: an empirical analysis of the socio-economic factors that influence the sensitive and resilience to drought of three major food crops in China (1961-2001)." Environmental science & policy **12**: 438-452.

Singh, R. B. and S. Singh (2011). "Rapid urbanization and induced flood risk in Noida, India." Asian Geographer **28**(2): 147-169.

Smith, K. and D. N. Petley (2009). Assessing risk and reducing disaster. New York, Taylor & Francis Routledge.

Smyle, J. and R. Cooke (2011). Climate Change Analysis and Adaptation Responses. Prepared for Informing IFAD's Country Strategic Opportunities Program 2012-2017 for Vietnam. W. Paper.

Social Republic of Vietnam (2004). National Report on Disaster reduction in Vietnam. For the World Conference on Disaster Reduction Kobe-Hyogo, Japan

Social Republic of Vietnam (2008). Decisison on approval of the National Target Program to respond to climate change. Ha Noi.

Socialist Republic of Vietnam (2007). National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020 Ha Noi, Vietnam.

Son, M. T., et al. (2011). Climate change: Impacts, Response ability and Policy issues (Case Study of Ethnic minorities in Northern Mountain of Vietnam). (In Vietnamese).

Spachinger, K., et al. (2008). "Flood Risk and Flood Hazard Maps - Visualisation of Hydrological Risks." Earth and Environmental Science **4**: 1-17.

Spilton, D., et al. (1981). "Developing an empirical socio-economic typology of countries in five western states." Soci-Econ.Plan. Sci **15**: 175-190.

Stimson, R., et al. (2003). Measuring community strength and social capital. Center for research into Sustainble Urban and Regional Futures, the University of Queensland Brisbane and the UQ Center for Social Research, Australia, ERSA 2003 Congress Jyvaskyla, Finland: 39 p.

Suriya, S. and B. V. Mudgal (2012). "Impact of urbanization on flooding: The Thirusoolam sub watershed - A case study." Journal of Hydrology **412-413** (210-219).

Taubenböck, H., et al. (2012). "Monitoring urbanization in mega cities from space." Remote Sensing of Environment **117**: 162-176.

Taubenbock, H., et al. (2010). "Flood risk in urbanized area - multi - sensoral approaches using remotely sensed data for risk assessment." Natural hazards Earth System Sciences **11**: 431-444.

Thieken, A., et al. (2006). Methods for flood risk assessment: Concepts and challenges. International Workshop on Flash Floods in Urban Areas, Muscat - Sultanate of Oman.

Thinh, N. V. and D. T. M. Duc (2005). Socio-economic Typology of Provinces and Districts of Vietnam. (In Vietnamese). Ha Noi, Vietnam, Encyclopeadia Pusblishing House.

Thy, P. T. M., et al. (2010). "Urban expansion of Can Tho city, Vietnam: A study based on multi - temporal satellite images." Urban expansion of Can Tho city, Vietnam: A study based on multi - temporal satellite images **21**(3): 117-160.

Townsend, P. A. and S. J.Walsh (2001). "Remote sensing of forested wetlands: application ofmultitemporal and

Tsutsui, K. (2005). "The Geography Character of Local Public Investment in Vietnamese Rural Area in the 1990s." Annuals of the Association of Economic Geographers **51**(3): 242-260.

Turner, B. L., et al. (2003). "A framework for vulnerability analysis in sustainable science." National Academy of Sciences of the United States of America **100**(14): 8074-8079.

Tym, R. and Partners (2011). Coastal typologies: detailed method and output. Marine Management Organization.

Uitto, J. I. (1998). "The geography of disaster vulnerability in megacities." Applied Geography **18**(1): 7-16.

UNEP (2002). Global Environment Outlook 3 - Past, present and future perspectives, Earthscan Publications.

UNICEF (2012). "UNICEF: Girls more vulnerable to climate disasters." from http://www.unicef.org.uk/Latest/News/Women-and-girls-key-to-building-resilience-against-disasters/.

UNISDR (2004). Living with Risk Aglobal review of disaster reduction initiatives, United Nations New York and Geneva.

UNISDR (2005). Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. World Conference on Disaster Reduction, Kobe, Hyogo, Japan.

UNISDR (2009). Global assessment report on disaster risk reduction (2009): 207p.

UNISDR (2011). Revealing Risk, Redefining Development - Chaper 1. Global Assessment Report on Disaster Risk Reduction 2011, United Nation.

UNISDR (2011). Revealing Risk, Redefining Development - Chaper 2. GAR, United Nation.

United Nation (2012). World Urbanization Prospects - The 2011 Revision, Department of Economic and Social Affairs, New York.

Viera, A. J. and J. M. Garrett (2005). "Understanding Interobserve Agreement: The Kappa Statistic." Family Medicine **37**(5): 360-363.

Vijayaraghavan, C., et al. (2012). "Utilization of Remote sensing and GIS in Managing Disasters - A Review." International Journal of Scientific & Engineering Research, **3**(1): 1-8.

Vogt, P., et al. (2007). "Mapping spatial patterns with morphological image processing." Landcape Ecology **22**: 171-177.

Walker, B., H. C. S., Carpenrer S.R., and Kinzig A. (2004). "Resilience, Adaptability and Transformability in Social-ecological Systems." Ecology and Society **9**(2): 9 pp.

Wickes, J., Zahnow, R., Baum, S., and Gellecum, Y.V. (2005). Community Resilience Research: Current Approaches, Challenges and Opportunities, Institute for Social Science Research. The University of Queensland, 29 pp.

Willinger, B. (2008). Katrina and the Women of New Orleans. Excecutive Report and Summary of findings, Tulane Univeristy.

Wilson, G. (2010). "Multifunctional 'quality' and rural community resilience." Royal Geographical Society **35**: 364-381.

Wilson, G. A. (2012). "Community Resilience, Globalization, and Transitional pathways of decision-making." Geoforum: 1218-1231.

Wisner, B., et al. (2003). At Risk: natural hazards, people's vulnerability and disasters.

World Bank (2009). Disaster Risk Management Programs for Priority Countries Global Facilities for Diaster Reduction and Recovery. Washington, DC 20433, USA.

World Bank (2011). Vietnam Urbanization Review - Technical Assisstance Report. Technique Assistance Report. Ha Noi, Vietnam.

World Bank (2013). "Vietnam: Disaster Risk Management Project." from http://www.worldbank.org/en/results/2013/04/09/vietnam-disaster-risk-management-project.

World Meteorological Organization (2008). Urban flood risk management - A Tool for Integrated Flood Management. Flood Management Tools Series. A. T. Document. **11**.

Xu, H., et al. (2000). "A remote sensing and GIS integrated study on urbanization with its impacts on arable lands: FuQuing city, Fulian Province, China." Land Degradation and Development **11**: 301-314.

Yamane, T. (1967). Statistics: an introductory analysis. the University of Michigan, Harper & Row.

Yuan F., S. K. E., Leoffelholz B.C., Bauer M.E. (2005). "Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitant Area by multitemporial LANDSAT remote sensing." Remote sesing of Environment **98**: 317-328.

Zhang, H., et al. (2008). "Rapid Urbanization and Implication for Flood Risk Management in Hinterland of the Pearl Delta, China: The Foshan Study." Sensor **8**: 2223-2239.

# About the Author

Ms. HUONG was born in Hue city, central Vietnam on 19th August 1982. She obtained B.Sc in Geography Science from Hue University of Science in 2004. After her graduation, she was given a great opportunity to become a lecturer in the Department of Geography and Geology, Hue University of Science. Her major focused mainly on Cartography and applications of Geographic Information and System (GIS) in Natural Resources and Environments. Four years later, she obtained a Master's degree of Science in Geography at the same university. In 2010, she was granted the Scholarship from The Vietnam Ministry of Education and Training for her Ph.D study. In October 2011, she started her Ph.D research in GIS and remote sensing applications in the Landscape Ecology and GIS Laboratory, United Graduate School of Agriculture of Sciences, Tottori University, Japan that is reported in this dissertation.

Her current research interests include applying RS and GIS in natural disaster management, land use change and urban expansion detection, Cartography design and mapping. She is the author and co-author of several national and international publications.

The above picture was taken when she attended the Autumn Conference of Japanese Agricultural Systems Society in November 2012 with her supervisor. And she was honoured granted the Best presentation Award (Kitamura) for her research topic.

# List of Publications

## CHAPTER 4

1.

**Author:** <u>Do Thi Viet Huong</u>, Ryota Nagasawa, and Kazunobu Tsutsui

**Title:** Analysis of urban expansion and flood risk change in Da Nang city in Central Vietnam

**Journal:** The Japanese Agricultural Systems Society (J.A.S.S), 2013, Vol.29, No.3, pp.123-134.

2.

**Author:** <u>Do Thi Viet Huong</u>, Ryota Nagasawa

**Title:** Flood risk assessment and mapping using Remote sensing and GIS: A case study at Hoa Chau Commune, Hoa Vang District in Central of Viet Nam

**Journal:** Proceeding of the 34th Asian Conference on Remote sensing, Indonesian Remote Sensing Society and Asian Association on Remote Sensing, pp. SC05 13 - 18, October 20-24, 2013.

3.

**Author:** <u>Do Thi Viet Huong</u>, Ryota Nagasawa

**Title:** Potential flood hazard assessment by integration of ALOS PALSAR and ASTER GDEM: A case study for the Hoa Chau Commune, Hoa Vang District, in Central Vietnam

Journal: Journal of Applied Remote Sensing (JARS), 2014, Vol.8, No.1, 083626 (2014). DOI: 10.1117/1.JRS.8.083626.

## CHAPTER 5

4.

**Author:** <u>Do Thi Viet Huong</u>, Kazunobu Tsutsui, Ryota Nagasawa

**Title:** Assessing Community Resilience to Flood Disasters in Rural District of Da Nang city, Vietnam

**Journal:** Journal of Rural Planning, 2014, Vol.33, No.1, pp. 64-73.

# Appendix - Tables

## Appendix 1 Matrices of land use/cover changes from 1990 to 2010

a. 1990-2001

| 2001 | 1990 Build up area | Water body | Paddy field | Upland field | Bare land | Forest | Shrubs | 2001 Total |
|---|---|---|---|---|---|---|---|---|
| Build up area | **2370.06** | 94.14 | 990.9 | 364.5 | 1547.64 | 1109.52 | 656.28 | 7133.04 |
| Water body | 87.3 | **1873.53** | 619.65 | 32.49 | 88.56 | 255.78 | 106.02 | 3063.33 |
| Paddy field | 314.82 | 78.12 | **3910.68** | 185.04 | 250.65 | 1345.41 | 281.52 | 6366.24 |
| Upland field | 196.38 | 6.66 | 268.38 | **195.48** | 244.53 | 513.54 | 143.37 | 1568.34 |
| Bare land | 672.3 | 90.99 | 604.53 | 331.38 | **3547.26** | 590.94 | 463.41 | 6300.81 |
| Forest | 1007.55 | 23.58 | 1372.68 | 482.13 | 567.36 | **64255.14** | 1038.06 | 68746.5 |
| Shrubs | 441.36 | 8.01 | 395.37 | 363.06 | 871.56 | 1668.15 | **727.92** | 4475.43 |
| 1990 Total | 5089.77 | 2175.03 | 8162.19 | 1954.08 | 7117.56 | 69738.48 | 3416.58 | 97653.69 |

b. 2001-2007

| 2007 | 2001 Build up area | Water body | Paddy field | Upland field | Bare land | Forest | Shrubs | 2007 Total |
|---|---|---|---|---|---|---|---|---|
| Build up area | **3998.7** | 255.87 | 489.42 | 173.34 | 2568.42 | 1034.28 | 970.56 | 9490.59 |
| Water body | 128.79 | **2235.6** | 132.75 | 15.39 | 175.86 | 96.12 | 36.27 | 2820.78 |
| Paddy field | 271.98 | 74.34 | **3643.38** | 145.89 | 139.5 | 405.18 | 114.12 | 4794.39 |
| Upland field | 92.52 | 6.03 | 58.5 | **244.08** | 99.45 | 175.14 | 60.48 | 736.2 |
| Bare land | 457.83 | 204.3 | 201.78 | 40.23 | **2074.41** | 262.62 | 217.62 | 3458.79 |
| Forest | 1224.81 | 96.21 | 1396.89 | 628.47 | 467.46 | **63063.81** | 1741.23 | 68618.88 |
| Shrubs | 969.57 | 207 | 445.05 | 321.57 | 798.21 | 3738.96 | **1338.57** | 7818.93 |
| 2001 Total | 7144.2 | 3079.35 | 6367.77 | 1568.97 | 6323.31 | 68776.11 | 4478.85 | 97738.56 |

**Appendix 1 Matrices of land use/cover changes from 1990 to 2010 (Cont.)**

c. 2007-2010

| 2010 | 2007<br>Build up area | Water body | Paddy field | Upland field | Bare land | Forest | Shrubs | 2010<br>Total |
|---|---|---|---|---|---|---|---|---|
| Build up area | **6050.66** | 346.96 | 471.63 | 217.87 | 1681.68 | 1272.52 | 1164.94 | 11206.26 |
| Water body | 149.53 | **1667.62** | 35.73 | 9.97 | 27.97 | 99.54 | 105.67 | 2096.03 |
| Paddy field | 91.83 | 78.8 | **2875.88** | 92.92 | 13.48 | 677.26 | 200.36 | 4030.53 |
| Upland field | 90.14 | 20.13 | 144.47 | **134.35** | 13.61 | 192.71 | 116.37 | 711.78 |
| Bare land | 977.95 | 130.7 | 193.07 | 49.31 | **1169.92** | 278.65 | 327.94 | 3127.54 |
| Forest | 804.39 | 219.91 | 449.92 | 127.48 | 217.2 | **62292.79** | 3802.28 | 67913.97 |
| Shrubs | 1303.43 | 312.98 | 618.27 | 100.83 | 299.02 | 3674.52 | **2087.3** | 8396.35 |
| 2007 Total | 9467.93 | 2777.1 | 4788.97 | 732.73 | 3422.88 | 68487.99 | 7804.86 | 97482.46 |

d. 1990-2010

| 2001 | 1990<br>Build up area | Water body | Paddy field | Upland field | Bare land | Forest | Shrubs | 2010<br>Total |
|---|---|---|---|---|---|---|---|---|
| Build up area | **2731.66** | 386.19 | 1801.5 | 560.53 | 3668.86 | 1658.45 | 958.63 | 11765.82 |
| Water body | 62.17 | **1328.27** | 254.77 | 46.48 | 78.46 | 225.44 | 97.65 | 2093.24 |
| Paddy field | 143.04 | 44.61 | **2390.02** | 147.78 | 179.82 | 758.52 | 173.06 | 3836.85 |
| Upland field | 75.77 | 12.06 | 186.22 | **96.56** | 87.78 | 192.04 | 61.11 | 711.54 |
| Bare land | 291.96 | 165.77 | 450.47 | 113.64 | **1320.81** | 400.31 | 204.47 | 2947.43 |
| Forest | 986.58 | 78.12 | 1592.73 | 569.59 | 803.12 | **62794.1** | 1094.39 | 67918.63 |
| Shrubs | 790.98 | 124.71 | 1477.59 | 416.4 | 951.43 | 3606.02 | **817.85** | 8184.98 |
| 1990 Total | 5082.16 | 2139.73 | 8153.3 | 1950.98 | 7090.28 | 69634.88 | 3407.16 | 97458.49 |

## Appendix 2 Accuracy Assessment of Land use/cove classification

2010

| ALOS Classified data | Reference data - Google Earth | | | | | | | Accuracy Assessment result | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Built-up | Water body | Paddy field | Upland field | Bare land | Forest | Shrubs /Grass | Producer's Accuracy | User's Accuracy | Kappa Statistic | Overall Classification Accuracy and Overall Kappa Statistic |
| Built - up | **339** | 15 | 8 | 7 | 76 | 6 | 49 | 82.68% | 67.80% | 0.64 | |
| Water body | 2 | **76** | 2 | 0 | 0 | 0 | 4 | 62.30% | 90.48% | 0.90 | |
| Paddy | 4 | 3 | **160** | 2 | 3 | 22 | 8 | 75.47% | 79.21% | 0.78 | Overall Accuracy = 85.29% |
| Upland field | 8 | 0 | 4 | **22** | 2 | 4 | 13 | 36.67% | 41.51% | 0.41 | Overall Kappa Statistics = |
| Bare land | 7 | 8 | 11 | 5 | **53** | 5 | 7 | 34.64% | 55.21% | 0.53 | 0.69 |
| Forest | 21 | 18 | 22 | 19 | 13 | **2631** | 135 | 98.14% | 92.03% | 0.75 | |
| Shrubs/Grass | 28 | 2 | 5 | 4 | 4 | 10 | **44** | 16.86% | 45.36% | 0.41 | |

1990

| ALOS Classified data | Reference data - Google Earth | | | | | | | Accuracy Assessment result | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Built-up | Water body | Paddy field | Upland field | Bare land | Forest | Shrubs /Grass | Producer's Accuracy | User's Accuracy | Kappa Statistic | Overall Classification Accuracy and Overall Kappa Statistic |
| Built - up | **163** | 3 | 12 | 4 | 8 | 18 | 6 | 67.92% | 76.17% | 0.7461 | |
| Water body | 0 | **73** | 6 | 0 | 2 | 4 | 0 | 84.88% | 85.88% | 0.8556 | |
| Paddy | 19 | 3 | **243** | 7 | 11 | 40 | 13 | 76.42% | 72.32% | 0.6986 | Overall Accuracy = 87.34% |
| Upland field | 3 | 1 | 2 | **36** | 8 | 8 | 3 | 46.75% | 59.02% | 0.5819 | Overall Kappa Statistics = |
| Bare land | 16 | 0 | 14 | 16 | **192** | 18 | 11 | 69.57% | 71.91% | 0.6977 | 0.7306 |
| Forest | 31 | 5 | 39 | 7 | 45 | **2646** | 60 | 96.04% | 93.40% | 0.7753 | |
| Shrubs/Grass | 7 | 0 | 2 | 7 | 10 | 18 | **54** | 36.24% | 55.10% | 0.41 | |

## Appendix 2 Accuracy Assessment of Land use/cove classification (Cont.)

2001

| ALOS Classified data | Reference data - Google Earth | | | | | | | Accuracy Assessment result | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Built-up | Water body | Paddy field | Upland field | Bare land | Forest | Shrubs /Grass | Producer's Accuracy | User's Accuracy | Kappa Statistic | Overall Classification Accuracy and Overall Kappa Statistic |
| Built - up | **313** | 3 | 5 | 6 | 6 | 18 | 19 | 73.82% | 84.59% | 0.8272 | |
| Water body | 5 | **105** | 1 | 3 | 3 | 3 | 0 | 92.11% | 87.50% | 0.8712 | |
| Paddy | 11 | 1 | **217** | 8 | 1 | 20 | 3 | 89.67% | 83.14% | 0.8203 | Overall Accuracy = 91.19% |
| Upland field | 4 | 0 | 2 | **26** | 0 | 10 | 2 | 47.27% | 59.09% | 0.5851 | Overall Kappa Statistics = |
| Bare land | 45 | 0 | 5 | 2 | **123** | 7 | 12 | 84.83% | 63.40% | 0.6199 | 0.8145 |
| Forest | 33 | 3 | 11 | 8 | 3 | **2693** | 35 | 97.26% | 96.66% | 0.8851 | |
| Shrubs/Grass | 11 | 0 | 1 | 2 | 8 | 16 | **82** | 53.25% | 68.33% | 0.6703 | |

2007

| ALOS Classified data | Reference data - Google Earth | | | | | | | Accuracy Assessment result | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Built-up | Water body | Paddy field | Upland field | Bare land | Forest | Shrubs /Grass | Producer's Accuracy | User's Accuracy | Kappa Statistic | Overall Classification Accuracy and Overall Kappa Statistic |
| Built - up | **355** | 8 | 2 | 1 | 11 | 13 | 18 | 76.84% | 87.01% | 0.8526 | |
| Water body | 3 | **93** | 3 | 0 | 2 | 4 | 2 | 78.81% | 86.92% | 0.8651 | |
| Paddy | 3 | 2 | **167** | 4 | 0 | 10 | 0 | 74.55% | 89.78% | 0.8916 | Overall Accuracy =89.26% |
| Upland field | 0 | 0 | 5 | **14** | 0 | 3 | 1 | 46.67% | 60.87% | 0.6057 | Overall Kappa Statistics = |
| Bare land | 31 | 1 | 1 | 0 | **73** | 6 | 7 | 76.04% | 61.34% | 0.6037 | 0.7729 |
| Forest | 34 | 5 | 37 | 7 | 2 | **2653** | 44 | 95.74% | 95.33% | 0.8387 | |
| Shrubs/Grass | 35 | 8 | 8 | 3 | 7 | 77 | **127** | 63.82% | 47.92% | 0.4513 | |

## Appendix 3 List of Flood pillar in Da Nang city

| ID | Location (village) | Location (Commune) | Name | Longitude X | Latitude Y | Height Z (m) | Flood 1999 (m) | Flood 2007 (m) |
|---|---|---|---|---|---|---|---|---|
| 1 | La Chau | Hoa Khuong | 32 | 108.1627778 | 15.95916667 | 4.759 | 1.6 | 1.33 |
| 2 | La Chau | Hoa Khuong | 06 Duc | 108.1488889 | 15.97527778 | 3.258 | 3.20 | 2.8 |
| 3 | Thon 4 | Hoa Khuong | 33 | 108.1472222 | 15.96972222 | 3.609 | 2.57 | 2.03 |
| 4 | Thach Bo | Hoa Phong | 27 | 108.16 | 15.98138889 | 2.428 | 3.2 | 2 |
| 5 | Cam Toai Dong | Hoa Phong | 26 | 108.1522222 | 15.9825 | 3.657 | 2.0 | 1.38 |
| 6 | Bo Ban | Hoa Phong | 28 | 108.1530556 | 15.98722222 | 2.505 | 3.0 | 1.9 |
| 7 | Nga3 Tuy Loan | Hoa Phong | 29 | 108.1416667 | 15.99583333 | 3.997 | 2.65 | 1.37 |
| 8 | An Tan | Hoa Phong | 05 Duc | 108.1219444 | 16 | 8.553 | 1.9 | 0.85 |
| 9 | Duong Lam 2 | Hoa Phong | 30 | 108.1308333 | 15.99194444 | 3.941 | 1.7 | 0.66 |
| 10 | Cam ToaiTrung | Hoa Phong | 31 | 108.1425 | 15.98111111 | 2.908 | 3.2 | 2.25 |
| 11 | An Trach | Hoa Tien | 21 | 108.1616667 | 15.95916667 | 4.607 | 1.9 | 1.32 |
| 12 | Bac An | Hoa Tien | 22 | 108.1566667 | 15.97972222 | 3.061 | 2.85 | 0.85 |
| 13 | Cam Ne | Hoa Tien | 23 | 108.1769444 | 15.98666667 | 2.169 | 3.25 | 2.72 |
| 14 | La Bong | Hoa Tien | 24 | 108.1711111 | 15.97 | 3.344 | 2.8 | 2.29 |
| 15 | Le Son 2 | Hoa Tien | 25 | 108.1663889 | 15.95944444 | 3.362 | 2.7 | 1.98 |
| 16 | Thach Bo | Hoa Tien | 07 Duc | 108.16 | 15.98194444 | - | 2.6 | 2.10 |
| 17 | Bau Cau | Hoa Chau | 10 | 108.2016667 | 15.99611111 | 2.287 | 2.5 | 2.2 |
| 18 | Dong Hoa | Hoa Chau | 11 | 108.1938889 | 15.99666667 | 2.236 | 2.1 | 2.63 |
| 19 | Cam Nam | Hoa Chau | 14 | 108.2083333 | 16.00722222 | 2.243 | 2.6 | 2.28 |
| 20 | Tay An | Hoa Chau | 17 | 108.1875 | 15.99194444 | 2.034 | 3.4 | 3.0 |
| 21 | Quan Chau | Hoa Chau | 18 | 108.1997222 | 15.97611111 | 2.871 | 2.0 | 1.73 |
| 22 | Quan Chau | Hoa Chau | 08 Duc | 108.2011111 | 15.97611111 | - | 1.55 | 1.05 |
| 23 | Giang Dong | Hoa Chau | 19 | 108.1947222 | 15.96611111 | 2.982 | 2.2 | 1.28 |
| 24 | Phong Nam | Hoa Chau | 20 | 108.1936111 | 15.98611111 | 2.297 | 2.65 | 1.34 |
| 25 | Quan Nam 2 | Hoa Lien | 001 DMU | 108.1125 | 16.10583333 | 1.789 | 1.4 | - |
| 26 | Truong Dinh | Hoa Lien | 010 DMU | 108.088055 | 16.11111111 | 1.808 | 2.2 | - |
| 27 | Truong Dinh | Hoa Lien | 01 Duc | 108.0872222 | 16.11083333 | - | 2.1 | - |
| 28 | Nhon Hoa | Hoa Phuoc | 12 | 108.2144444 | 15.95888889 | 2.156 | 2.4 | - |
| 29 | Giang Nam | Hoa Phuoc | 13 | 108.2205556 | 15.95111111 | 1.825 | 2.5 | 1.94 |
| 30 | Qua Giang 1 | Hoa Phuoc | 15 | 108.2097222 | 15.96361111 | 1.657 | 2.9 | 2.62 |
| 31 | Nhon Tho 2 | Hoa Phuoc | 16 | 108.2102778 | 15.95305556 | 2.456 | 2.5 | 2.04 |
| 32 | Giang Nam 1 | Hoa Phuoc | 09 Duc | 108.2197222 | 15.95611111 | - | 1.95 | 1.45 |
| 33 | Nam Yen | Hoa Bac | 004 DMU | 108.0505556 | 16.13361111 | 2.658 | 3.03 | - |
| 34 | Bau Bang (Loc My) | Hoa Bac | 005 DMU | 108.0263889 | 16.13777778 | 6.774 | 1.8 | 0.26 |

## Appendix 3 List of Flood pillar in Da Nang city (cont.)

| ID | Location (village) | Location (Commune) | Name | Longitude X | Latitude Y | Height Z (m) | Flood 1999 (m) | Flood 2007 (m) |
|---|---|---|---|---|---|---|---|---|
| 35 | Nam My | Hoa Bac | 006 DMU | 108.0283333 | 16.13555556 | 8.52 | 2.7 | 1.4 |
| 36 | Ta Lang | Hoa Bac | 007 DMU | 107.9916667 | 16.12833333 | 18.197 | 1.5 | 1.1 |
| 37 | Pho Nam | Hoa Bac | 13 Duc | 108.0569444 | 16.12388889 | - | 3.6 | 2.2 |
| 38 | Hoa Phuoc | Hoa Phu | 008 DMU | 108.1061111 | 15.99583333 | 4.575 | 2.25 | - |
| 39 | Dong Lam | Hoa Phu | 009 DMU | 108.0769444 | 15.98194444 | 8.623 | 2.5 | 1.2 |
| 40 | Hoi Phuoc, Dong Lang | Hoa Phu | 003 DMU | 108.0830556 | 15.98694444 | 8.694 | 2.4 | - |
| 41 | Hoi Phuoc, Dong Lang | Hoa Phu | 12 Duc | 108.0847222 | 15.99777778 | - | 3.65 | 2 |
| 42 | Thai Lai | Hoa Nhon | 04 Duc | 108.1236111 | 16.00611111 | - | 3.18 | 1.68 |
| 43 | Dong Son | Hoa Ninh | 03 Duc | 108.0694444 | 16.04777778 | - | 2.50 | - |
| 44 | An Ngai Tay 2 | Hoa Son | 02 Duc | 108.1044444 | 16.07333333 | - | 1.35 | - |
| 45 | Gan UBND | Hoa Xuan | 01 | 108.2188889 | 15.9975 | 2.05 | 2.1 | 2.08 |
| 46 | Lo Giang 2 (Truong hoc) | Hoa Xuan | 02 | 108.2186111 | 16.00694444 | 2.482 | 2.8 | 2.45 |
| 47 | Co Man (Truong hoc) | Hoa Xuan | 03 | 108.2166667 | 15.99055556 | 1.921 | 2.7 | 2.25 |
| 48 | Liem Lac | Hoa Xuan | 04 | 108.2127778 | 15.98 | 1.969 | 2.5 | 1.45 |
| 49 | Tung Lam | Hoa Xuan | 05 | 108.2227778 | 15.99583333 | 2.107 | 2.9 | 2.5 |
| 50 | Trung Luong | Hoa Xuan | 06 | 108.2288889 | 16.0175 | 1.866 | 2.6 | 1.66 |
| 51 | Con Dau | Hoa Xuan | 07 | 108.2247222 | 16.01388889 | 1.806 | 3 | 1.9 |
| 52 | Cam Chanh | Hoa Xuan | 08 | 108.2225 | 16.01972222 | 2.41 | 2.5 | 0.5 |
| 53 | Dong No | Hoa Xuan | 09 | 108.2438889 | 16.01277778 | 2.382 | 2.5 | 0.58 |
| 54 | Thi An | Hoa Quy | 01 | 108.2311111 | 15.96333333 | 2.482 | 1.7 | 1.25 |
| 55 | An Luu | Hoa Quy | 02 | 108.22031 | 15.96797 | 2.188 | 2.9 | 2.6 |
| 56 | Man Quang 3 | Hoa Quy | 03 | 108.22571 | 15.97666667 | 1.866 | 3.1 | 2.45 |
| 57 | Man Quang 4 | Hoa Quy | 04 | 108.225415 | 15.98237984 | 1.787 | 3.1 | 2.42 |
| 58 | Khue Dong 1 | Hoa Quy | 05 | 108.2355556 | 16.00972222 | 2.482 | 3.3 | 2.4 |
| 59 | Khue Dong 2 | Hoa Quy | 06 | 108.2413889 | 16.00583333 | 1.485 | 3.4 | 2.58 |
| 60 | To 24 Man Quang 2 | Hoa Quy | 11 Duc | 108.2261111 | 15.97305556 | - | 2.7 | 2.2 |
| 61 | Dong Tra | Hoa Hai | 07 | | | 1.45 | - | - |
| 62 | To 2 Son Thuy | Hoa Hai | 10 Duc | 108.2522222 | 16.00361111 | - | 2.65 | 1.6 |
| 63 | Da Man | Khue My | 08 | | | - | - | - |
| 64 | Thuy Tu | Hoa Hiep Bac | 002 DMU | 108.1038889 | 16.10694444 | 1.526 | 2.1 | - |

## Appendix 4 Questionnaire form for households interview establishing (Work inside laboratory)

HOUSEHOLD QUESTIONNAIRE

**COMMUNITY RESILIENCE ASSESSMENT OF RURAL COMMUNITY TO NATURAL DISASTER**

For the theme of Doctoral research: Community Resilience of rural community to natural disaster in Hoa Vang district, Da Nang, Central of Vietnam
Done by PhD candidate Do Thi Viet Huong
Geography and Geology Department, Hue Science of Science

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| |
|---|
| Code of sheet:<br>Residential area (Section):<br>Village:<br>Commune: Hòa Vang district, Đà Nẵng city<br>Interviewer:<br>Date of Interview:<br>Number of pictures taken of household despondence |

### Part 1. Basic information about response and head of household

1.1. Respondent's name………………………………………………………………………………..
  a. Sexual: ☐1 Male ☐2 Female b. Age ………… years old
1.2. Relationship of respondent with head of household
  ☐1 Head of household ☐2 Spouse ☐3 Children ☐4 Parents
  ☐5 Other (Specify)….
1.3. Name of head of household……………………………………………………………………….……
  a. Sexual: ☐1 Male ☐2 Female b. Age …………years old
1.4. Marriage status of household head:
  ☐1 Single ☐2 Married ☐3 Widower ☐4 Divorce/Separation
1.5. Employment status:
  ☐1 Working ☐2 No working ☐3 Un-employment ☐4 Loss ability of employee

**If head of household is not working, skip to 1.8.**

1.6. Working with position
  ☐1 Self-organization business ☐2 Wage ☐3 Labor family ☐4 Apprentiship
1.7. If head of household is a wage person, is he is an officer?
  ☐1 Officer ☐2 No
1.8. Highest education of household's head:
  ☐1 Not goes to school ☐2 Not yet finished elementary school ☐3 Finished elementary school
  ☐4 Finished secondary school☐5 Finished high school ☐6 Basic Vocational training
  ☐7 Secondary Vocational training ☐8 Intermediate Vocational training☐9 Vocational colleges
  ☐10 College ☐11 Undergraduate ☐12 Post - graduate

1.9. How many people are currently living in the household?

| No | Description | Number | Male | Female |
|---|---|---|---|---|
| 1 | Total number of household members | | | |
| 2 | Number of members in working age (15-60) | | | |
| 3 | Number of member below 15 years old | | | |
| 4 | Number of member above 65 years old | | | |
| 5 | Disability/Chronic illness | | | |
| | | | | |

## Part 2. Economical Capital

**Income**

2.1. What are the main sources of your household income? Rate the degree of important of income sources (in which 1 is the most important)

| No | Source of income | Select | Rate |
|---|---|---|---|
| 1 | Agriculture/Gardening/Farming | ☐ | |
| 2 | Fishing, aquaculture | ☐ | |
| 3 | Livestock - animal husbandry | ☐ | |
| 4 | Small agricultural business | ☐ | |
| 5 | Forestry and Small forestry business | ☐ | |
| 6 | Business, non-agricultural services | ☐ | |
| 7 | Wage | ☐ | |
| 8 | Other: Remittance, social subsidies…..<br>Specify………………………………………… | ☐ | |

2.2. Average amount of income per month?
About ………………….. VNĐ

**Economic sector**

2.3. Main economic sectors?

☐1 Agriculture ☐2 Forestry ☐3 Aquaculture ☐4 Industry
☐5 Construction ☐6 Trade ☐7 Service ☐8 Others (Specify)……………………

2.4. The trend of significant changes in the main employment sector in the last 20 years of your household?

☐1 Maintain ☐2 Change ☐3 Diversification ☐4 Other (Specify)…………………

**Status of house**

2.5. House status:

a. Storey: ☐1 1 store ☐2 1 storey+mezzanine ☐3 2 floor ☐4 > 2 floor
b. Construction: ☐1 New (< 5 years ☐2 Recent (5-10 years) ☐3 Old (> 10 years)
c. Condition: ☐1 Temporary ☐2 Semi-solid ☐3 Solid
d. Level of ground floor house\street ground:
☐1 < 0,2m ☐2 0,2 - 0,5m ☐3 0,5 - 1m ☐4 > 1m

**Accessibility**

| How are perceptions of you on the issues below? | Very high | High | Medium | Low | Very low | No |
|---|---|---|---|---|---|---|
| 2.6. Accessibility of transport system internal village and inter-villages and communes? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.7. Degree of disruption of transport system as intense rain and flood | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.8. Accessibility of clean water for life? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.9. Accessibility of clean water for life during and after flood disaster? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.10. Accessibility of health service system? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.11. Accessibility of education system? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.12. Accessibility of computer and Internet? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Poverty status**

2.13. Are your family in this condition?

☐$_1$ Lonely Household/Regular relief ☐$_2$ Poverty household ☐$_3$ Near poor poverty ☐$_4$ No poverty

**Savings**

2.14. Do your family have savings for coping with future natural hazards?

☐$_1$ Sure ☐$_2$ May be have ☐$_3$ Don't know ☐$_4$ Don't have ☐$_5$ Completely don't have

**Part 3. Social capital**

**Awareness of Natural hazards**

3.1. According to your experience, which circumstances can be occurred to your family?

| Circumstance | Certainly occur | Can be occurred | Less occur | Rarely occur | No occur | Don't know |
|---|---|---|---|---|---|---|
| Experiencing damages caused by floods | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experiencing damages caused by flash flood | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience damages caused by typhoons | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience damages caused by land slide | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience damages caused drought | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

3.2. How will the consequences of the circumstances below to your family?

| Circumstance | Very serious | Serious | Usual | Less consequen ce | Very little consequen ce | No consequence |
|---|---|---|---|---|---|---|
| Experiencing damages caused by floods | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experiencing damages caused by flash flood | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience damages caused | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | | |
|---|---|---|---|---|---|---|
| by typhoons | | | | | | |
| Experience damages caused by land slide | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience damages caused drought | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

3.3. How importance of reducing the consequences of natural disaster?

| Circumstance | Very important | Importa nt | Usual | Less importa nt | No important |
|---|---|---|---|---|---|
| Experiencing damages caused by floods | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experiencing damages caused by flash flood | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience damages caused by typhoons | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience damages caused by land slide | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience damages caused drought | ☐ | ☐ | ☐ | ☐ | ☐ |

3.4. How is the importance of local knowledge in resolving natural disaster?

☐1 Very important ☐2 Important ☐3 Usual ☐4 Less important

☐5 Very little important ☐6 No important

**Community cohesiveness**

3.5. When flood disasters occur, can your family get any helps when necessary from neighborhoods?

☐1 Certainty have ☐2 Maybe have ☐3 Don't know ☐4 Don't have

**Participating in community activities**

| What is your level assessment of your household for the following issues | Don't have | No attend | Very high | High | Mediu m | Low | Very low |
|---|---|---|---|---|---|---|---|
| 3.6. Participate in decision - making on plan and solution for natural disaster mitigation and prevention. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.7. Participate in training course on enhancing awareness of local residential | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.8. Opportunity participation of women and young generation on community activities, decision-making relating to natural disaster mitigation and prevention | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Community preparation during disaster**

3.9. Level of preparation the items for response with typhoon and flood hazards?

☐1 Certainly good preparation ☐2 May be good preparation ☐3 Normal

☐4 Moderate preparation ☐5 Poorly preparation ☐6 Completely no preparation

3.10. What the traditional experiences that your family has been used to cope with typhoon?

| Short-term | Select | Long term | Select |
|---|---|---|---|
| Update information on climate | ☐ | Building safe house | ☐ |
| Reinforcing the house | ☐ | Moving to safe places | ☐ |
| Preparing food and water | ☐ | Changing livelihood activities | ☐ |
| Anchoring boats | ☐ | Changing crop pattern | ☐ |
| Seeking shelter | ☐ | Building a shelter | ☐ |
| Evacuating | ☐ | Equipping good warning systems | ☐ |
| Other (Specify)………………….. | ☐ | Drills | ☐ |
| | | Other (Specify)………………… | ☐ |

3.11. What the traditional experiences that your family has been used to cope with flood?

| Short-term | Select | Long term | Select |
|---|---|---|---|
| Update information on climate | ☐ | Plant forest | ☐ |
| Moving the items to the high areas | ☐ | Changing crop pattern | ☐ |
| Solidification houses | ☐ | Changing livelihood activities | ☐ |
| Preparing food and water | ☐ | Building safe house | ☐ |
| Anchoring boats | ☐ | Heighten the animal husbandry facilities | ☐ |
| Seeking shelter | ☐ | Equipping good warning systems | ☐ |
| Evacuating | ☐ | Other (Specify)…………………. | ☐ |
| 8. Other (Specify)………………….. | | | ☐ |

3.12. In the future, do you have any plan for protect yourself and your family from natural disaster? (E.g. heighten the ground of house, changing crop pattern...)

☐1 Certainty have ☐2 Maybe have ☐3 Don't know ☐4 Don't have

3.13. Ability of family to provide volunteer manpower when natural hazards occur in available conditions?

☐1 Certainty have ☐2 Maybe have ☐3 Don't know ☐4 Don't have

**Institutional**

| How is your level assessment of your household for the following issues | Very high | High | Medium | Low | Very low | No |
|---|---|---|---|---|---|---|
| 3.14. Ability of local government in providing the accuracy information to resident about natural disaster | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.15. Effectiveness of flood pillar in your areas when flood occur? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.16. Ability of local government in implement the prevention and mitigation natural disaster plan and evacuation instruction for residents | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | | |
|---|---|---|---|---|---|---|
| when natural disasters occur? | | | | | | |
| 3.17. Effective of "Đội xung kích" and "Tiểu Ban PCLB" of village meet the preparation and mitigation when natural disasters occur? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.18. Local government have services and programs to help residents after a disaster | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.19. Degree of trust in the successful of "Đội xung kích" and "Tiểu Ban PCLB" of village in preparation and mitigation in in future natural disasters? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

## Part 4. Environment capital

**Intensive of natural hazards**

4.1. Type of natural hazards that often influence to your village?
☐1 Typhoon ☐2 Flood ☐2 Flash flood ☐3 Drought
☐4 Land slide ☐5 Other (Specify………………………………………………………)

4.2. Has your family ever experienced a typhoon in last 15 years?
☐1 Yes ☐2 No

**If No, skip to Frequency and Changes of Natural hazards**

4.3. What is the highest flood level in your house during last 20 year?
a. Year …………
b. Level ☐1 < 0.5 m ☐2 0.5-1.0 m ☐3 1.0-2.0 m ☐4 2.0-3.0 m ☐5 >3.0 m

4.3. Could you rate the level of flood damages to your family?
☐1 Very high ☐2 High ☐3 Medium ☐4 Low ☐5 Very low ☐6 No

**Frequency and changes of Natural hazards**

4.4. How was the natural hazards frequency in last 15 years?
☐1 Very frequently ☐2 Frequently ☐3 Medium
☐4 Don't know ☐5 Less frequently ☐6 Very less frequently ☐7 No occur

4.5. How change is the natural hazards from the last flood of 1999?
☐1 Increase ☐2 Stable ☐3 Decrease ☐4 Fluctuate ☐4 Don't know

**Environment quality**

| How is your level assessment of your household for the following issues | Very good | Good | Normal | Less ensure | No ensure |
|---|---|---|---|---|---|
| 4.6. Water quality in your village | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4.7. Sanitation conditions in village | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4.8. Solid waste collection condition in village | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4.9. Waste water drainage system in village | ☐ | ☐ | ☐ | ☐ | ☐ |

## Part 5. Community information

5.1. How long have your family lived in this village?

☐1 <5 years ☐2 5-10 years ☐3 10-50years ☐4 >50 years

| Assessment of your household with the following statements | Very high | High | Medium | Low | Very low |
|---|---|---|---|---|---|
| 5.2. Residents in this village have solidarity relationship with each other | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.3. Residents in this village are willing to help each other | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.4. Residents in this village often attend the community activities | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.5. Residents work and discuss together to solve the community issues | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.6. Residents can discuss with leader of village for solving community issues | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.7. Community has priorities and sets goals for the future development of village | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.8. Residents in village try to prevent and mitigate natural disaster | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.9. Community looks at its successes and failures from natural disaster response in the past so it can learn and for better development in the future | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.10. Community works with the other communities and organization out side village for better develop | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.11. Residents have trust and hope about the future develop of village | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.12. Residents in this village are committed to the well-being of the community. | ☐ | ☐ | ☐ | ☐ | ☐ |

5.13. How satisfied level of your household's for living in this village is?
☐1 Very satisfy ☐2 Satisfy ☐3 Normal ☐4 Less satisfy ☐5 Dissatisfy
5.14. Do your family have a plan for living long -term in this village?
☐1 Certainty have ☐2 Maybe have ☐3 Don't know ☐4 Don't have

***Thank you for taking the time to help us!***
--------------------------------------------

## Appendix 5 Official Questionnaire used for household interview - Vietnamese languages (After pilot test and discussion with group of implemented - questionnaire in field survey)

BẢNG CÂU HỎI ĐIỀU TRA THÔNG TIN HỘ GIA ĐÌNH

**ĐÁNH GIÁ KHẢ NĂNG CHỐNG CHỊU CỦA CỘNG ĐỒNG**
**DÂN CƯ NÔNG THÔN ĐỐI VỚI THIÊN TAI**

Người thực hiện: Nghiên cứu sinh Đỗ Thị Việt Hương
Đại học Tottori, Nhật Bản

| |
|---|
| Mã phiếu:………………………………………………………………………………………… |
| Điểm dân cư (Tổ):………………………………………………………………………….. |
| Thôn:……………………………………………………………………………………….. |
| Xã: ……………………………………………………Huyện Hòa Vang, thành phố Đà Nẵng .. |
| Phỏng vấn viên:…………………………………………………………………………….. |
| Ngày phỏng vấn:…………………………………………………………………………… |
| Mã số ảnh chụp: Từ ………………………………đến……………………………………………… |

1.1. Tên người trả lời: ……………………………………………………………………………………..
b. Giới tính: ☐$_1$ Nam ☐$_2$ Nữ b. Độ tuổi …………. tuổi
1.10. Mối quan hệ với chủ hộ gia đình
☐$_1$ Chủ hộ ☐$_2$ Vợ/chồng ☐$_3$ Con ☐$_4$ Bố/mẹ ☐$_5$ Khác (Ghi cụ thể)…………….
1.11. Họ và tên chủ hộ:……………………………………………………………………………………
b. Giới tính: ☐$_1$ Nam ☐$_2$ Nữ b. Độ tuổi …………. tuổi
1.12. Tình trạng hôn nhân của chủ hộ:
☐$_1$ Chưa vợ/chồng ☐$_2$ Có vợ/chồng ☐$_3$ Góa ☐$_4$ Ly hôn/Ly thân
1.13. Tình trạng lao động của chủ hộ:
☐$_1$ Đang làm việc
☐$_2$ Không cần làm việc (nội trợ, học sinh, nghĩ hưu, già… đã có người khác nuôi dưỡng, chăm sóc, chu cấp kinh tế hoặc có nguồn kinh tế khác như cho thuê nhà, tài sản, lãi tiết kiệm, lãi cho vay)
☐$_3$ Thất nghiệp
☐$_4$ Mất khả năng lao động (đối với người trong tuổi lao động)

**NẾU CHỦ HỘ LÀ KHÔNG PHẢI NGƯỜI ĐANG LÀM VIỆC, CHUYỂN ĐẾN CÂU 1.8**

1.14. Đang làm việc với vị thế:
☐$_1$ Tự tổ chức SXKD ☐$_2$ Làm công ăn lương ☐$_3$ Lao động trong gia đình ☐$_4$ Học việc
1.15. Nếu chủ hộ là người làm công, ăn lương. Có phải là cán bộ công chức Nhà nước không?
☐$_1$ Là cán bộ, công chức Nhà nước ☐$_2$ Không
1.16. Trình độ học vấn cao nhất chủ hộ đã đạt được:
☐$_1$ Chưa đến trường ☐$_2$ Chưa xong tiểu học ☐$_3$ Tốt nghiệp tiểu học
☐$_4$ Tốt nghiệp THCS ☐$_5$ Tốt nghiệp THPT ☐$_6$ Sơ cấp nghề
☐$_7$ Trung cấp nghề ☐$_8$ Trung học chuyên nghiệp ☐$_9$ Cao đẳng nghề
☐$_{10}$ Cao đẳng ☐$_{11}$ Đại học ☐$_{12}$ Trên đại học

1.17. Trong hộ gia đình ông/bà có bao nhiêu người?

| | **Mô tả** | **Số người** | **Nữ** |
|---|---|---|---|
| 1 | Tổng số thành viên trong hộ | | |
| | - Số thành viên trong tuổi lao động (15-65 tuổi) | | |
| | - Số thành viên nhỏ hơn 15 tuổi | | |
| | - Số thành viên lớn hơn 65 tuổi | | |
| 2 | - Số người khuyết tật, bệnh tật | | |

## PHẦN 2. NGUỒN VỐN KINH TẾ

**Thu nhập**

2.1. Nguồn thu nhập chính của gia đình ông/bà là gì? Xin vui lòng xếp thứ tự quan trọng của nguồn thu nhập trong gia đình, trong đó số 1 là quan trọng nhất)

| STT | Nguồn thu nhập | Chọn | Xếp thứ tự |
|---|---|---|---|
| 1 | Trồng trọt (làm ruộng, rau màu các loại, vườn cây…) | ☐ | |
| 2 | Đánh bắt, nuôi trồng thủy sản | ☐ | |
| 3 | Chăn nuôi gia súc, gia cầm | ☐ | |
| 4 | Hoạt động dịch vụ nông nghiệp | ☐ | |
| 5 | Lâm nghiệp và dịch vụ lâm nghiệp | ☐ | |
| 6 | Các hoạt động sản xuất, kinh doanh dịch vụ phi nông nghiệp | ☐ | |
| 7 | Tiền lương, tiền công | ☐ | |
| 8 | Các khoản khác: tiền gửi từ bên ngoài (nước ngoài, bà con, con cái), trợ cấp xã hội…)<br>Ghi cụ thể………………………………………… | ☐ | |

2.2. Ông/bà cho biết nguồn thu nhập của gia đình ông/bà trung bình một tháng khoảng bao nhiêu tiền?
Khoảng …………………. nghìn đồng

**Ngành kinh tế**

2.3. Ngành kinh tế đang hoạt động chủ đạo của hộ gia đình ông/bà là gì?
☐1 Nông nghiệp ☐2 Lâm nghiệp ☐3 Thủy sản ☐4 Công nghiệp
☐5 Xây dựng ☐6 Thương mại ☐7 Dịch vụ ☐8 Khác (ghi rõ)…………………

2.4. Xu thế chuyển đổi ngành kinh tế do thiên tai trong 15 năm qua của hộ gia đình ông/bà là gì/?
☐1 Giữ nguyên ☐2 Thay đổi ☐3 Đa dạng hóa

**Tình trạng nhà ở**

2.5. Tình trạng nhà ở của ông/bà:
a. Số tầng: ☐1 Nhà trệt ☐2 Nhà trệt+gác lửng ☐3 1 tầng
☐4 Trên 1 tầng
b. Thời gian xây dựng: ☐1 Dưới 5 năm ☐2 Cách đây 5-10 năm ☐3 Trên 10 năm
c. Tình trạng: ☐1 Nhà tạm ☐2 Bán kiên cố ☐3 Kiên cố
d. Chênh lệch nền nhà so với đường - mặt đất:
☐1 Dưới 0,2m ☐2 Từ 0,2 - 0,5m ☐3 Từ 0,5 - 1m ☐4 Trên 1m

**Khả năng tiếp cận**

| Mức độ đánh giá của hộ gia đình ông/ bà đối với các vấn đề sau như thế nào? | Rất cao | Cao | Trung bình | Thấp | Rất thấp |
|---|---|---|---|---|---|
| 2.10. Khả năng tiếp cận hệ thống giao thông nội thôn và liên thôn xã | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.11. Mức độ gián đoạn hệ thống giao thông khi mưa cường độ lớn và ngập lụt | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.12. Khả năng tiếp cận nguồn nước sạch phục vụ sinh hoạt | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.13. Khả năng tiếp cận nguồn nước sạch phục vụ sinh hoạt trong và sau thời gian xảy ra lũ lụt | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.10. Khả năng tiếp cận hệ thống dịch vụ y tế | ☐ | ☐ | ☐ | ☐ | ☐ |
| . Khả năng tiếp cận hệ thống giáo dục | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2.12. Khả năng tiếp cận vi tính, mạng Internet | ☐ | ☐ | ☐ | ☐ | ☐ |

**Tình trạng nghèo đói**

2.13. Hiện nay gia đình ông/bà có thuộc một trong các diện sau không?
☐1 Hộ neo đơn/cứu tế thường xuyên ☐2 Hộ nghèo ☐3 Hộ cận nghèo ☐4 Không thuộc 3 diện trên

**Tiết kiệm**

2.14. Gia đình ông/bà có kế hoạch tiết kiệm tiền để sẵn sàng ứng phó với thiên tai xảy ra trong tương lai không?

☐1 Chắc chắn là có ☐2 Có thể có ☐3 Không biết ☐4 Không có

## PHẦN 3. NGUỒN VỐN XÃ HỘI

**Nhận thức về thiên tai**

3.1. Theo kinh nghiệm của cá nhân, ông/bà thấy những trường hợp sau đây có thể xảy ra đối với bản thân

| Trường hợp | Chắc chắn xảy ra | Có thể xảy ra | Ít xảy ra | Hiếm khi xảy ra | Không xảy ra | | Không biết |
|---|---|---|---|---|---|---|---|
| Phải trải qua những thiệt hại về của cải do **NGẬP LỤT** gây ra | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ |
| Phải trải qua những thiệt hại về của cải do **LŨ QUÉT** gây ra | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ |
| Phải trải qua những thiệt hại về của cải do **BÃO** gây ra | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ |
| Phải trải qua những thiệt hại về của cải do **SẠT LỞ** gây ra | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ |
| Phải trải qua những thiệt hại về của cải do **HẠN HÁN** gây ra | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ |

**Nếu nằm trong trường hợp không xảy ra thì không hỏi mục tương ứng của câu 3.2 và 3.3.**

3.2. Theo ông/bà **HẬU QUẢ** của những trường hợp dưới đây có ảnh hưởng đến như thế nào đối với gia đình ông bà?

| Trường hợp | Rất nghiêm trọng | Nghiêm trọng | Bình thường | Hậu quả nhỏ | Hậu quả rất nhỏ | Không để lại hậu quả |
|---|---|---|---|---|---|---|
| NGẬP LỤT | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| LŨ QUÉT | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| BÃO | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| SẠT LỞ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| HẠN HÁN | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

3.2. Việc **GIẢM THIỂU** hay **NGĂN CHẶN HẬU QUẢ** của thiên tai dưới đây quan trọng như thế nào 3.3.

| Trường hợp | Rất quan trọng | Quan trọng | Bình thường | Ít quan trọng | Rất ít quan trọng | Không quan trọng |
|---|---|---|---|---|---|---|
| NGẬP LỤT | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| LŨ QUÉT | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| BÃO | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| SẠT LỞ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| HẠN HÁN | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

3.4. Ông/bà nghĩ mức độ quan trọng của kiến thức cộng đồng/tri thức bản địa trong việc góp phần giải quyết các vấn đề thiên tai như thế nào?

☐1 Rất quan trọng ☐2 Quan trọng ☐3 Bình thường ☐4 Ít quan trọng ☐5 Không quan trọng

**Gắn kết cộng đồng**

3.5. Khi thiên tai bão lụt xảy ra, gia đình ông/bà có thể nhận được hỗ trợ giúp đỡ kịp thời từ láng giềng xung quanh thôn không?

☐1 Chắc chắn có ☐2 Có thể có ☐3 Không biết ☐4 Không có

**Tham gia trong các hoạt động của cộng đồng**

| Mức độ đánh giá của hộ gia đình ông/ bà đối với các vấn đề sau như thế nào? | Không có | Không Tham gia | Rất cao | Cao | Trung bình | Thấp | Rất thấp |
|---|---|---|---|---|---|---|---|
| 3.6. Mức độ **THAM GIA ĐÓNG GÓP Ý KIẾN** của người dân trong các **BUỔI HỌP** bàn về kế hoạch và giải pháp phòng tránh lụt bão của thôn | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.7. Mức độ **THAM GIA TẬP HUẤN** kỹ năng, nâng cao nhận thức về thiên tai của dân cư trong thôn như thế nào? (Thông qua các khóa tập huấn, hoạt động cộng đồng, truyền thanh…) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.8. Cơ hội của **PHỤ NỮ THAM GIA** vào các hoạt động của cộng đồng liên quan đến phòng chống thiên tai, bão lụt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Chuẩn bị của cộng đồng trước thiên tai**

3.9. Ông/bà cho biết mức độ chuẩn bị các vật dụng phòng chống thiên tai lụt bão như thế nào? (thuyền, thùng nước, túi cứu thương, đèn pin, thức ăn…)
☐1 Chắc chắn chuẩn bị tốt ☐2 Có thể chuẩn bị tốt ☐3 Bình thường
☐4 Chuẩn bị vừa phải ☐5 Chuẩn bị sơ sài ☐6 Hoàn toàn không chuẩn bị
3.10. Ông/bà cho biết những kinh nghiệm truyền thống nào được người dân địa phương sử dụng để ứng phó với thiên tai **BÃO** và **LŨ LỤT** (có thể lựa chọn nhiều mục)

| Ngắn hạn | Lựa chọn | Dài Hạn | Lựa chọn |
|---|---|---|---|
| Cập nhật thông tin về thời tiết | ☐ | Xây dựng nhà an toàn | ☐ |
| Giằng chống nhà cửa | ☐ | Di chuyển đến điểm an toàn | ☐ |
| Chuẩn bị lương thực | ☐ | Thay đổi các hoạt động sinh kế | ☐ |
| Kiên cố nhà cửa | ☐ | Xây dựng chuồng trại cao hơn | ☐ |
| Di chuyển đồ vật lên cao | ☐ | Trồng rừng | ☐ |
| Neo đậu tàu thuyền | ☐ | Thay đổi cơ cấu mùa vụ | ☐ |
| Tìm nơi trú ẩn | ☐ | Xây hầm trú ẩn | ☐ |
| Sơ tán | ☐ | Trang bị hệ thống cảnh báo tốt | ☐ |
| Khác (ghi rõ)………………….. | ☐ | Diễn tập | ☐ |
| | | Khác (ghi rõ)…………………. | ☐ |

3.11. Trong tương lai, bản thân ông/bà có dự định có những phương án gì để bảo vệ bản thân và gia đình khỏi thiên tai không? (Ví dụ: Nâng cao nền nhà, xây gác lửng, cao tầng, thay đổi lịch mùa vụ, đa dạng nguồn thu nhập)
☐1 Chắc chắn có ☐2 Có thể có ☐3 Không biết ☐4 Không có
3.12. Ông/bà hãy cho biết khả năng của gia đình có thể cung cấp nhân lực tình nguyện hỗ trợ khi thiên tai xảy ra trong điều kiện có thể?
☐1 Chắc chắn có ☐2 Có thể có ☐3 Không biết ☐4 Không có

**Thể chế**

| Mức độ đánh giá của hộ gia đình ông/ bà đối với các vấn đề sau như thế nào? | Rất cao | Cao | Trung bình | Thấp | Rất thấp |
|---|---|---|---|---|---|
| 3.13. Khả năng của chính quyền địa phương trong việc cung cấp thông tin chính xác cho người dân trước và trong suốt thời gian xảy ra thiên tai | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| 3.14. Hiệu quả của mốc báo lũ trong khu vực ông bà sinh sống khi xảy ra lũ lụt | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.15. Khả năng của chính quyền thôn trong việc hoạch định các phương án di dời, cung cấp thông tin hướng dẫn các điểm an toàn cho người dân khi có thiên tai xảy ra? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.16. Hiệu quả của đội xung kích và Tiểu Ban PCLB của thôn trong đáp ứng công tác chuẩn bị, phòng chống và giảm thiểu khi thiên tai xảy ra | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.17. Chính quyền địa phương có phương án hỗ trợ hiệu quả người dân chịu ảnh hưởng ngay sau khi thiên tai xảy ra | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3.18. Mức độ tin tưởng vào khả năng thành công của đội xung kích và Tiểu ban PCLB trong việc ứng phó và thích ứng đối với thiên tai và biến đổi khí hậu trong tương lai. | ☐ | ☐ | ☐ | ☐ | ☐ |

## PHẦN 4. NGUỒN VỐN MÔI TRƯỜNG

**Cường độ của thiên tai từ trước đến nay**

4.1. Ông/bà cho biết những loại thiên tai nào sau đây thường ảnh hưởng đến thôn ông/bà đang sinh sống (có thể lựa chọn nhiều phương án)

☐1 Bão ☐2 Lụt ☐3 Lũ quét ☐4 Hạn hán ☐5 Xói lở

☐6 Khác (ghi rõ)……………………………………………………………………………………………

4.2. Gia đình ông/bà đã từng trải qua lũ lụt trong vòng 15 năm qua?

☐1 Có ☐2 Không

**NẾU KHÔNG, CHUYỂN ĐẾN PHẦN TẦN SUẤT VÀ BIẾN ĐỘNG THIÊN TAI**

4.3. Ông/bà hãy cho biết mực nước ngập sâu nhất trong lịch sử mà gia đình ông/bà đã từng trải qua

a. Năm …………

b. Mức độ ngập

☐1 < 0.5 m ☐2 0.5-1.0 m ☐3 1.0-2.0 m ☐4 2.0-3.0 m ☐5 >3.0 m

4.4. Ông bà cho biết mức thiệt hại do thiên tai gây ra đã ảnh hưởng đến gia đình ông/bà như thế nào?

☐1 Rất cao ☐2 Cao ☐3 Trung bình ☐4 Thấp ☐5 Rất thấp ☐6 Không

**Tần suất và biến động thiên tai**

4.5. Ông/bà hãy cho biết tần suất xảy ra thiên tai trong vòng 15 năm qua như thế nào?

☐1 Xảy rất thường xuyên ☐2 Xảy thường xuyên ☐3 Xảy ra trung bình

☐4 Không biết ☐5 Ít xảy ra ☐6 Không xảy ra

4.6. Ông/bà hãy cho biết các loại hình thiên tai biến động như thế nào từ trận lụt năm 1999?

☐1 Tăng hơn ☐2 Ổn định ☐3 Giảm đi ☐4 Thất thường ☐5 Không biết

**Chất lượng môi trường**

| **Mức độ đánh giá của hộ gia đình ông/ bà đối với các vấn đề sau như thế nào?** | **Rất tốt** | **Tốt** | **Bình thường** | **Chưa đảm bảo** | **Không đảm bảo** |
|---|---|---|---|---|---|
| 4.7. Chất lượng môi trường nước ở địa bàn thôn | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4.8. Tình hình sử dụng công trình vệ sinh ở địa bàn thôn | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4.9. Tình hình thu gom chất thải rắn ở địa bàn thôn | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4.10. Vấn đề hệ thống thoát nước thải (nước thải sinh hoạt và nước thải sản xuất) ở địa bàn thôn | ☐ | ☐ | ☐ | ☐ | ☐ |

## PHẦN 5. THÔNG TIN CHUNG VỀ CỘNG ĐỒNG THÔN XÓM

5.1. Gia đình của ông/bà ở trong thôn này đã được bao nhiêu năm?
………………… năm

| Đánh giá của hộ gia đình ông/ bà đối với các ý kiến sau? | Rất cao | Cao | Trung bình | Thấp | Rất thấp |
|---|---|---|---|---|---|
| 5.2. Người dân trong thôn xóm có mối quan hệ đoàn kết gắn bó với nhau | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.3. Người dân trong thôn xóm có thể giúp đỡ nhau khi cần thiết | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.4. Người dân trong thôn thường xuyên tham gia các hoạt động chung của thôn (lễ hội, phong trào…) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.5. Người dân trong thôn xóm có thể trao đổi thảo luận cùng nhau để giải quyết các vấn đề chung của thôn | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.6. Người dân có thể trao đổi với trưởng thôn để giải quyết các vấn đề xảy ra trong thôn xóm | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.7. Cộng đồng thôn xóm có các ưu tiên trong xác định mục tiêu phát triển tương lai của cộng đồng | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.8. Người dân trong thôn luôn nỗ lực cùng nhau ứng phó, phục hồi và giảm thiểu tác hại của thiên tai | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.9. Cộng đồng thôn xóm có thể rút ra các bài học từ những kinh nghiệm thực tiễn của thành công và thất bại trong ứng phó với thiên tai trong quá khứ để có giải pháp phát triển tốt hơn cho cộng đồng trong tương lai | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.10. Thôn luôn có mối liên kết với các thôn khác, các tổ chức khác bên ngoài để góp phần phát triển thôn | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.11. Người dân trong cộng đồng luôn có niềm tin vào sự phát triển tương lai của thôn xóm | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5.12. Dân cư trong thôn xóm cam kết cùng nhau góp sức cho sự thịnh vượng của cồng đồng thôn xóm (Xây dựng nông thôn mới) | ☐ | ☐ | ☐ | ☐ | ☐ |

5.13. Ông/bà cho biết mức độ hài lòng với cuộc sống hiện tại trong thôn này
☐1 Rất hài lòng ☐2 Hài lòng ☐3 Bình thường ☐4 Ít hài lòng ☐5 Không hài lòng
5.14. Ông/bà có dự định sống lâu dài ở trong thôn này không
☐1 Chắc chắn có ☐2 Có thể có ☐3 Không biết ☐4 Không có

***Xin chân thành cám ơn sự giúp đỡ của ông/bà cho nghiên cứu này!***

# Appendix - Figures

**Appedix 6 Image of flood pillars in field survey has been captured by authors (March 2012, May 2013, and June 2013)**

Dong Hoa - Hoa Chau, Hoa Vang

Phong Nam - Hoa Chau, Hoa Vang

Tay An - Hoa Chau, Hoa Vang

Quan Chau - Hoa Chau, Hoa Vang

Hoa Chau - Giang Dong, Hoa Vang

An Tan - Hoa Phong, Hoa Vang

Cam Toai Dong, Hoa Phong, Hoa Vang

Tuy Loan Dong 2, Hoa Phong, Hoa Vang

An Ngai Tay 2, Hoa Son, Hoa Vang

Giang Nam 1, Hoa Phuoc, Hoa Vang

Bau Bang (Loc My), Hoa Bac, Hoa Vang

Pho Nam, Hoa Bac, Hoa Vang

**Appedix 6 Image of flood pillars in field survey has been captured by authors (March 2012, May 2013, and June 2013) (Cont.)**

Nam My, Hoa Bac, Hoa Vang

Thai Lai, Hoa Nhon, Hoa Vang

Quang Nam 2, Hoa Lien, Hoa Vang

Dong Lang, Hoa Phu, Hoa Vang

Dong Lam, Hoa Phu, Hoa Vang

Hoi Phuoc - Hoa Phu, Hoa Vang

Hoa Hiep Bac, Lien Chieu

To 24 Man Quang 2, Hoa Quy, Ngu Hanh Son

Khue Dong 1- Hoa Quy- Ngu Hanh Son

**Appedix 6 Image of flood pillars in field survey has been captured by authors (March 2012, May 2013, and June 2013) (Cont.)**

Thi An, Hoa Quy, Ngu Hanh Son

Gan UBND, Hoa Xuan, Cam Le

Khue Dong 2 - Hoa Quy- Ngu Hanh Son

To 2 Son Thuy - Hoa Hai - Ngu Hanh Son

Man Quang 4, Hoa Quy, Ngu Hanh Son

Man Quang 3, Hoa Quy, Ngu Hanh Son

An Luu, Hoa Quy, Ngu Hanh Son


Flood mark in house's wall - Cam Le

## Appendix 7 Questionnair survey for community resilience assessment in targeted villages (during March, May, and June 2013 in Hoa Vang district)

Group discussion on Questionnair form and methods for households interview

Conduct a pre - test for questionnair form in Tuy Loan Dong 2 village, Hoa Phong commune

Conduct a deep - interview to village's leader (Tuy Loan Dong 2)

Conduct a household interview in Tay An village

Capture the location of interviewed houshold in Cam Ne village by GPS camera/handheld GPS device

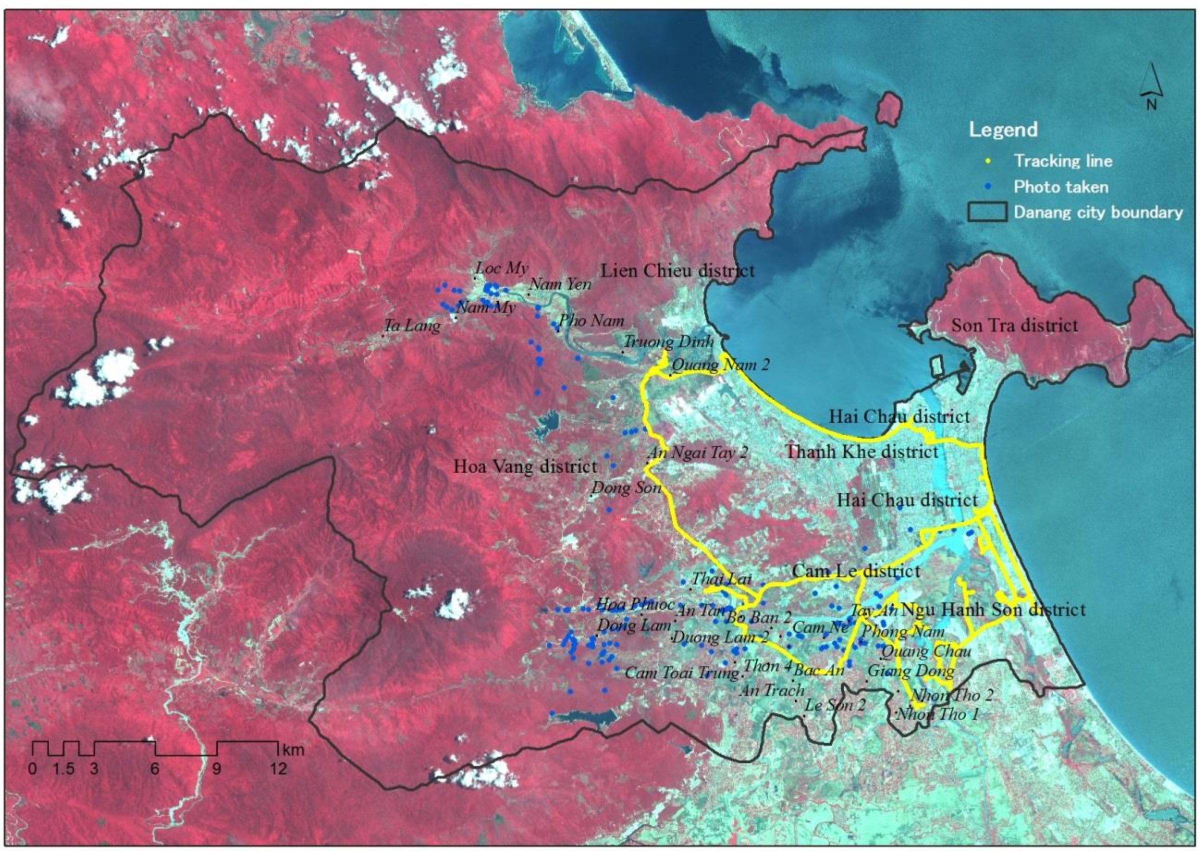
Experienced highest flood depth level of Ngo Van Quang's house, Tay An village

## Appendix 8 Equipments used for field survey

Used for field survey
(collected ground truth for land use/cover classification and flood pillar point for flood hazard analyzing)

Used for household questionnair survey
(handheld Garmin GPS and Elixim GPS camera)

## Appendix 9 Base map used during field survey



# Summary

Floods are by far the most hazardous, frequent and widespread natural hazards in the world caused hundreds of thousands of deaths, loss of livelihoods and infrastructure, interruptions of economic developments and the loss of property worth billions of dollars. Better understanding on floods risk and the potential consequences is crucial for the development of flood control policies as well as flood risk management strategies. High concerns in flood risk is paid on the frequency and intensity of floods, the urbanization led to high expose of humans and assets to flood risk, the vulnerability and their susceptibility to suffer damage and recently the building resilience community to flood disaster. This dissertation addressed the flood risk in relation to urbanization and examined the dimensions that affect community resilience to flood disaster. The study conducted flood risk assessment in Da Nang city and analyzed the relation between flood risk and urbanization during past 20 years (1990 to 2010). And then it focused on 4 villages in the rural district to identify how different of community resilience in the context of socio-economic conditions, historical flood disaster and the policies of the local authorities. The studies combined quantitative and qualitative methods including remote sensing and GIS techniques, statistical analysis and questionnaire surveys to obtain the objectives of study. The focus of *the first chapter* is to provide the background, objectives and brief statement of the methodology used in the whole dissertation.

The study in *chapter 2* focuses on the theoretical and conceptual framework that used in the research. We selected the suitable definition of risk and the related concepts (hazard, vulnerability and resilience) in context of flood risk management. In this dissertation research, we approved the risk definition given by United Nation International Strategy Disaster Reduction (2004) in which, flood risk is a product of hazard and vulnerability and was represented as a formula: Risk=Hazard x Vulnerability. Community Resilience to flood disaster is also taking into account due to its effective way for community preparedness, awareness, coping and recovery from hazards and disaster. We adopted the community assessment framework given by Wilson (2012) as it conceptual basic for assessment community since it applies to natural disasters, particular flood disasters. The model presented the interaction between three pillars of resilience including economic capital, social capital and environmental capital.

In *chapter 3*, I describe the background of study area of Da Nang city including characteristics of physical geography, socio-economic profile, and urbanization history and flood disasters during last 20 years. The study reveals that Da Nang city is a coastal city and high exposes to severe consequences of natural disasters. During last 10 years, Da Nang suffered from some severe natural disasters in 1964, 1999, 2006, 2007, 2009 and 2011 caused damage to life, houses, infrastructure, and agriculture products. In recent years, urbanization has taken place rapidly in Da Nang city. The coastal and central areas of Da Nang city witness a high rate of urbanization may face risk of flooding and environmental degradation especially during the rainy season.

In *chapter 4*, firstly I attempt to develop a method for flood risk assessment based on remote sensing and GIS techniques. Flood risk was obtained by evaluating the flood hazard and demographic vulnerability with a ranking matrix in two- dimensional multiplication model. The achievement of this analysis is the potential flood hazard was successful derived by integrating the inundation extracting from ALOS PALSAR and flow direction extracting from ASTER GDEM. This method is effective when hydrological and meteorological data are inadequate and the remote sensing images taken during flood times are not available or insufficient. Secondly, we attempt to identify where exposed to high flood risks are during 20 years in Da Nang city. Time series Landsat TM/ETM+ images and multi seasonal ALOS images were analyzed to generate temporal land use/cover maps (for 1990, 2001, 2007 and 2010), which was then utilize to analyze the urban expansion process. During 20 years, Da Nang city experienced a high rate of urbanization, the approximate rate of increased built-up in the area was 220%. The main directions of urbanization are seen in the West, Northwest, South and Southeast and long the coastal line. By overlaying expanded urban/settlement expansion during 20 years (from 1990 to 2010) with those extracted flood risk areas, the rate of settlement exposure to flood risk was clarified. The result shows that some of urbanization has clearly invaded into the higher risk areas of flood. The potential risk revealed by such urban/settlement expansion into the relatively high flood risk areas increased from 1.9 to 3.5% (nearly twofold) in the urbanization periods of 1990-2001 and 2007-2010, respectively.

My analysis of *chapter 5* is to assess the resilience of the rural communities to flood disaster. The community resilience assessment was conduct based on typology technique and questionnaire surveys. Flood affected villages typology was constructed by using two multivariate statistical techniques, respectively Principle Component Analysis (PCA) and Cluster Analysis (CA). The use of typology in zoning flood affected villages as a background for community resilience assessment is an effective and novel approach to flood disaster rerated in Vietnam. Household questionnaires were carried out by the authors with the assistance of Hoa Vang Statistical Office's staffs including face to face interview with the respondent's household and capturing the location and image of household by GPS camera/handheld GPS device. A total of 300 households were administered in four plot site villages of Hoa Vang rural district, Da Nang city by using simplified sample formula of Yamane (1967). The application of the 47 indicators of community resilience to the case study of Tay An, Cam Ne, Tuy Loan Dong 2, Hoi Phuoc villages showed that those indicators are applicable, duplicable, and effective for better describe how resilience of community to flood disaster in the study area sites. The linking typology potential vulnerability flood affected villages and capital-based approach in community resilience measurement (including economic capital, socio capital and environmental capital) has showed an effective and unique methodology/conceptual framework for representing and assessment community resilience to flood disaster. The findings of this study showed that various types of resilience community were found for each target village. Based on those differences, some solutions, recommendations can provide for the authorities to base their policy decisions for the enhancement of community resilience as well as meet the objectives of the new rural development program in the face of flood disaster and other climate related disasters.

In *the final chapter*, some main research findings are given: (i) The integrating of ALOS PALSAR and ASTER GDEM in mapping potential flood hazards shows effective contributing to flood risk assessment (ii) urban expansion in Da Nang city has been increasing in the present study area into regions where settlements are subject to significant flood risk during past 20 years (iii) the use of regional typology technique in zoning flood affected villages has demonstrated the interaction between differential socio-economic conditions and spatial distribution of flood affected villages in term of potential vulnerability that have providing background for community resilience assessment (iv) linking typology potential vulnerability flood affected villages and capital-based approach in community resilience measurement (including economic capital, socio capital and environmental capital) has showed an effective and unique methodology/conceptual framework for representing and assessing community resilience to flood disaster.

**Key words:** Flood Risk, Urban Expansion, Community Resilience, Vulnerability, Regional Typology, Da Nang city, Vietnam

# Japanese Summary

## 要旨

洪水は世界の至る地域で頻発する最も危険度の高い災害現象のひとつであり，人類の生命，食糧，社会インフラの損失をもたらし，甚大な経済的損失を引き起す。このため，洪水の潜在的な危険度を事前に評価，把握することは，リスク管理を担当する政策担当者にとって極めて重要な課題である。洪水の頻度や強度の甚大化に伴う危険度，脆弱性の増加は，近年の都市化の急速な拡大に伴い一層危機的な状況になっている。この論文では，都市化に関連した洪水リスク評価の手法と水害に対するコミュニティレジリエンスについて議論している。事例研究として，中部ヴェトナムのダナン市を事例とし過去 20 年間における都市化の拡大と洪水リスクの関係について考察した。リスクの評価は，ダナン市内の一つの県（郡に相当する農村行政区）にある 4 つの村（集落に相当）を対象として社会経済状況，過去の水害履歴，自治体の政策方針に関連したコミュニティレジリエンスの違いに注目して行われた。調査手法としてリモートセンシングと地理情報システム（GIS）技術を駆使し，現地では地域統計や住民へのアンケート調査を実施して定量的なモデルを構築して解析を進めた。本論の第 1 章では，本研究の目的とともにこうした解析手法の詳細について論じている。

第 2 章は，本研究の理論的背景と概念的なフレームワークについての議論である。特に，洪水危険度管理に関連した用語の定義として，リスク，ハザード，脆弱性，レジリエンスなどについて明確に解説している。すなわち，本論で採用されているリスクという概念は UNISDR（United Nation International Strategy Disaster Reduction : 2004）によって定義されたものを踏襲しており，ハザードと脆弱性の総体としてとらえている。一方，水害に対するコニュニティレジリエンスは，ハザードや災害に対して，コミュニティが備え，意識し，対処し，そして回復するための効果的な方法を検討する概念である。本研究では概念的な基礎として，Wilson（2012）が自然災害，特に水害を念頭において提示したコミュニティアセスメントの枠組みを適用した。このモデルでは，経済資本，社会資本，環境資本という 3 つの柱の相互作用としてのレジリエンスが提示されている。

第 3 章では，研究対象地域であるダナン市の自然環境，社会経済的状況に加え過去 20 年間における都市化と水害の歴史的過程について概観している。実際に，ダナン市は 1964, 1999, 2006, 2007, 2009 および 2011 年に大きな水害を経験しており，特に近年の急速な都市化の拡

大が被害の甚大化を引き起こしていることが議論されている。特に，沿岸域や河川流域の低地帯へ拡大した新興の住宅地は，極めて危険度の高い洪水リスクを潜在的に抱えている。

第 4 章は，リモートセンシングと GIS 技術にもとづいた洪水リスク評価の解析結果に関する記述である。ここで，洪水リスクは洪水のハザードと人口データによる洪水に対する脆弱性の視点から評価されている。潜在的な洪水のハザードは，ALOS PALSAR を用いた浸水地域の抽出と ASTER GDEM から抽出した洪水流方向性解析によって導き出された。この手法は，実際に河川流量（水文）データや気象データを入手することができないような場合においても，リモートセンシングのみから得られる情報をもとに適用することができる。次に，時系列的な LANDSAT 画像や ALOS Avnir 画像を用いて過去 20 年間におけるダナン市の都市化の拡大，特に土地利用の変化を抽出し図化を行った。実際に，ダナン市は過去 20 年間に急速に拡大し，都市的土地利用は 220%の割合で増加した。その結果，洪水リスク危険度のかなり高い地域に都市的土地利用が侵入していることが明らかにされた。

本論の第 5 章は，水害に対するコミュイティレジリエンスの評価に関する議論である。コミュニティレジリエンスの評価は統計的な地域類型化の手法とアンケート調査とを用いて行った。水害を受けた村の類型化は主成分分析（PCA）とクラスター分析（CA）の二つの多変量解析を用いて行った。水害を受けた村を類型化してコミュニティレジリエンスの評価を行う本研究の手法は，ヴェトナムにおける既存の水害に関連する研究では見られないアプローチである。世帯アンケートは，ダナン市ホアヴァン区統計局のスタッフの支援を受けて対面式インタビューで行うと同時に，GPS カメラや携帯型 GPS による調査対象世帯の位置情報および景観情報を取得した。調査対象となった合計 300 世帯は，Yamane（1967）の方法によってダナン市ホアヴァン区の 4 つの村から抽出された。コミュニティレジリエンスの 47 の指標を研究対象としたタイアン村，カムネ村，第二トゥイロアンドン村，ホイフオック村へ適応をすることによって，これらの村の水害へのコミュニティレジリエンスがどの程度あるのかを検討する上で本研究方法が適切であることが示された。さらに，水害を受けた村の潜在的脆弱性の評価と，コミュニティーレジリエンスの測定における経済資本，社会資本，環境資本を含むキャピタルベースのアプローチを組み合わせることによって，水害に対するコミュニティレジリエンスの評価を行うことは，有用で新しい方法論的/概念的フレームワークを提示できたことになり，このことも本研究の成果である。本研究では分析の結果，コミュニティレジリエンスのいくつかのタイプが知見として得られた。これらのタイプの違いから，コミュニティレジリエンス強化の

政策決定の基盤だけではなく，水害をはじめ気候変動に関連した災害に直面した新たな農村開発プログラムの目標を達するための解決方法や提言を，行政に対して提供することができる。

最終章では，本研究で明かにされた点について要約している。(i) 潜在的な洪水ハザードを地図化するために ALOS PASLAR 画像と ASTER GDEM を統合的に活用し，洪水リスク評価を効果的に行うことができた。(ii) 過去 20 年間におけるダナン市の都市拡大によって，周辺地域における洪水リスク危険度は著しく上昇した。(iii) コミュニティレジリエンスを評価するために，潜在的脆弱性という観点から社会経済的特徴と自然的特徴を明らかにする指標を用いた水害を受けた村の地域類型化を行うことで社会経済状況の差異と水害を受けた村の空間的配置との相互関係を例証した。(iv) それぞれの村のコミュニティレジリエンス 3 つの側面に焦点を当てたアンケート調査に基づく，定量的方法と定性的方法によって計測した。3 つの側面とは経済資本，社会資本，環境資本であり，これらはそれぞれの村同士の比較を容易にし，コミュニティレジリエンスを保つためのそれぞれの資本の強弱がどの程度であるかを判断することができた。(v) 地域類型の手法とコミュニティレジリエンスの評価における水害に関する現状課題を考慮した 3 つの資本をベースにしたコミュニティレジリエンスに関するアンケート調査を統合したアプローチは，有用かつ独創的な概念的枠組みを提示した。(vi) 対象とした村のコミュニティレジリエンスの違いが明らかになったことで，水害をはじめ気候変動に関連した災害に直面することを想定して，それぞれの地域に適したコミュニティレジリエンスの強化を行政政策的に進めていく必要があるが，本研究はそのための解決方法や提言などを提示することができた。

キーワード：洪水リスク，都市拡大，コミュニティレジリエンス，脆弱性，地域類型，ダナン市，ヴェトナム