Assessing vulnerability of communities and understanding policy implications of adaptation responses to flood-related landslides in Asia

Final report for APN project: ARCP2008-09CMY-Espaldon

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Overview of project work and outcomes

Minimum 2pages (maximum 4 pages)

The project analyzed the vulnerability of communities to rainfall induced landslides in selected Asian countries, namely China, Nepal, Philippines and Vietnam using an agent-based framework. Drawing from the methods of an agent-based modeling framework “intervulnerability”, we applied complementary methods to understand vulnerabilities and adaptations of farmers and residents in vulnerable areas in these four Asian countries. These include vulnerability mapping, vulnerability profiling, and agent-based modeling. Vulnerability maps were used to identify vulnerable areas where case studies were conducted, vulnerability profiles were used to understand the adaptive behavior of the people in the selected vulnerable areas, and agent-based model was applied to understand the effects of dynamic interactions between the socio-economic and biophysical profiles on the level of vulnerability and adaptation to landslide impacts.

Whilst the vulnerability map for Vietnam was generated by applying Analytical Hierarchy Process (AHP) technique on the various socio-economic and biophysical data, those for China, Nepal and the Philippines were drawn from past studies. The state of Enshi in China, Matatirtha Village Development Committee in Nepal, Dak Nong province in Vietnam, and Quezon province in the Philippines were selected as case studies because these were identified as hotspot landslide areas in the vulnerability maps. All these areas have experienced landslide disaster events in the past years, causing casualties and damages to vulnerable people.

Survey was conducted in all these case study areas to collect data relevant to the household socio-economic (e.g. income, family size, membership in organizations, etc.) and farm biophysical (e.g. land cover, elevation, soil, etc.) characteristics as well as information on adaptation strategies and disaster experiences. Applying cluster analysis on these survey data and information, we develop vulnerability profiles of the farmers and residents in these areas. Although the survey data and information that have been collected from the case study areas were based on the same methodological framework (and thus very similar list of variables), the cluster analysis generated different number and description of clusters in the different case study areas:

China	Cluster 1 (High Vulnerable - Small Traditional Farmers); Cluster 2 (Medium Vulnerable - Large economical Farmers); and Cluster 3 (Low Vulnerable - Commercial and less-Farm)
Nepal	Cluster 1 (Migrant Residents); Cluster 2 (Mid-age Native Residents); and Cluster 3 (Old-age Native Residents)
Vietnam	Cluster 1 (Large Commercial Farm); Cluster 2 (Diversified Farm); Cluster 3 (Household with Non-farm Works); and Cluster 4 (Small Traditional Farm)
Philippines	Cluster 1 (Low Vulnerable Upland Farmers); Cluster 2 (Low Vulnerable Lowland Non-Farmers); Cluster 3 (High Vulnerable Coastal Farmers); and Cluster 4 (High Vulnerable Coastal Non-Farmers)

The agent-based model was applied in the Philippines to pilot test its applicability landslide related environmental problems. The model inputs include the vulnerability profiles of the farmers with their associated adaptation strategies and disaster experiences. Moreover, other biophysical characteristics of the study area such as soil texture, plasticity index and cation exchange capacity (CEC), digital elevation model, slope, geology, and land use map were derived from published secondary data, laboratory analysis, and satellite image processing thru GIS and remote sensing applications. The combination of biophysical hazard and socio-economic profile of households represents the potential risk, while the combination of potential risk and the corresponding adaptation is the basis of the computation of vulnerability. The adaptation is currently a parameter that is set dynamically in the simulation, so as to represent the varying levels of effectiveness of adaptation measures like the early warning system.

Based on the vulnerability profiles and agent-based scenarios generated from this study, appropriate design policies may be recommended in order to minimize vulnerability to landslides and to maximize the long-term sustainability of their adaptive decisions.

Non- technical summary

The study characterized the demographic, socio-economic, climatic, biophysical and institutional aspects that contribute to vulnerability thru household survey and cluster analysis. Adaptation mechanisms were drawn from the survey, key informant interview and focus group discussions conducted with the stakeholders in the respective case study sites. Existing policies and measures in response to landslide occurrence were also evaluated and recommendations to improve capacity to cope with such disasters were given accordingly. The researchers of the participating countries were trained with practical use of complementary methods for vulnerability assessments including vulnerability mapping, vulnerability profiling and agent-based modeling using various tools such as Analytical Hierarchy Process (AHP) technique, cluster analysis, JAVA programming, GIS and remote sensing. This study showed that assessment of flood-related landslides in Asia is of paramount importance considering the devastating impacts of global climate change.

Objectives

The project aims to identify landslide prone areas in selected countries in Asia including China, Nepal, Vietnam, and the Philippines and assess their vulnerability to flood-related landslide events by applying an agent-based modeling framework. It seeks to compare the adaptive behavior of vulnerable people and their disaster experiences. The specific objectives are:

a) to characterize the demographic, socio-economic, climatic, biophysical and institutional aspects contributing to vulnerability;
b) to study the capacity of communities to deal with landslides and analyze the adaptation mechanisms after these events;
c) to evaluate existing policies and available measures to respond to the occurrence of such disasters;
d) to make recommendations to improve the capacity to cope with them; and
e) to train researchers on the practical use of complementary methods for vulnerability assessment.

Amount received and number years supported

The Grant awarded to this project was:
Year1, 2007-2008: USD 56,000
Year 2, 2008/2009: None, the remaining USD 14, 000 will be released by APN upon the submission of final outputs

Activity undertaken

Project preparation

1. Completion of Kick-off Meeting and Agent-Based Modelling (ABM) Training

2. Creation of acronym for the title of the project
3. Development of the VALE project brochure and website
4. Establishment of respective research teams in each country

Data Preparation
1. Identification of study sites and site visits
2. Review of related literature
3. Formulation and finalization of Survey and Key Informant Questionnaire
4. Pre-testing of survey questionnaire
5. Completion of primary data gathering
6. Completion of secondary data gathering
7. Creation of Project database

Data Analysis
1. International Framing Workshop (Attended by partners from Belgium, China and Viet Nam)
2. Capacity-building for actual Agent-based modeling (Philippines)
3. Completion of Vulnerability mapping (Vietnam)
4. Formulation of Agent Based Model (ABM) Framework
5. Completion of Data Encoding, Cluster Analysis and Data Profiling
    - Completion of Vulnerability profiles
    - Generation of behavioral model
6. Creation of ABM prototype model

Coordination and dissemination
1. Establishment of Project Networks
2. Coordination with local partners in the study
3. Publishing of press releases of activities in the project in university publication (Philippines)
4. Dissemination of Project Information
    - article printed at UPLB Link (2008)
    - seminars for ABM (February 2008 and January 2009)
    - presentation of project to LGUs, key stakeholders, graduate students, professors and the scientific community

Summary of Results

The state of Enshi in China, Matatirtha Village Development Committee in Nepal, Dak Nong province in Vietnam, and Quezon province in the Philippines were selected as case studies because these were identified as hotspot landslide areas in the vulnerability maps. In recent years, flash flood and land slides occurred in these areas with higher frequency and intensity causing large damage to infrastructure, assets and human life.

The ecological setting, consists of the biophysical and socio-economic characteristics, plays an important function in understanding the level of vulnerability and adaptation of an individual or group. Aside from the ecological setting, the chances of survival in the midst or after the disaster depend on the degree of disaster impact to the ecological background of the population.

The biophysical condition affects the level of vulnerability and adaptation of an individual or a group. Most of the populations especially in rural areas highly depend on the benefits that the environment provides. Their livelihoods that being tied up with the soil. On the other hand, the socio-economic background provides the foundations for the populations' capacity to survive and sustain before and after the disaster.

Cluster analysis is an effective multivariate analysis used in order to come up with typology of vulnerable groups of people, based on their biophysical and socioeconomic characteristics. Using these typologies, the adaptive capacity, adaptive and emergency preparedness strategies were identified. The adaptive capacity of vulnerable communities is a function of income, market, institutions, education, social networks.

Experience with disasters makes the victims less vulnerable to disasters. These people become aware and thus prepared for any eventualities that may pose danger to their lives and properties. Adaptation strategies to disasters, on the other hand, include not only household decisions but also institutional contingency plans from local government and non-government organizations.

Adaptive and emergency preparedness strategies of the various clusters before and after the landslide became the basis for the behavior of the agents (e.g. shifts in livelihood and crops planted were observed after the 2004 landslide, as reflected by the respondents' responses), in the developed prototype agent based modeling (ABM) model. One main point that was observed based on the behavioral model is that though there were changes in the livelihood of the people in the area, outmigration was not an option.

Relevance to APN's Science Agenda and objectives

The project addresses three crosscutting themes of APN's science agenda by tracing the links of both extreme climate events and unsustainable land use patterns to the occurrence and consequences of landslides through vulnerability assessment. Moreover, by applying an agent-based tool that explicitly models not only the link between affected people and their environment (human ecosystem), but also the decision processes of concerned authorities on adaptation, it promotes APN's policy agenda.

Self evaluation

In general, the VALE project was guided accordingly. The direction of the project was anchored on the objectives set. The necessary baseline knowledge and activities were accomplished to ensure that the project objectives were achieved. Based on the household survey and cluster analysis, the demographic, socio-economic, climatic, biophysical and institutional aspects that contributed to vulnerability to flood-related landslides were characterized. Emergency preparedness and adaptation strategies were generated from the household survey, key informant interview and focus group discussions. These methods were conducted by the researchers along with the various stakeholders in each respective case study site. Behavioral models were constructed from the information on emergency preparedness and adaptation strategies. The researchers of the participating countries were trained with practical use of complementary methods for vulnerability assessments including Agent-Based Modeling, JAVA programming, GIS and remote sensing tools. The project team has started preparing joint publications for international journals focusing, among others, on inter-country comparison of vulnerability profiles and adaptation strategies,

Potential for further work

- Application and validation of the agent-based model in other case study areas
- Capacity building for the application of agent-based modeling

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1 Introduction

For the period of 1900-2000, Asia has had the highest number of people reported affected by natural hazards in the world, in particular droughts and floods (EM-DAT Disaster Database). Frequent droughts are causing huge economic damage and health problems, but flood effects are increasingly more devastating. Flooding due to extreme climate events and unsustainable land use has already caused massive landslides, which have damaged not only property, but also claimed lives of many people in Asia. Abramovitz (2001) attributed forty-nine percent (49%) of global deaths to flooding while the fifty-one percent (51%) are induced by windstorm, volcanic activity and other disasters. Statistics show that more than 228,400 lives in the region were claimed because of typhoons, tropical cyclones and earthquake (Zimmerli, 2009). The estimated number of people who were reportedly killed globally is 579,539. The average annual deaths from 1998-2008 is more than 57,000 (Ollet, 2008).

Moreover, according to Papathhoma-Kohle et al. (2007), landslides are responsible for the significant loss of life and injury to people and their livestock as well as loss of and damage to lifelines, critical infrastructures, agricultural lands, housing and public and private infrastructures and assets. A database of reported events of slope instability extending back many decades has been developed for the Greater Woolagong urban area in Australia. Champati ray et al. (2007) believed that the increase of landslide risk is often due to the increase in both the hazards (continued deforestation in landslide-prone areas, increased regional and local precipitation and increased seismic activity) and the elements at risk (increased urbanization and development). Papathoma-Kohle et al. (2007) further cited that the increase in the occurrence of landslides can possibly be attributed to climate change, by the increase in rainfall intensity and the changes in soil temperature that may lead to reduced slope cohesion and stability. Varnes (1981) estimated that from 1971 to 1974, nearly 600 people were killed every year world-wide as a consequence of slope failures. Approximately, 90% of these deaths occurred within the Circum Pacific Region. Moreover, the International Association of Engineering Geology Commission on Landslides (1979) estimated that some 14% of the lives lost in natural catastrophes could be attributed to landslides.

Considering the negative impacts of climate change on the intensity and frequency of precipitation and global trade on the sustainability of land use and ecosystem, floods and landslides are expected to become a perennial problem in Asia. For example, in Nepal, a least developed Asian country, landslides and flash floods are the most severe types of natural disaster because mountains occupy about 83% of the territory. Between 1983 and 2005, an average of 309 people was killed (about 32% of the total deaths) and more than 27,000 families were affected annually from these hazards (Li and Behrens, 2002). Likewise, in the Philippines and Vietnam, thousands of people mainly in rural areas have lost their lives due to flash floods and landslides during monsoon season since the 1990s. More than 1,000 people were killed in the Philippines alone in 2004 (PNDCC, 2005) by thick mudslides and heavy logs that covered and wiped out entire villages. In China, there were more than 3,000 landslide disasters that claimed more than 10,000 lives in recent years (Zhang, 2004). As disaster risk management is interpreted differently in various Asian countries (ISDR, 2002), there is different understanding on vulnerability and adaptation among policy makers in the region.

Vulnerability is defined as an aggregate of conditions and processes resulting from physical, social, economic, and environmental factors, which increase the susceptibility of a community to the impact of hazards (De Sherbinin et al., 2007 and Ollet, 2007). Thus, it is the ability of a system to attenuate stresses or cope with the consequences through various strategies/mechanisms (De Sherbinin et al., 2007). It is also time bound depending on the alterations generated basically for economic and political contexts, which are manifested through government decision making and actions (Gentile and Gonzales, 2001).

According to IPCC, vulnerability can be defined as a function of three interrelated elements: exposure ("degree to which a human group or ecosystem comes into contact with particular stress"), sensitivity ("degree to which a system will respond to a given change in climate, including beneficial and harmful effects") and adaptive capacity ("the ability of a system to cope better with existing or anticipated internal stress"). These elements are concurrently the products of political and socio-economic structures and the capacity of social institutions and individual actors to adapt to hazard stress (Pelling, 1999), as cited by Few (2003). Indicators of vulnerability include system exposure to crises, stresses and shocks, inadequate system capacity to cope and consequences and attendant risks of slow/ poor system recovery (de Sherbinin et al., 2007).

Vulnerability is the concept that explains why a community is more or less at risk to a given hazard. However, neither vulnerability alone nor hazard alone determines the occurrence of a disaster (Manila Observatory, 2005). A hazard, by itself, simply refers to a potentially damaging event or physical disturbance. The fusion of hazard and vulnerability seeds disaster. There are different factors at play, the analytical framework for assessing risks to disasters, which is adapted from the UNDP model and previously cited, is as follows:

Risk = Hazard x Exposure x Vulnerability

Based on this formula, "risk refers to the likelihood of disaster, loss or harm and a function of hazard frequency or severity, the exposed element or element at risk, and the vulnerability of that element"

Assessment of damages and formulation of post-disaster management plans and policies are necessary since these landslides may possibly occur again in the future. There is a need to assess and manage areas that are susceptible to land sliding in order to mitigate any associated damage (Lee, 2006).

Policy can help enforce scientifically-based recommendations, and ensure the proper dissemination of information which will make the early warning and disaster management systems and rehabilitation measures more effective and responsive to the peoples' needs. Science-policy linkage can thus facilitate a systematic procedure for predicting, warning of, and possibly forestalling, landslide events caused by floods, as well as in providing mitigation and rehabilitation measures to deal with them. Whilst policy should be able to provide measures to help vulnerable regions and communities to recover from and adapt to landslide risks, science has the challenging task of identifying landslide-prone areas and vulnerable people and informing policy about the sustainability of these measures.

The proposed project aims to contribute to the fulfilment of this task by developing an agent-based framework to assess vulnerability to flood-related landslide events in selected countries in Asia including China, Nepal, Philippines and Vietnam. As these countries represent parts of Asia (i.e. East, South, and Southeast) with different economic, political, social, and cultural settings, the project seeks to compare the adaptive behavior of vulnerable people to the the impacts of landslides. The project's specific objectives are: a) to characterize the demographic, socio-economic, climatic, biophysical and institutional aspects contributing to vulnerability; b) to study the capacity of communities to deal with landslides and analyze the adaptation mechanisms after these events; c) to evaluate existing policies and available measures to respond to the occurrence of such disasters; d) to make recommendations to improve the capacity to cope with them; and e) to train researchers on the practical use of complementary methods for vulnerability assessments.

2 Conceptual Framework

This project was anchored on the concept of “intervulnerability” framework (Figure 1), which was first applied in a START-supported pilot project to assess current and future vulnerability of farming communities to droughts in the Philippines (Acosta-Michlik 2005). This framework emphasizes the importance of considering the interaction of the impacts of global processes (i.e. trade liberalization and climate change) and the interconnection of global to local changes in assessing vulnerability (Acosta-Michlik and Rounsevell 2005). This is achieved by combining the socio-economic and biophysical attributes of an agent’s local environment, which are directly influenced by global changes, and by understanding the adaptive behavior of the agents to these changes. A change in the environment causes the agents to make decisions (not making any decision is also a decision), which when translated into actions result into outcomes. In a dynamic environment, vulnerability can be explained through the outcomes, and not the causes, of the actions. Because the socio-economic and biophysical environments, which shape the agent’s profile, vary not only in space, but also change through time, agents are inherently heterogeneous and adaptive. The agent’s profile influences his level of intelligence and degree of autonomy. “As such, the agent’s adaptive behavior to environmental stresses is contingent on his particular profile” (Acosta-Michlik and Rounsevell 2005). Profiling entails understanding the distinct socio-economic and biophysical attributes of the agents that make them behave in a certain way. Building farm typologies through cluster analysis offers a formal way of developing agent profiles.

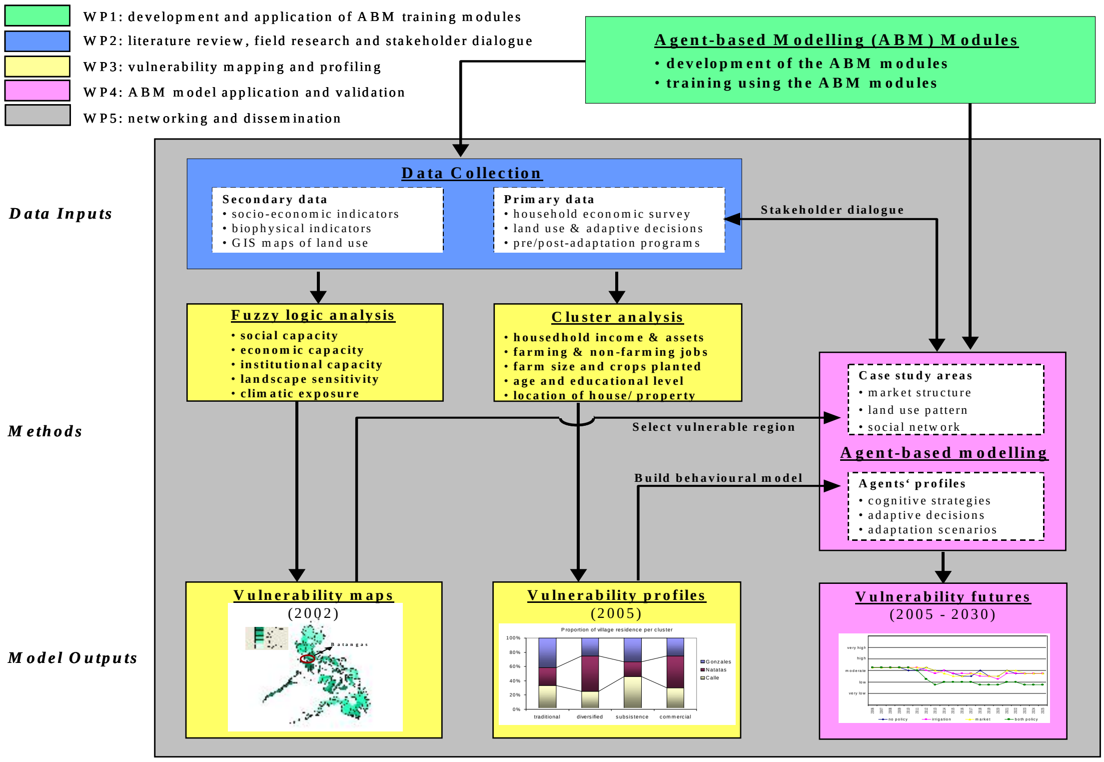


Figure 1 Intervulnerability Conceptual framework (based on Acosta-Michlik 2005)

The intervulnerability framework suggests that agent’s vulnerability to global environmental changes is a function not only of his exposure, sensitivity and adaptive capacity (as suggested in IPCC 2001), but also of his cognition (Acosta-Michlik and Rounsevell 2005). Cognition is an important determinant of vulnerability because it allows the agents to receive and exchange information, to perceive and evaluate risks, to identify and weigh options, to make decisions and take actions, and to modify and update his profile according to the outcome of these actions. Whilst some agents may have the same social and economic capacity to respond to environmental changes, their adaptive decisions and actions can be either constrained or promoted by their cognitive abilities. Cognition thus enables adaptation. Cognition is interpreted by constructing a behavioral model. Human interaction among each other and with the environment is a complex system. Behavioral models allow the representation of this system into a simplified framework to investigate a strand of the structural whole. A model of human behavior is important in vulnerability assessment because it represents the adaptive process inherent in human system. Behavioral models used for empirical application of an agent-based approach require simplicity and manageability for practical reason. Agents' decisions are based on some rules, which may be drawn from observation of the real world, empirical enquiry, established theories or common sense. Intricate behavioral models demand more decision rules, and the larger the number of rules the harder to trace the relationship between the input variables and to interpret the results of the agent-based model.

The intervulnerability framework aims to fill significant research gaps in vulnerability assessment by applying a method that takes into account the dynamics of human-environment interactions and by proposing a shift in foci of vulnerability studies from generic indices to adaptive agents Figure 1. It captures both the spatial and temporal dynamics of human-environment interactions and the adaptive behavior of local people to global environmental change. The methods follow three approaches – indicator-based, profile-based and agent-based. The first two approaches are commonly used in vulnerability studies in the fields of climate change, food security and poverty. Whilst an agent-based approach fills the important gaps in global environmental change research, this project shows that the other approaches are important to complement the empirical application of agent-based models. Generic indices of vulnerability guided the identification of case study areas in hotspot regions and social profiles of vulnerability were used to develop typologies from a large number of heterogeneous agents. The development of typologies is the focus of the analysis for most of the case study areas in this project because of its relevance in the assessment of vulnerability adaptation profiles of heterogeneous agents. Moreover, the profiles were required to build the behavioral model for the agent-based approach. Some experts have recognized the potential use of agent-based approach in assessing vulnerability. Because agent-based models are processed-based, they are useful for dynamic analysis of future vulnerabilities. Estimating dynamic vulnerability is hardly possible using indicator-based and profile-based approaches as they only aggregate and stratify past and present information. Studies that have projected vulnerability using indicator-based approach are based on comparative-static, and not dynamic analysis. However, very little empirical applications have been undertaken using this approach and they only deal with droughts. We thus tested the application of agent-based model in the assessment of vulnerability to landslides impacts in the case study areas in the Philippines.

3 Methodology

Following the conceptual framework presented in Figure 1, the discussion of the methods consists of three parts: vulnerability mapping, vulnerability profiling, and agent-based modeling. Because the case study areas were selected partly as a result of the vulnerability maps, the description of the case study areas is presented in the results.

3.1 Vulnerability mapping

The vulnerability maps are valuable in identifying hotspot regions in terms of a particular environmental hazard such as landslide. These maps were used in the project to identify the case study areas to ensure that the analysis prioritize the communities with high level of vulnerability to landslide impacts. Because these maps are available from previous studies for China, Nepal and the Philippines, we decided not to develop vulnerability maps in this project so as not to duplicate past research and to devote more time in improving the analysis for the other methods, in particular vulnerability profiling. Only Vietnam carried out vulnerability mapping because the available maps are not sufficient for locating hotspot areas for landslide. The following methodological description thus refers only to the Vietnamese case study.

The criteria selection for landslide assessment in the study area was divided into two steps: (1) physical assessment and (2) social-economic and environmental evaluation. For the physical assessment (step 1), five main physical factors were used for considering and calculating to address the landslide: (1) soil unit type (according to FAO soil classification system); (2) soil texture; (3) geology; (4) soil slope degree; and (5) rainfall. The general process for landslide analysis is shown in Figure 2. In this process, each factor requirement could be organized in form of one map layer in GIS. The overlay of these map layers in GIS produces a composite map of land mapping units. Landslide vulnerability evaluation requires investigation not only of the natural physical conditions, but also of the socio-economic and environmental conditions. In order to determine which criteria (and at what levels or weights) affect landslide for each parameter, experts were consulted to provide judgments on important of criteria. Using Analytical Hierarchy Process (AHP) technique these judgments on important of criteria were converted to criteria weights (w_i). Score for each criterion (x_i) on each land mapping unit were then determined. The weighted linear combination of w_i and x_i gives the landslide index for each mapping unit. Through the above procedure, landslide vulnerability map were produced.

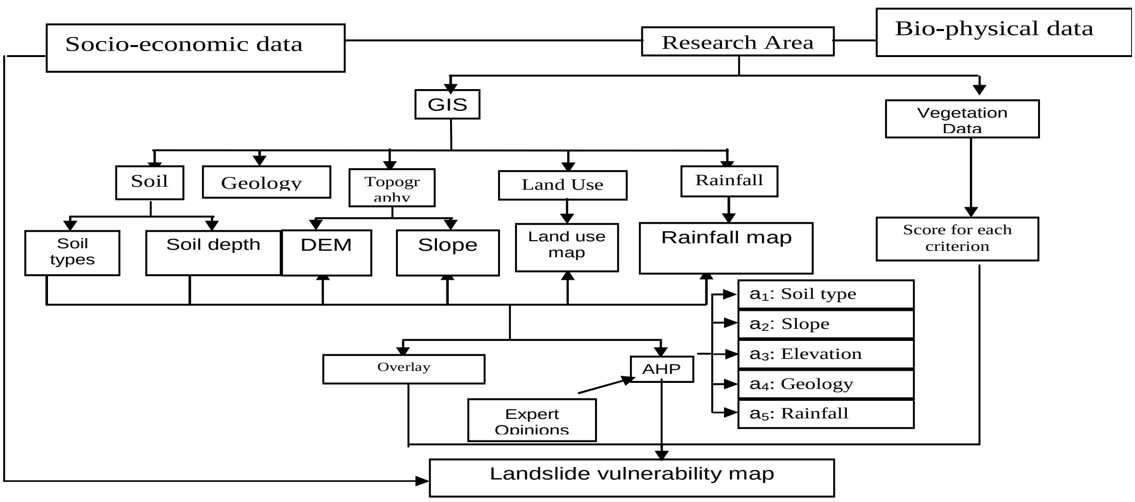


Figure 2 General method for landslide analysis for Vietnam

The first AHP was developed in the mid 1970s (Saaty, 1990) and since that time, has been applied to many types of decision problems. The fundamental process of AHP is to underlie perception, decomposition and synthesis. The purpose is to provide a methodology for modeling unstructured problems in the economic, social and management sciences. A hierarchy is an abstraction of the structure of a system to study the functional interactions of its components and their impacts on the entire system. This abstraction can take several related forms, all of which essentially deserved form an overall objective, down to sub – objectives, down further to force which affect these sub – objectives, down to the people who influence these forces, down to the objectives of the people and then to their policies, still further to the strategies, and finally the outcomes which result from these strategies (Saaty, 1990). In the theory context, Harker (1989) briefly described the three major concepts behind the AHP as follows :

Analytic: Simply choose the alternative that is most desired by numbering the scale of preference. In this sense, all methods will describe a decision as analytical by using mathematical logical reasoning.
Hierarchy: The AHP structures the decision problem in levels by breaking the problem. The decision maker can focus on smaller sets of decisions; in which the evidence from psychology suggests that humans can only compare 7 $\pm$ 2 items at a time, the so–called Miller's Law.
Process: The AHP cannot be expected to counteract the basic human tendency within a single meeting. People need time to think about a decision, gather new information, negotiate if it is a group decision, etc. Thus, in real world of decision problem involves a process of learning, debating and revising one's priorities.

The AHP is based on set of axioms that can be simplified in order to understand their meaning. Harker (1989) further explains this aspect of AHP as follows:

Axiom 1. Given any two alternatives i and j out of the set of alternatives A, the decision maker is able to provide a pairwise comparison a_{ij} of these alternatives under any criterion c the subset of criterion C on a ratio scale which is reciprocal; i.e.,

$$a_{ij} = 1/a_{ji} \quad \text{for all } i, j \in A.$$

Axiom 2. When comparing any two alternatives i, j $\in$ A, the decision maker never judges one to be infinitely better than another under any criterion c $\in$ C_{ij} i. e.,

$$a_{ij} \neq \infty \quad \text{for all } i, j \in A$$

Axiom 3. One can formulate the decision problem as a hierarchy.

Axiom 4. All criteria and alternatives which impact the given decision problem are represented in the hierarchy.

Saaty (1980) indicated that since the AHP is the specified decision–aiding tool, the group must first construct an appropriate decision hierarchy that reflects the problem under study. Most groups are willing to accept the basic hierarchy structure of the AHP as a rational way of modeling their problem. It allows a group with widely varying perspective to decompose a complex problem into its most basic and important components.

Consistency: The eigenvector method for estimating weights (priorities) in the AHP yields a way of measuring the consistency of a decision maker's entries in a pairwise comparison matrix. Saaty (1980) defined the consistency index (C.I.) as :

$$C.I. = (\lambda_{max} - n) / (n-1)$$

where :

n = The dimension of the square matrix comparison

λ_{max} = The largest eigen value of an $n \times n$ pairwise comparison matrix

If it is perfectly consistent, then

λ_{max} = N and

C.I. = 0

If the decision maker is inconsistent, then

λ_{max} > N

Saaty (1990) indicated that consistency ratio (C.R.) less than or equal to 10% is the acceptable level. On the other hand, it can be said that there is a 10% chance by which the decision maker answered the questions in a purely random manner. The degree of inconsistency can be measured through the equation:

$$C.R. = C.I. / R.I.$$

where: R.I. = Random Index

The determination of bio-physical criteria weight based on Analytical Hierarchy Process (AHP) is given in Figure 3.

where:

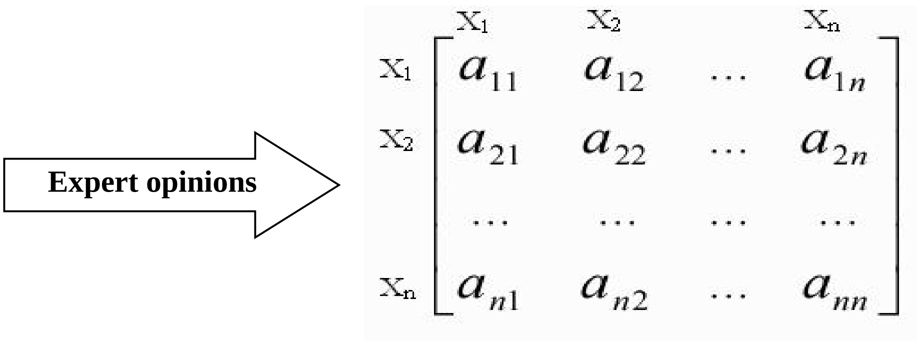
X_1: Soil type

X_2: Slope

X_3: Elevation

X_4: Geology

X_5: Rainfall



$$a_{ij} > 0,\ a_{ij} = 1/a_{ji},\ a_{ii} = 1.$$

Figure 3 determination of bio-physical criteria weight in AHP

After identifying the weights (wi), the score of each criterion based on the criteria selection were identified. The landslide assessment to determine vulnerability index in Vietnam were divided into two ways: (1) physical landslide assessment of vulnerability as shown in Figure 4, and (2) social-economic, environmental suitability evaluation as shown in Figure 5. The landslide vulnerability index is calculated from the weights and score of each criterion through the following equation:

$$Y = M_1 * w_{11} + M_2 * w_{22} + M_3 * w_{33} + M_4 * w_{44} + M_5 * w_{55} = \sum_{i=1}^{n} M_i * w_i$$

Where:

Y = Landslide vulnerability Index

Mi = Score of criterion i

Wi = Weight of criteria i

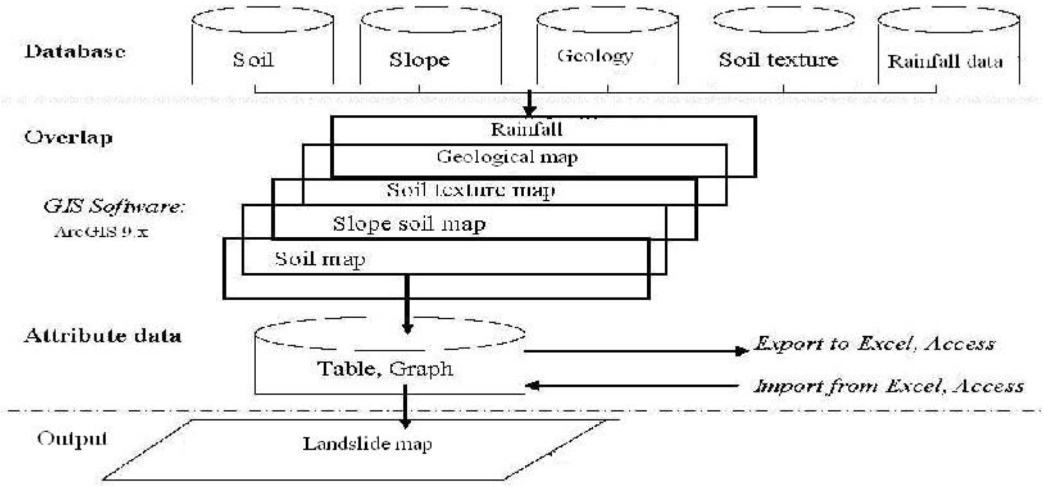


Figure 4 Physical landslide assessment of vulnerability

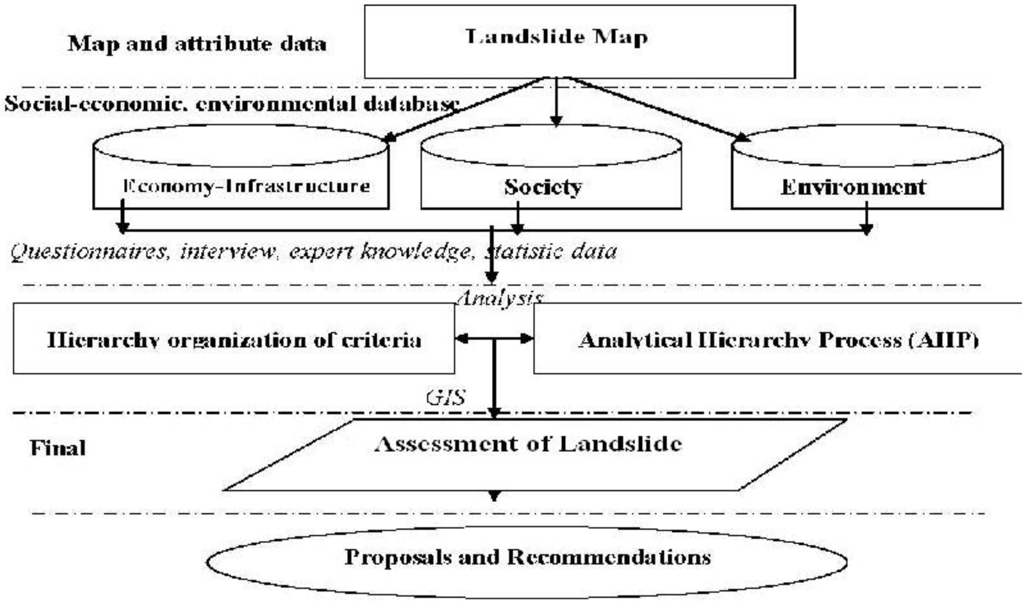


Figure 5 Socio-economic, environmental suitability evaluation

The data for landslide hazard mapping were collected from the secondary sources. ArcGIS 9.2, a GIS software, was used to prepare various spatial layers. A digital terrain model was obtained from the 1:25000 scale topographic maps. In order to prepare a geological map, land use map, and soil types and depth map as well as to verify, edit, and update the collected information, these data were analyzed to develop vulnerability maps using ArcGIS 9.2. The main spatial data sources (maps) that were collected for this study include:

- sheets of soil map with scale 1:50,000 (Dinh Linh, 2007);
- sheets of topography map with scale 1:50,000;
- current land use maps in year 2008 with scale 1:50,000;
- existing land use maps for period of 2000-2008;

The main attribute data sources required for this study including the data accompanying the above spatial data and the non spatial data are:

- data of location, climate;
- last census of physical, social-economic, infrastructures;

3.2 Vulnerability profiling

The development of vulnerability profiles for the different case study areas followed the four steps:

(1) Establish knowledge on landslide impacts through review of literature, key informant interviews and focus groups, and survey in the Philippines;
(2) Using this knowledge, develop a methodological framework for assessing landslides impact through a framing workshop with all project partners;
(3) Using this framework, develop survey questionnaire for and carry out survey in the other case study areas (i.e. China, Nepal, Vietnam); and
(4) Using the survey results, generate vulnerability profiles using cluster analysis for all case study areas.

Step (1): Secondary data sources were gathered from Annual Municipal and Village Plans of Infanta, Quezon. In January 2008, Key Informant interviews and Focus-group were also conducted among the local government officials in Infanta at the municipal and village levels of Ilog, Pinaglapatan and Magsaysay. The government officials were the key stakeholders and they provide information on what has transpired during and after the 2004 flashfloods and mudslides in their respective communities. Household interviews were conducted using a structured questionnaire composed of open- and close-ended questions. It aimed to determine the respondents profile and characteristics before and after the November 2004 flashflood and mudslides as well as their experience with disaster, and their disaster preparedness and adaptation strategies. Pilot testing of the questionnaire was conducted at Village Lalakay, Los Baños, Laguna to identify items in the questionnaire that need to be improved or deleted. Village Lalakay was chosen because of the similarities experienced in terms of flashfloods and landslides. Thirty residents served as respondents.

One hundred seven households were sampled from the three villages: Magsaysay, Ilog, and Pinaglapatan (33, 39 and 35 households respectively). The number of respondents was generated using the following equation:

$$n = \frac{\frac{Z^2}{E^2} PQ}{1 + \frac{\mathbf{1}}{N}\left[\left(\frac{Z^2}{E^2} PQ\right) - 1\right]}$$

Households affected by landslides denoted by P and Q is defined as 1-P, when the values of P and Q are between 1 and 0, inclusively;

E = maximum tolerable error
Z = tabular value of the Z statistics at a certain level of α
N = total number of households

All the 107 interviews were accomplished based on the survey questionnaire in the Villages of Ilog, Magsaysay and Pinaglapatan of Infanta.

Step (2): In the assessment of the impacts of landslides the ecological setting, consists of the biophysical and socio-economic characteristics, plays an important function in understanding the level of vulnerability and adaptation of an individual or group. The strategic location provides a glimpse on whether the population is at risk because either they are situated or not in disaster-prone areas. The chances of survival in the midst or after the disaster also depend on the degree of disaster impact to the ecological background of the population. Most of the populations especially in rural areas highly depend on the benefits that the environment provides. Their livelihoods that being tied up with the soil. On the other hand, the socio-economic background provides the foundations for the populations' capacity to survive and sustain before and after the disaster. Experience with disasters makes the victims less vulnerable to disasters. These people become aware and thus prepared for any eventualities that may pose danger to their lives and properties. Adaptation strategies to disasters, on the other hand, include not only household decisions but also institutional contingency plans from local government and non-government organizations. These complex interrelationships were framed in Figure 6, which show that social vulnerability to flashfloods and mudslides was dependent on the biophysical and socio-economic characteristics. In addition, aside from man's experience with disasters, emergency preparedness and adaptation strategies to disasters (inclusive of the interventions provided by the local government units and non government organizations) was considered as an important factor in determining the level of the vulnerability of the population. Social vulnerability was gleaned from the individual and household characteristics.

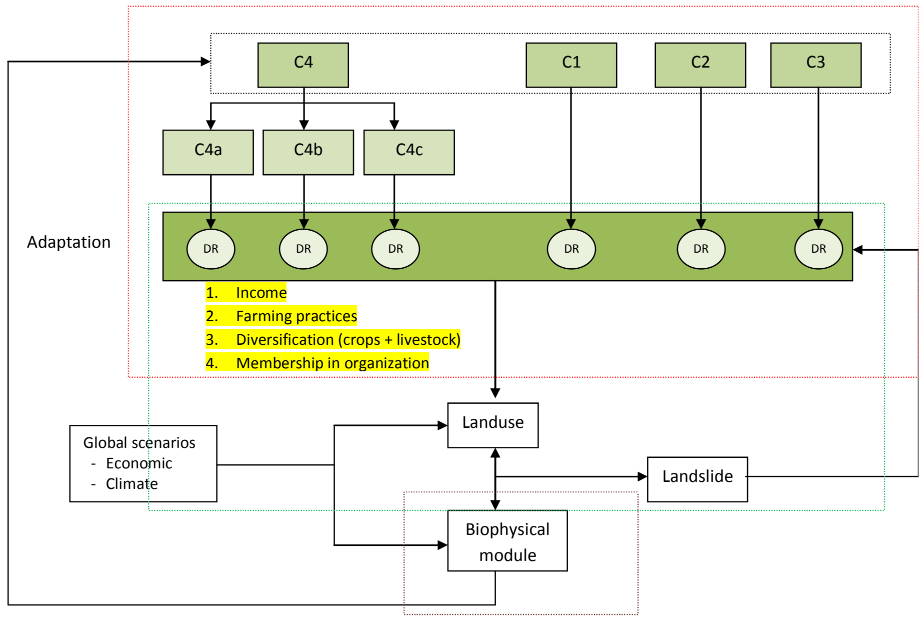


Figure 6 Methodological framework for assessing landslide impacts

In the above framework, C1 to C4 are examples of profiling characteristics like income, farming practices, diversification and organization, whilst C4a – C4c represents sub-characteristics. The decision rules (DR) of the vulnerable households were assumed to be influenced by these criteria. The framework was instrumental in guiding all the other partners in the project in identifying most relevant information for the survey questionnaire. The aim was to ensure that the all the case study areas have a common basis for comparison of vulnerability to landslides.

Step (3): Field survey was conducted in each of the case study areas in China, Nepal and Vietnam, following the methodological framework jointly developed by all partners in the framing workshop and the pre-tested survey questionnaire developed for the Philippines. The questionnaire was however adapted and modified to the socio-economic and physical contexts in the partner countries.

In China, the Mufu town in the state of Enshi was selected as the main study site area because of its proneness to landslide. Household survey was conducted in the three villages of the Mufu town namely Mufu Neighborhood committee, Yingshang village and Mugong village. A survey was conducted in order to evaluate the vulnerability of the local landslide. Local farmers were the respondents. The survey provided information on socio-economic, agricultural biological physics, local climatic conditions and government mechanisms etc. in Mufu. Details of the research include: Agricultural and Biological physics (field elevation, slope, fertility, the soil characteristics, soil layer thickness and so on), agricultural Information (the crop Planting, planting area, planting patterns and the reasons for such selection), farmers with basic information (demographic situation , the level and main source of income), farmers disaster experiences and disasters before, during and after the measures taken by the government and the people and so on. A total of 99 households were randomly selected for the Yingshang village, Mufu village and the Mugong village (55, 15 and 29 households, respectively). The investigation period is from March 8th until March 14th in 2009.

In Nepal, the field survey was conducted in Matatirtha Village Development Committee (VDC), one of the peripheral villages of the Kathmandu City. Thirty seven households were sampled in Matatirtha Village Development Committee. The respondents were grouped based on years of residing in a community; educational attainment, age, crops consideration, Crops change, farm size, number of plots, number of trees per plot and no of crops grown. Since last decade, population of Kathmandu city has grown exponentially due to political conflict in the country. As a consequence, the population growth has extended in the peripheral villages of the Capitol as well and Matatirtha village is one of these peripheral villages, which has observed growing population in the recent years (Dahal et al. 2009). On 23rd July 2002, massive landslide was triggered due to heavy rainfall, called cloud burst. The single event has claimed 16 human lives, damaged 9 houses and damaged millions of rupees (Poudel et al. 2003).

In Vietnam, the field survey was conducted in this district of Dak Nong province. The household survey was conducted in two communes with similar experiences in landslides. A total of 90 households were sampled from the two communes, namely Dak Bukso (53 households) and Dak Rtih (37 households). The household survey gathered information on the social and economic characteristics on the local households. The information on the household's social characteristics includes farmer's age, education, location of residence, household size, dependency ratio, availability and number of farm successors, level of participation in social organization, source of information, experiences with flash flood and land slides. The survey also gathered information on households'' income and sources of income, level of household spending, other jobs, household and farm assets, farm size, crops cultivated, type of land ownership, economic losses due to flood and land slides. The surveyed households were also asked about their personal views on the effects of climate change and land slide as well as their adaptive measures to these effects.

Step (4): Based on the data collected from the survey in the study areas in the Philippines, China, Nepal and Vietnam, the cluster analysis provided an empirical support for the building of farmer typologies, which are assumed to have different adaptive behavior to flash flood and land slide risks. The clustering of the respondents was based on the identification of its similarities and differences of characteristics before and after the disaster. Cluster groups were identified possessing unique characteristics in terms of biophysical, socio-economic, disaster experience, and emergency preparedness and adaptation strategies. These characteristics purposively identified the typologies and the level of vulnerability and adaptation among cluster groups. Through these, the determinants of vulnerabilities of respondents to flash floods and mudslides were identified. The clustering procedure for the case in the Philippines is presented in Figure 7, but the same procedure is more or less followed in all the other case study areas. Cluster analysis, a procedure for organizing objects into clusters or groups high level of similarities or dissimilarities (San et al, 2004 as cited in Acosta-Michlik, 2005), was employed to determine the groups of similar characteristics in the following variables: biophysical characteristics, socio-economic characteristics, disaster experience, and emergency prepared and adaptation strategies among the communities based on the household's responses. The clusters were generated based on the equation below:

$$k = (n/4)^{1/2}$$

Where: k = number of clusters

n = sample population

A series of procedures was utilized in deriving the groups: generation of priority variables: biophysical, socio-economic, experience with disasters (vulnerability), and emergency preparedness and adaptation strategies characteristics (adaptation) then determination of the extent of relationships between two variable using chi square test, a correlation test. One-Way ANOVA (Analysis of Variance) was employed in order to test the relationship for two or more independent groups. This statistical test produces an F statistic that defines the ratio of the variance among the means of the variance within the samples. A higher ratio implies significant differences between two groups (Kirk, 1995). Statistics Packages for Social Sciences (SPSS) was used for all the statistical procedures.

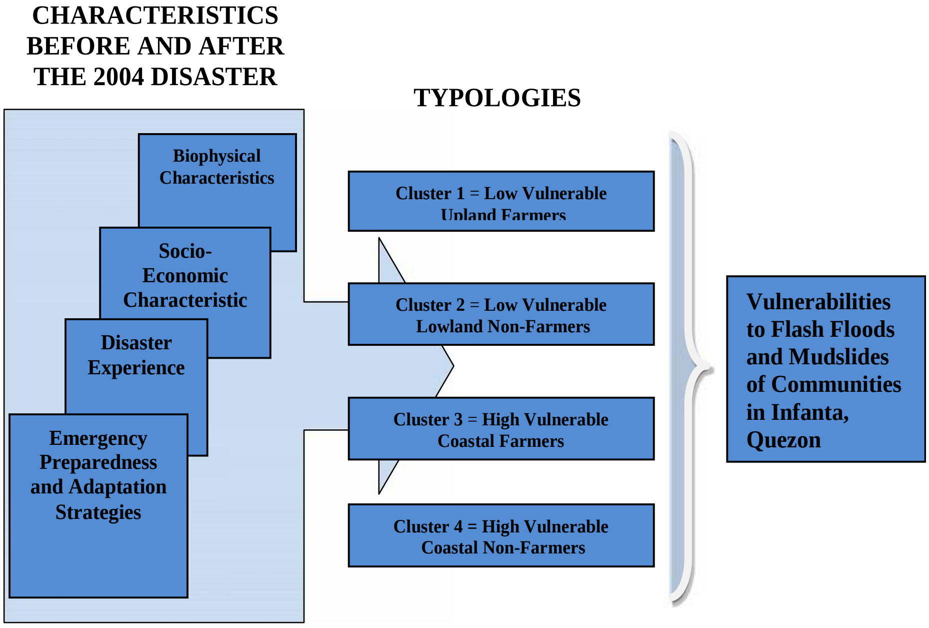


Figure 7 Clustering procedure for the case study in the Philippines

3.3 Agent-based modeling

The vulnerability and adaptation profiles developed from the cluster analysis for the Philippines as well as the land and soil profiles generated from land use and soil analyses used to test the applicability of agent-based models in assessing vulnerability to landslide impacts. Agent-based models (ABM) are a promising tool for analyzing and simplifying such a complex problem. The models are based on the concept of multi-agent systems, which originated in the computer sciences (i.e. artificial intelligence research) in the 1970s. Recently, ABM has also gained popularity in the social sciences. The concept builds on computer simulation technology that describes and explains social phenomena (Sawyer 2003). Agent-based modeling tools aim to reproduce spatial and demographic features in order to understand the evolution of society (e.g. Gilbert and Doran 1994; Kohler and Gumerman 2000). Axtell (2000) reviewed various motivations for agent computing in the social sciences with particular reference to computational economics. Economists have sought alternative tools to classical equation-based models (e.g. statistical techniques and mathematical programming) so as to move away from the restrictions imposed by rational agent and equilibrium assumptions. In geography, there is also growing interest in considering human decision-making and non-rational decisions to understand changes in land use and land cover (e.g. Van der Veen and Rotmans 2001; Parker et al. 2003; Huigen 2004; Acosta-Michlik et al. 2005b). Others have applied ABM to explore the relationship between human activities and natural resources (e.g. Jager et al. 2002) and to evaluate policy support (e.g. Berger 2001). The increasing application of agent-based approach to answer research questions that link human to natural system underpins their usefulness in assessing human vulnerability to global environmental changes. However, very few authors are exploring the empirical application of ABM to vulnerability science (e.g. Ziervogel et al. 2004; Acosta-Michlik and Rounsevell 2005, Acosta-Michlik and Espaldon 200?) and they so far focus on drought-related issues. In this this project, we tested the application of agent-based model to assess vulnerability to landslides events in the case study area in the Philippines.

The design of the agent-based model is illustrated in Figure 8. There are three major agents in computing for the vulnerability namely: biophysical hazard, the socio-economic profile of households and lastly their adaptation. The combination of biophysical hazard and socio-economic profile of households represents the potential risk. The combination of potential risk and the effect of adaptation is the basis of the computation of vulnerability.

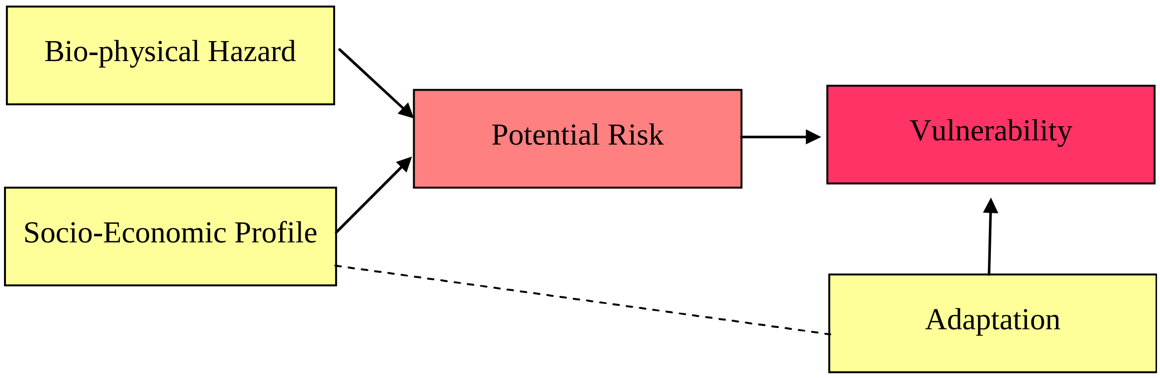


Figure 8 Methodological framework of the agent-based model

Figure 9 shows the simplified computation of vulnerability based on the framework shown in Figure 8. The biophysical hazard was initially computed based on the following biophysical components: amount of rainfall, elevation, land use, slope and soil characteristics. Analytical Hierarchy Process (AHP) was used to rank the weights of effect of each component (Taha 2007) (see discussion on AHP in section 3.1). The socio-economic profile of respondents was based on the cluster analysis of households. The adaptation is currently a parameter that can be set dynamically in the simulation, it could represent the varying effectivity of adaptation measures like the early warning system.

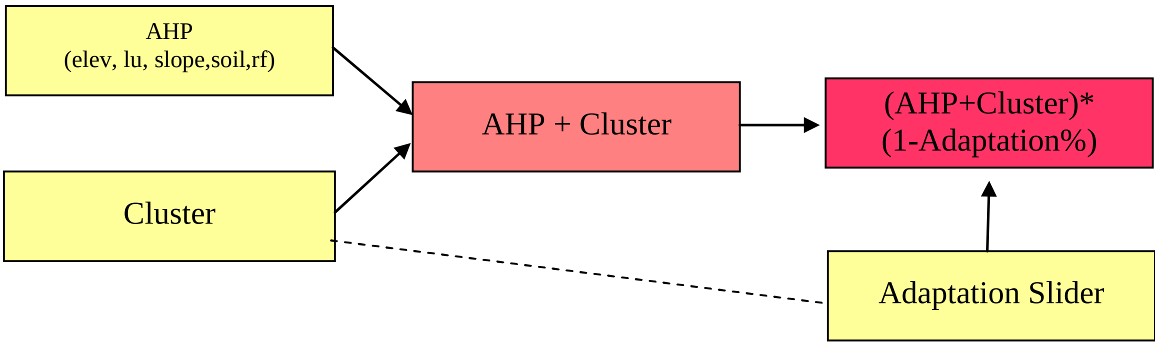


Figure 9 Simplified computation of vulnerability

The land use before and after the landslide events are necessary to model the landslide impacts on the physical profiles of the case study area. The freely downloadable Terralook collection (aster image) from NASA (http://glovis.usgs.gov) was used utilized in the derivation of the before and after the 2004 flashflood landuse of the study area. The aster images have an approximate resolution of 30m. The temporal time considered in the study is 2002 (before the landslide) and 2008 (after the landslide). The images are presented in simulated true color, 3 bands (RGB) and in jpeg format. All maps were processed in ArcGIS 9.2 (licensed to SESAM, UPLB). The projection of all maps was set to Geographic WGS84. This will allow overlays of different map layers for analysis and comparison. A 30-day trial version of Image Analysis developed by ERDAS for ArcGIS 9.2 was used for the image classification. All maps were projected to Universal Transverse Mercantor (UTM) North Zone 51 format with WGS84 datum.

An unsupervised image classification was done for both aster image of 2002 and 2008. This image classification served as the basis for the supervised classification. The classifications were validated thru ground truths and from the high resolution quickbird image. The training units or signatures of the different land uses were prepared in ArcGIS 9.2 for both 2002 and 2008 images by digitizing at least 100 polygons for each land use. A supervised image classification was then carried out with the maximum likelihood as the method in classification.

The agent-based model for the Philippine case study was implemented and simulated using NetLogo 4.0.4 (Wilensky, 1999). NetLogo is a cross-platform software for developing agent-based models of complex systems. It is a programming language and it also provides an environment for modeling, simulation, and visualization.

4 Results and discussion

4.1 Hotspot regions and the case study areas

This section provides an overview of the extent of vulnerability to landslide impacts in China, Nepal, Vietnam and the Philippines using vulnerability maps, which were either drawn from previous studies or generated in the project (see section 3.1). These maps also show the location of the case study areas, where indepth assessments of vulnerability and adaptation of local communities were carried out. Detailed description of the case study areas are also presented in this section.

4.1.1 China

Chinese territory is vast, the landform is complicated, the climate is diverse, the geology is peculiar, the geology disaster is one of the most serious areas in Asia and even the whole world. Landslide is the main type of geology disaster in China. The investigation of geology disaster in 290 provinces and cities in China revealed that the proportion of landslide in geology disaster is up to 51% (Li Yuan 2004). Landslide disaster often causes great economic losses and casualties, thus the damage is very big to the society. It is estimated that each year the losses caused by disasters as landslides up to 20 billion Yuan in China. Figure 10 shows a map of landslide disaster regions in China. About 80 percent of large-scale landslides were found in the first slope-descending zone of the mainland topography around the eastern margin of Tibet plateau. Moreover, this area is the most active area of the plate tectonic activities (Zhu et al., 2003).

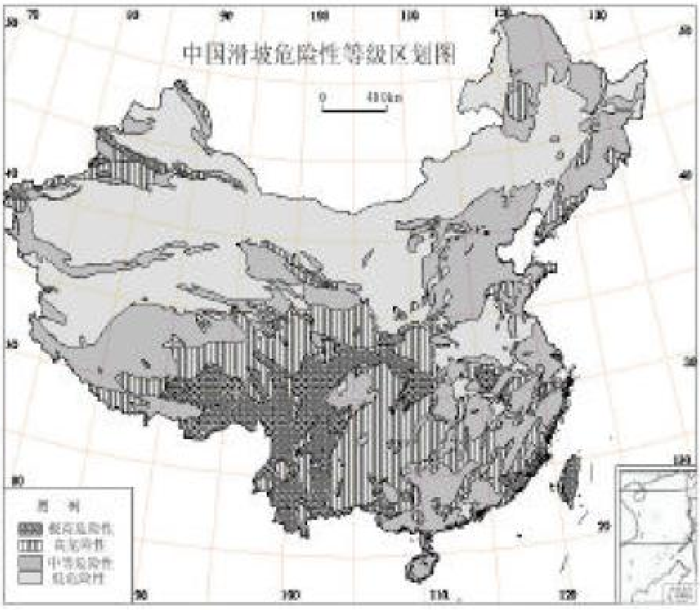


Figure 10 Vulnerability map related to landslide disaster in China
(Source: Zhu et al., 2003)

Case study area: The Mufu town in the state of Enshi is the main study site area for China. The total land area of Enshi is 24,000km2, 75% of which are considered as forested area, with diverse flora and fauna. The state has three mountains with elevations above 1,000 meters (3,281 feet) in general. The prefecture bears a subtropical monsoon mountain climate. The annual average temperature is around 10, and the annual average precipitation is about 1,500mm (70%-80% in flooding season). As of 2008, the total population of the region is 3.95 million, 52.6% of which consist of 28 minority groups such as Tujia, Miao and Dong. Landslides and other geological disasters happen frequently in Enshi State (full name: Enshi Tujia and Miao Autonomous

Prefecture). Enshi is located at the southwest part of Hubei province (108°23’12"-110°38’08"E, 29°07’10"-31°24’13"N) and the northeast of Yunnan-Guizhou Plateau (Figure 11). This is where geological disaster mostly occurs. Based on the statistics gathered from the preliminary investigation in 2006, there are 2085 geological disaster events since the 1980s, resulting to direct economic losses up to 45.44542 million dollars. Moreover, these disasters caused the loss of lives of 262 people, maimed 1078 person and posed threat to 174,997 civilians. The forecasted economic loss for these incidences summed to 481.64784 million dollars. Overall, Enshi state experienced 343 geological disasters. It is interesting to note that in 2006, Enshi state experienced 43 disaster events, 21 of which were landslides. These disasters affected 785 households and 1855 people, and led to direct economic losses of 4,640,000 Yuan.

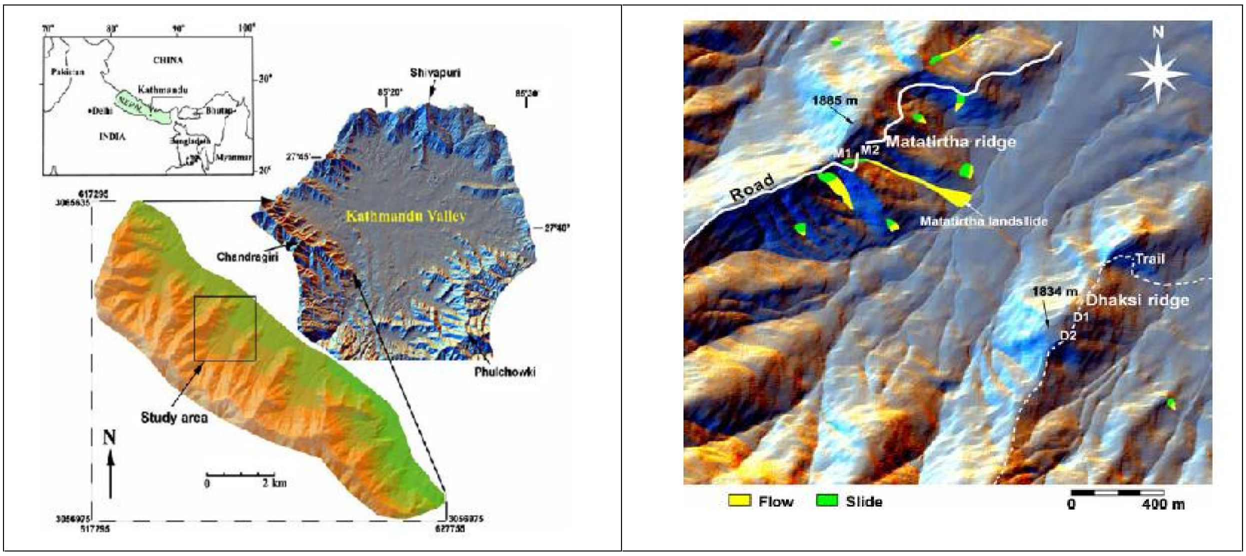
Figure 11 Experimental investigation site geographical povillagen-Enshi Tujia nationality Miao Nationality Autonomous County in Hubei Province, China

4.1.2 Nepal

The Himalayas, with extreme variation in relief, are characterized by very steep slopes, harsh climate, and a dynamic geotectonics. These characteristics appear responsible for widespread slope failures and mass movements, which are often accentuated by various human activities. Nepal has roughly a rectangular outline with an area of about 147,181 km2 and is bounded by the northern latitudes 26°22’ N and 30° 27’ N and the eastern longitude 80° 04’ E and 88° 12’ E. its length is about 885 km from east to west and the width varies from 130 km to 255 km. Because of its location in the Himalayas, with its fragile geology, steep slopes, high relief, and the intense monsoon climate, Nepal is prone to water induced disasters such as flood and landslides.

Figure 12(a) shows a map of landslide disaster regions in Nepal. According to Li and Behrens (2002), between 1983 and 2005, an average of 309 people was killed annually due to landslides and floods. This loss of lives from flood, landslide and avalanche is about 32% of the total deaths by natural hazards. Similarly, every year, about 70 percent of the total families affected from all types of natural disasters was due to the floods and landslides. In a typical year of 1993, the human deaths were more than 1300 persons and the estimated amount of loss was approximately 3% of GDP, 13% of the total government expenditure, 22% of the development expenditure and about 53% of the total foreign loans. On an average about 13% of the development expenditure of

Nepal and 5.4% of its real GDP are spent on response and recovery activities to disasters every year (Li and Behrens, 2002).



(a) Nepal and Kathmandu (b) Case study area

Figure 12 Vulnerability map related to landslide disaster in Nepal
(Source: Dahal et al 2009)

The severity of landslide phenomenon in Himalayas, including in Nepal, was not recognised until recently because of sparse habitation, remoteness of its occurrence, and limited sphere of influence of the individual slides. Widespread slope failures and mass movements are believed to have been occurring veer since the formation of the Himalayan ranges. During the last few decades, excessive population growth and consequent anthropogenic interference, in the form of developmental activities like unplanned urbanisation, road construction, communication, dam construction, and agriculture, have greatly aggravated the situation in Nepal (Petley et al. 2007). Figure 13 shows increasing trend in reported human life due to landslides. Landslides in Nepal are one of the most common natural hazards, claiming a significant number of lives each year and resulting in untold damage to the environment. About 75% of landslides in Nepal are caused by the natural movement of land during rainy season, particularly in the mountainous areas of Nepal. The landslides are also caused by the erosion of base of the slopes by rivers, small / large earthquakes, and the result of melting glaciers.

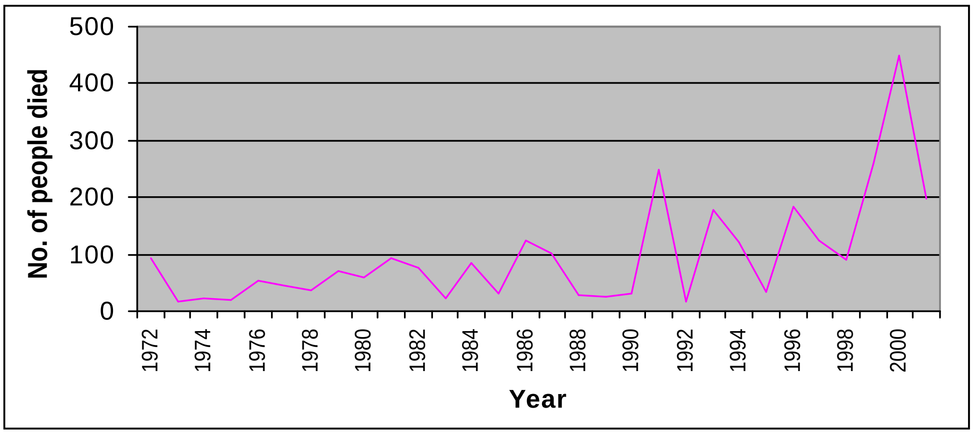


Figure 13 Number of people died every year due to landslide in Nepal
(data source: DesInventar.com, 2008)

Case study area: Matatirtha Village Development Committee (VDC) is one of the villages of Kathmandu District and lies 10km southwest of the Capitol Kathmandu Metropolitan City. According to the study of Dahal et al (2009), the village stretches along the vulnerable regions in Nepal (Figure 12a). The extent of landslide event in 2002 is revealed in Figure 12(b). Matatirtha is one of the peripheral villages of the Kathmandu City (Figure 12a and Figure 14). Since last decade, population of Kathmandu city has grown exponentially due to political conflict in the country. As a consequence, the population growth has extended in the peripheral villages of the Capitol as well and Matatirtha village is one of these peripheral villages, which has observed growing population in the recent years (Dahal et al. 2009). Total population of the village is 3653, with male population 1862 and female 1791. The total household is 758. Total population of the village is 3653, with male population 1862 and female 1791. The total household is 758. Some demographic information is presented in Table 1 (source: CBS, 2007).

Table 1 General Socio-economic status of Matatirtha Village in Nepal

	Total
Economically active population over 10 years	1596 (Male:929, Female:667)
Literacy	2198 (Male:1271,Female:927)
Households having	
Agricultural land only	169
Livestock only	17
Poultry only	3
Land and Livestock	240
Land and Poultry	27
Livestock and Poultry	12
Land, Livestock and Poultry	154
None of the above	136
Households having economic activities	461
Manufacturing	12
Trade/business	90
Transport	7
Services	300
Others	52

On 23rd July 2002, massive landslide was triggered due to heavy rainfall, called cloud burst. This single event has claimed 16 human lives, damaged 9 houses and damaged millions of rupees (Poudel et al. 2003). The massive landslide and debris flow was caused due to the heavy rainfall by cloud burst event (Figure 6). The closest rain gauge located at Thankot recorded 300 mm of rainfall on 23rd July. The rainfall occurred at night/early morning of 22-23rd July, which has induced about 12 landslides and debris flow in the Matatirtha village (Dahal, et al. 2009). The rainfall was accompanied by intense lighting and loud thunder. The landslide volume was 9000m3 (Poudel, et al. 2003), with debris and flash flood of estimated maximum velocity 40m/s (Dahal et al. 2009). If similar kind of event occurs in the village the impact would be greater. Therefore, this village has been selected for the study of vulnerability assessment, basically for two reasons. The first is because of the growing population that leads to an increased in the vulnerability. Secondly, since it is close to the city, the community might be able to build the capacity to be prepared for the disaster.

Most of the ridge of the village is covered with the young forest, planted about 25 years back (Dahal et al. 2009). The southern higher elevation is covered with temperate mountain oak forest, the central larger part of the VDC with lower temperate oak forest and northern flatter land with schima-castanopsis forest. Most of the landslides were initiated from the lower temperate forest. The local people were surprised to observe landslide in the forest as the forests were considered as the preventive measures for landslides (Shrestha, 2004; personal communication with community). Dahal et al (2009) has conducted soil investigation in the affected area. The investigation showed that steep slopes (about 42 degrees) have colluvial soil with depth ranging from 1 to 2.1 m, with average depth of only 1 m. At the gentle slopes (34 degrees) the average soil depth is 1.46m, while in the base of the ridges the soil thickness is about 5.5m. Average annual rainfall in the Matatirta VDC is about 2000mm with maximum rainfall in July. These physical and climatic features thus make the case study area vulnerable to landslides.

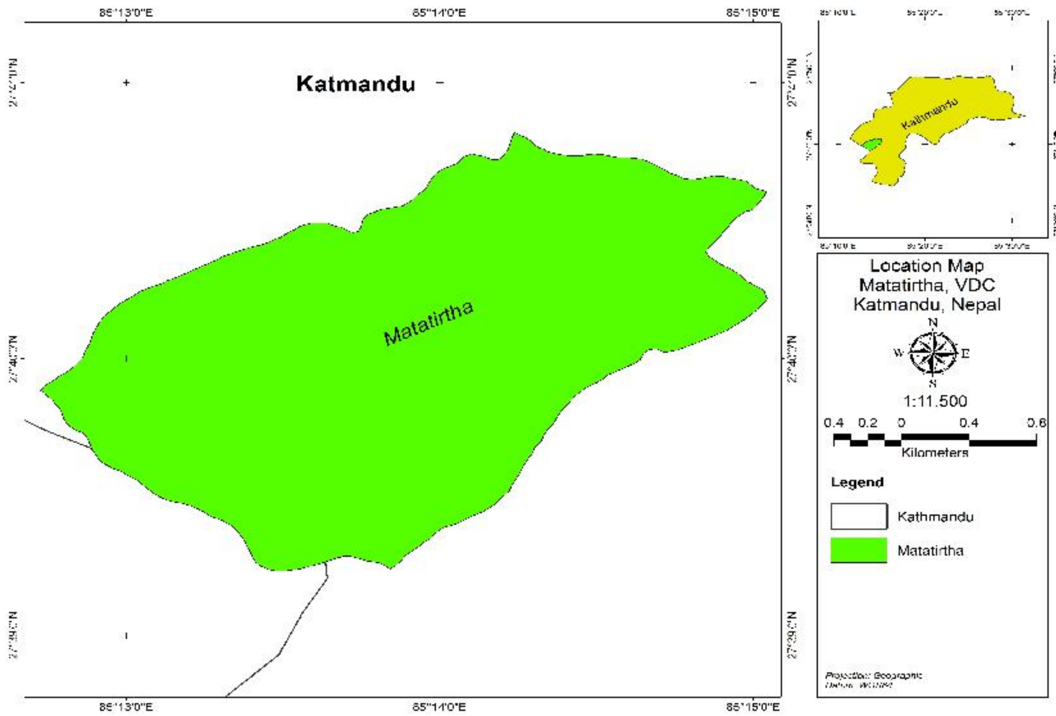


Figure 14 Location of Matatirtha VDC in Kathmandu District, Nepal

4.1.3 Vietnam

Viet Nam has a diverse topography. The country's territory is made up of hills, mountains, deltas, coastal lines and continental shelf, reflecting the long history of geology and topography formation in a monsoon, humid climate and a strongly weathered environment. The topography is lower from the Northwest to the Southeast, which is clearly shown in the flows of major rivers. Three quarters of Viet Nam's territory are made up of low mountains and hilly regions. Regions with elevations less than 1,000 meters above sea level make up 85% of the territory. Mountainous regions over 2,000 meters above sea level only account for 1%. Mountain ranges and hills form a large bow facing the Eastern Sea with 1,400 km length from the Northwest to the Southeast. The highest mountain ranges are all located in the West and Northwest. Viet Nam's climate is characterized by a considerable amount of sunshine with the number of sunny hours varying between 1,400 and 3,000 per year. The average rainfall each year stands between 1,500 mm and 2,000 mm. Given the influence of monsoon and complex topography, Viet Nam is often prone to natural disasters such as storms, floods and droughts (each year, the country suffers from 6 to 10 tropical storms). The damage caused by natural diaster in Vietnam is sumarized in Table 2. In 2007, it was report that about 495 persons were dead or missing and about 728,178 houses were damaged or affected due to natural disaster. The number of landslide-induced deaths in Vietnam was reported to be 130 persons in year 2007, with about 2.9 deaths per landslide on the average.

Table 2 Damages caused by natural disaster in Vietnam

Year	Human losses		Number of houses damaged/ affected	Total material losses	
	Dead/missing (persons)	Injured (persons)		(Billion VND)	% in GDP
1995	399	315	501,302	1,129	0.49
1996	1,243	907	2,120,952	7,998	2.94
1997	3,083	1,617	416,801	7,730	2.46
1998	522	522	568,362	1,797	0.5
1999	901	544	1,126,260	5,427	1.36
2000	775	413	1,039,616	5,098	1.15
2001	629	288	518,172	3,370	0.7
2002	389	275	392,749	1,958	0.37
2003	186	191	175,849	1,590	0.26
2004	278	190	244,669	1,004	0.14
2005	399	262	223,271	5,809	0.69
2006	612	2,098	632,679	18,566	1.91
2007	495	856	728,178	11,514	1.01

To assess the degree of vulnerability in the different regions in Vietnam, vulnerability map was generated using the methods discussed in section 3.1. The vulnerability map was based on the analysis of GIS maps with the following parameters: slope gradient, slope aspect, elevation, slope shape, geology, land use, soil type, average annual rainfall, distance from a road, distance from a stream, distance from a geological structure, Distance from a house, cultivated land, and population density. At first, the parameter maps were crossed by vulnerability map using the map calculator tool in ArcGIS 9.2. Then, the weight values were added in the attribute table of all the parameter maps. The combined vulnerability map was reclassified into very low, low, fair, high, and very high hazard zones. The result showed that about 35% the total area in the very high vulnerability, and mainly in northern and central highland of Vietnam.

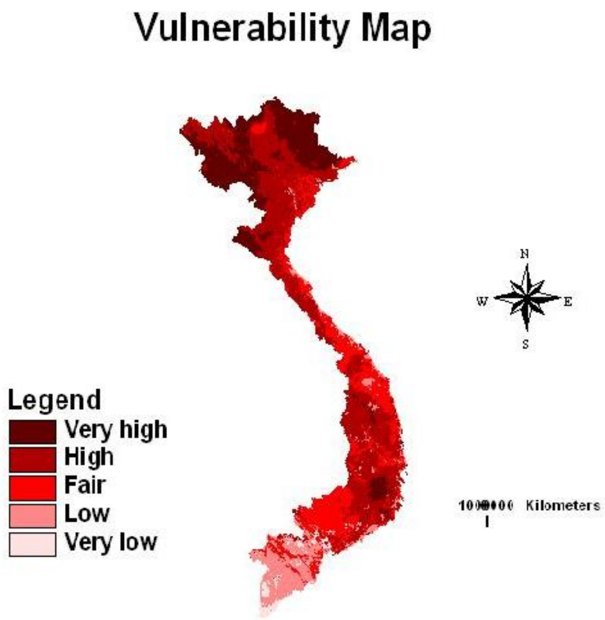


Figure 15 Vulnerability map related to landslide disaster in Vietnam
(Source: Own calculations, see section 3.1)

Case study area: The Dak Nong province was chosen for the study based on results from the vulnerability mapping which showed that the provinces in northern and central highland of Vietnam have very high vulnerability to landslides. The Dak Nong province is located in the Central Highland of Vietnam. The province has high risk of land slides. In recent years, flash flood and land slides occurred with higher frequency and intensity causing large damage to infrastructure, assets and human life. Within the province of Dak Nong, Tuy Duc district was selected as a case study area due to its past experiences with several land slides. Tuy Duc district is located in the North-west of the Dak Nong province, about 250km from Ho Chi Minh City. The study area has an elevation from 550-850 m above see level. Topographically, it is hilly with high sloping hill sides in the north east area of the district. The district consists of 6 communes with a total land area of about 112 thousand hectares, with forest covering 70 percent and agriculture only 23 percent of the land area (Table 3). Basaltic soil is the major soil type in this area. This soil type is suitable for coffee, black pepper, rubber, maize, sweet potato, jam, and vegetables. For local farmers, perennial cash crops such as coffee, cashew, and rubber are most important crops cultivated in the district. Almost half of the total agricultural area in the district is planted to coffee, and only less than a quarter is planted to food crops. The area cultivated with food crops includes about 427 ha of rice, 153 ha of vegetables and beans, and about 599 ha of sweet potato.

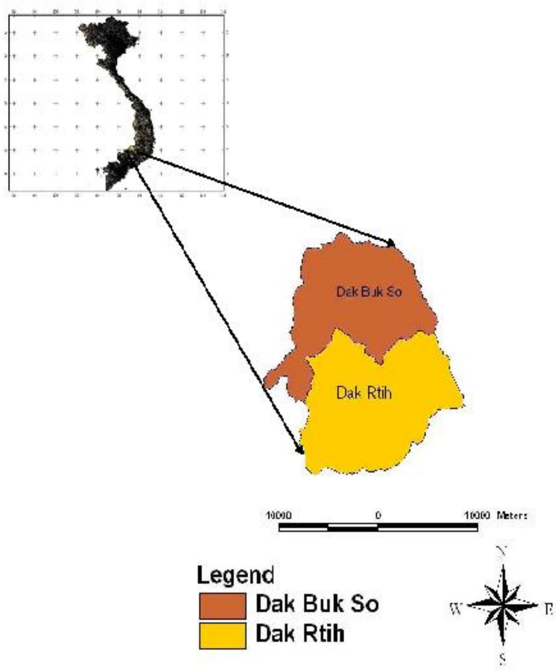


Figure 16 Location of the two case study districts in Vietnam

Table 3. Land use types in Tuy Duc district in Nepal, 2007

Land use type	Land area (ha)	%
Agriculture land	25,751	23
Forest land	78,778	70
Other land use (aquaculture, resident land, others)	3,728	3
Non-use land	4,127	4
Total	112,384	100

4.1.4 Philippines

For the period 1900-2000, Asia has had the highest number of people reported affected by natural hazards in the world, in particular droughts and floods (EM-DAT Disaster Database). Frequent droughts are causing huge economic damage and health problems, but flood effects are increasingly more devastating. Flooding due to extreme climate events and unsustainable land use has already caused massive landslides, which have damaged not only property, but also claimed lives of many people in Asia and the Philippines in not an exception. The Philippines incurred an average annual direct damage of PHP15 billion per year (in real 2000 prices) between 1970 and 2000 because of losses in agriculture, infrastructure and in private sector (World Bank, 2005 as cited in the Philippine: A Country Depth Review Report). In an analysis of natural disaster hotspots by the Hazard Management Unit of World Bank, the Philippines is among the countries where large percentages of population reside in disaster-prone areas. Many highly populated areas are exposed to multiple hazards; 22.3% of the land area is exposed to three or more hazards and in that area, 36.4% of the population is exposed. Areas where two or more hazards are prevalent comprise 62.2% of the total area where 73.8% of the population are exposed. The Philippines experienced enormous property damage and both direct and indirect costs (Saro, 2007; Ollet, 2008; Zimmerli, 2009) because of landslide, specifically rainfall-induced landslides caused by tropical storms. Figure 17 shows that the highest number of vulnerable provinces to rainfall changes in the Philippines is found in Luzon region, followed by Visayas. In Luzon, Manila and all its neighboring provinces are all very vulnerable to the impacts of rainfall changes. In the last decade, many of the disastrous landslide events in the Philippines occurred in these areas including Cherry Hill (1999) and Payatas (2000) in Greater Manila, Real-Infanta (2004) in Quezon Province and Mt. Makiling (2006) in Laguna (Cruz 2007 and Aurelio 2010).

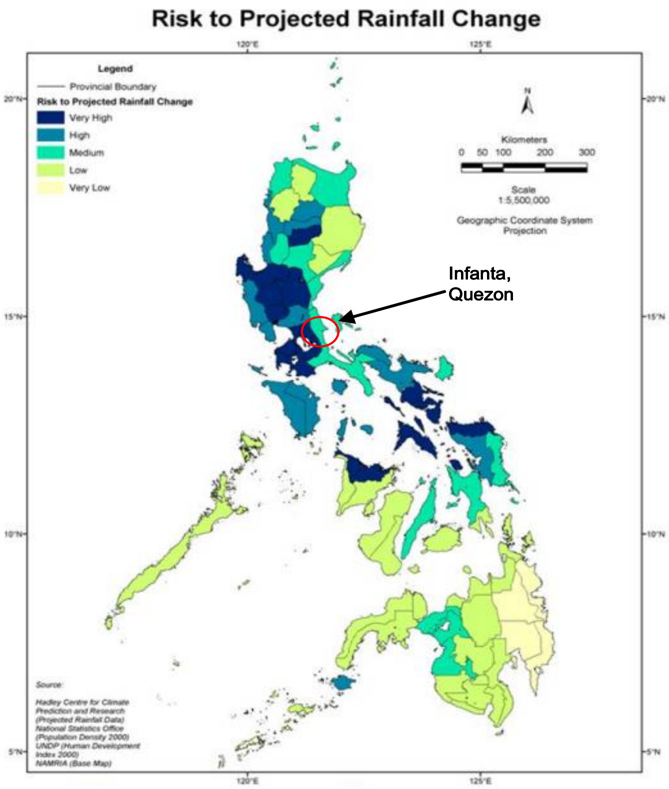


Figure 17 Vulnerability map related to landslide disaster in the Philippines
(Sources: DENR and Manila Observatory, 200?)

Case study area: Founded in 1696, Infanta is one of the oldest municipalities in the province of Quezon. Lying along the coast of the Pacific Ocean and blessed with a portion of the nature's bounty of the Sierra Madre Mountains, Infanta, Quezon is located 144 northeast of Metro Manila and 136 kilometers north of Lucena City (Figure 18). The town had a total land area of 34,276 hectares and accounts to a population of 58,540. In the 2004 census, Infanta, Quezon has a total of 36 villages (villages) (David and Felizardo, 2005). In addition, Infanta is a second class municipality based on income classification. The major industry found in the municipality is agriculture and fishery (www.infanta.gov.ph).

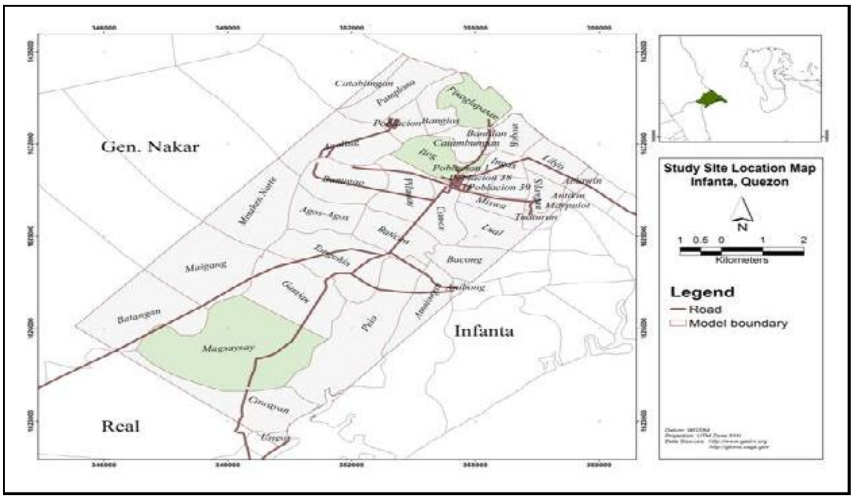


Figure 18 Location and landuse map of Infanta, Quezon indicating study areas of Villages Magsaysay, Ilog and Pinaglapatan in the Philippines

With regards to the geophysical condition of the community, Infanta is classified to have a climate where there is no dry season but has prolonged period of maximum rainfall from November to February. Predominantly woodland in terms of land cover and the presence of small percentage of coconut and grass land areas spread across the municipality and deltaic portions grow mangrove spots. In addition, the downstream area lays agricultural areas that are remotely spread beyond residential spaces (David and Felizardo, 2005). Figure 18 shows the map of Infanta, Quezon indicating location of the three study areas namely villages Magsaysay (upland), Ilog (lowland) and Pinaglapatan (coastal). It also shows the distance of the three villages from the political center of the municipality. Crossing all three villages is the Ilog river. The Ilog river runs from the mountainous areas of Village Magsaysay passing through the Village Ilog (lowland) and Village Pinaglapatan (coastal) before it heads to the shore.

Infanta, Quezon was determined as the study site based on the findings of the Department of Environment and Natural Resources-Mines and Geoscience Bureau (DENR-MGB) National Geohazard Mapping and Assessment Program and the Project Mapping Philippine Vulnerability to Environmental Disasters that the area is vulnerable to climate and weather risks. Figure 19 shows the landslide susceptibility map of Infanta, Quezon. Majority of the upland areas is moderately susceptible to landslide, but some parts are also highly susceptible. Localized susceptibility is thus often hidden in a highly aggregated level of analysis such as provincial level (see Figure 18). In 2004, the Philippines was hit by four (4) successive tropical cyclones (Tropical Storm Muifa and Merbok, Tropical Depression Winnie and Typhoon Nanmadol) in the months of November and December. These tropical cyclones heavily affected Luzon and Visayas islands. One of the most severely affected areas is the triangular low-lying plain east of the Sierra Madre mountain range in Quezon province, where the municipalities of Real, Infanta and General Nakar (known as REINA) are located (Ollet, 2007). The third tropical depression (Winnie), had the strongest sustained winds of 55 km/hr near the centre, landed at Infanta on November 29-30, 2004. PAGASA as cited in Ollet (2007) recorded a 342 mm rainfall on the evening of November 29. The intense rainfall progressively caused the Agos River, the main drainage system in the Northern part of REINA, to overflow. These successive typhoons induced flashfloods and numerous landslides, predominantly natural terrain landslides, in Infanta, Gen. Nakar and Real, Quezon; and Dingalan, Aurora. In terms of the impacts of flood and landslides, the municipality of Infanta was the most severely affected since the area is geographically located as a catch basin of the three major tributaries flowing directly to the Pacific Ocean. Debris flow came from landslide materials transported along Agos River. More than 20 million m3 of sand, mud, rocks and logs was estimated to have cascaded through the river system (Ollet, 2007). Ollet further (2007) cited that approximately three meters of flood waters and one meter of mud/sand, caused thousands of residents in the area homeless.

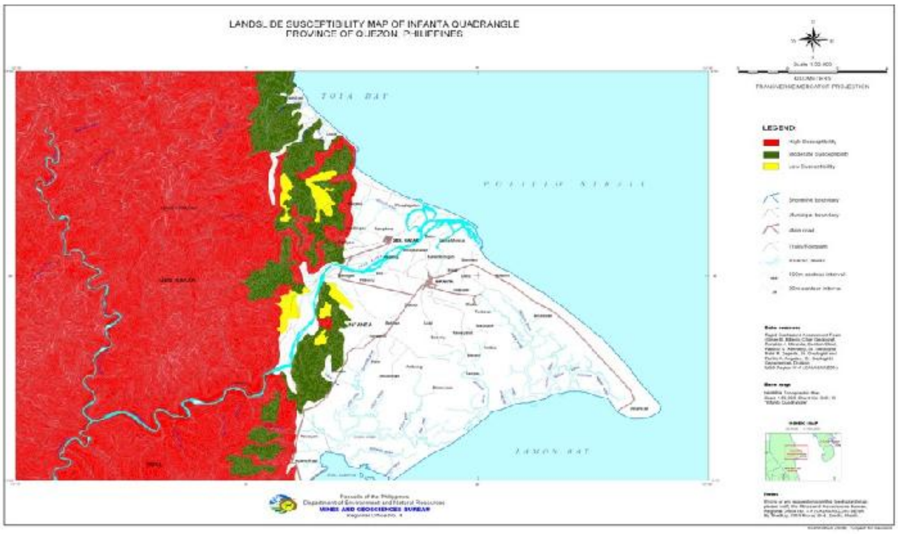


Figure 19 Landslide Susceptibility map of Infanta, Quezon in the Philippines
(Source: Mines and Geosciences Bureau, 1:50,000)

As reported by the Office of the Civil Defense, more than 2.3 million people were affected and about P4.6 billion were lost in terms of infrastructure and agricultural damages. Table 4 shows the damages incurred by the 2004 flashfloods and landslides in Infanta, Quezon.

Table 4 Summary of Damages caused flashfloods and landslides in Infanta, Quezon in the Philippines, 2004

Number of severely affected villages:	16 out of 36 villages
Number of affected locals:	176 casualties, 112 recovered bodies, 53 reported missing, 11 injured, 12,007 affected families
Number of damaged houses:	4,256
Number of washed out houses:	1,592
Number of partially damaged houses:	3,674
Damage costs to: -Agriculture - Livestock - Fisheries	 Php 103.3 million Php 57.5 million Php 46.7 million

(Source: Infanta Municipal Engineering Office)

4.2 Vulnerability Profiles

This section discusses the results of the quantitative (i.e. cluster) and qualitative (i.e. narrative) analyses of the survey data collected from the different case study areas in China, Nepal, Vietnam and the Philippines. The cluster analysis aims to classify the survey respondents according to their common socio-economic and biophysical characteristics and identify the level of vulnerability of the respondents according to their membership in the clusters. The narrative analysis describes the disaster experiences of the respondents in selected case study areas (i.e. Nepal and the Philippines) to identify adaptive behavior that can contribute to understanding vulnerability and adaptation to landslide impacts.

4.2.1 Cluster Description

The cluster analysis in each of the case study areas generated three to four clusters. Table 5 summarizes the typologies (i.e. cluster descriptions) of these clusters. Although the socio-economic and biophysical variables that have been collected from the case study areas are based on the same methodological framework (and thus very similar list of variables), the cluster analysis generated different number and description of clusters in the different case study areas. This implies that the respondents in the case study areas have quite diverse socio-economic and biophysical characteristics, and would thus have different strategies to cope and adapt to landslides impacts. In the following discussion, the typologies of the respondents are discussed in details to reveal the vulnerabilities of each of the clusters in the different case study areas in China, Nepal, Vietnam and the Philippines.

Table 5 Cluster and typologies of survey respondents in all the case study areas

Cluster	Typologies			
	China	Vietnam	Nepal*	Philippines
Cluster 1	High Vulnerable -Small Traditional Farmers	Large Commercial Farm	Migrant Residents	Low Vulnerable Upland Farmers
Cluster 2	Medium Vulnerable - Large economical Farmers	Diversified Farm	Mid-age Native Residents	Low Vulnerable Lowland Non-Farmers
Cluster 3	Low Vulnerable - Commercial and less-Farm	Household with Non-farm Works	Old-age Native Residents	High Vulnerable Coastal Farmers
Cluster 4	---	Small Traditional Farm	---	High Vulnerable Coastal Non-Farmers

Note: * Native is defined as born in or longest residency

China

Data were gathered from 99 residents in three villages (Mufu Neighborhood committee, Yingshang village and Mugong village) in Enshi Autonomus Prefecture, Hubei Province, China. The respondents were clustered based on years of residing in a community, Ecology code, No. of parcels, Total farm size, Dominant farm slope, Soil fertility status, Soil texture, HH size, Age, Education, Income, Available government help and so on. From the analysis, the residences are grouped into three clusters: Cluster 1, Cluster 2 and Cluster 3.

Figure 20 shows the three cluster groups from the three villages. Cluster 1 group is mainly from Yingshang (52.2%) and 31.9% are from Mugong village. Cluster 2 group consists of 59.1% Yingshang village, and 22.7% of Mugong village, while the rest are Mufu neighborhood committee (18.2%) residents. Cluster 3 group has a few residents and 75% residents are from Yingshang sitio.

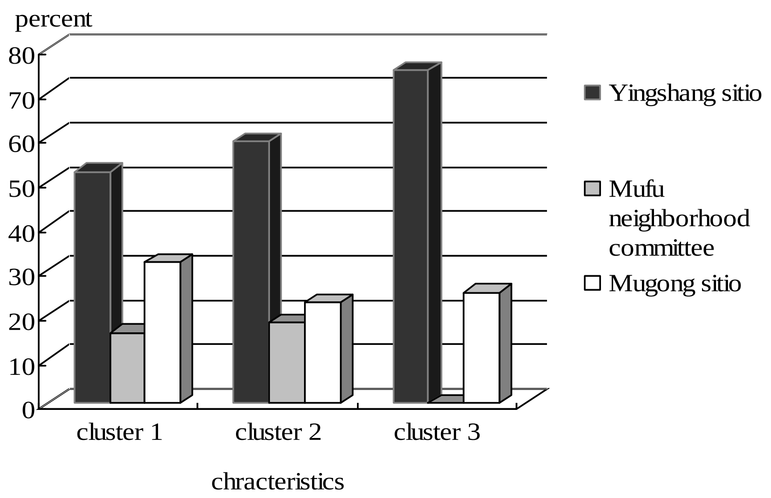


Figure 20 Distribution of the Samples According to Cluster Groups (in Percent) in Enshi, China

The F-ratio of ANOVA reveals further the significant differential characteristics of cluster groups. Table 6 shows that the cluster groups differ significantly in griculture/Agriculture-related, Social and Physical characteristics. No. of parcels, dominant farm slope, soil texture, age, education and income are the main factors for evaluate the frangibility. The results of the cluster analysis of the survey data generated three clusters with the following descriptions:

Cluster 1 (High Vulnerable -Small Traditional Farmers) - This group is mainly depended on agriculture; with poor soil fertility status; also the residences attained the lowest education; and also with the lowest income; and with the youngest members. They have not enough experience to landside. Also they are easy to affect by landside disaster. This cluster is the highest vulnerable group by the occurrence of landslide.

Cluster 2 (Medium Vulnerable -Large economical Farmers) - This group has comparatively better soil fertility status; they not only plant more crops and also manage some other business and services. They have comparatively higher education and earn more than the cluster 1, while less than cluster 3. The age of this group is comparatively higher than cluster 1. They had experienced some landside before and known some measures to adopt disaster. This cluster is the medium vulnerable group by the occurrence of landslide.

Cluster 3 (Low Vulnerable -Commercial and less-Farm) – they have the highest educational attainment; with the highest income; they plant less farms which is only enough for their food. They mainly depended on managing other business and services to earn money. They are not easy to affect by landside disaster. They had experienced much more landside before and known what to do in case of disaster happens. For having affected by landside, they turn to manage business to live. This cluster is not easy the highest vulnerable group by the occurrence of landslide.

Table 6 Characteristics of Enshi Prefecture residents using ANOVA (F-Test), China

	ANOVA					
	cluster		error			
	Mean square	df	Mean square	df	F	Sig.
No. of parcels	40.977	2	1.095	96	37.409	.000***
Total farm size	.616	2	.167	96	3.681	.029**
Dominant farm slope	27.696	2	1.253	96	22.111	.000***
Soil fertility status	2.587	2	.571	96	4.534	.013**
Soil texture	1.209	2	.225	96	5.372	.006***
HH size	.710	2	.426	96	1.667	.094*
Age	5.946	2	1.129	96	5.264	.007***
Education	.147	2	.361	96	.406	.068*
Income before	10.613	2	1.397	96	7.596	.001***
Income after	5.938	2	2.083	96	2.851	.063**
Available government help	1.013	2	.220	96	4.600	.012**

Note: Level of Significance: $p \leq 0.01$***, $p \leq 0.05$**, $p \leq 0.10$*

Nepal

Thirty seven households were sampled in Matatirtha Village Development Committee (VDC) in Nepal. The respondents were grouped based on years of residing in a community; educational attainment, age, crops consideration, Crops change, farm size, number of plots, number of trees per plot and no of crops grown. Three clusters: Cluster 1, Cluster 2 and Cluster 3, were identified (Figure 21). Some characteristics of the clusters are explained below:

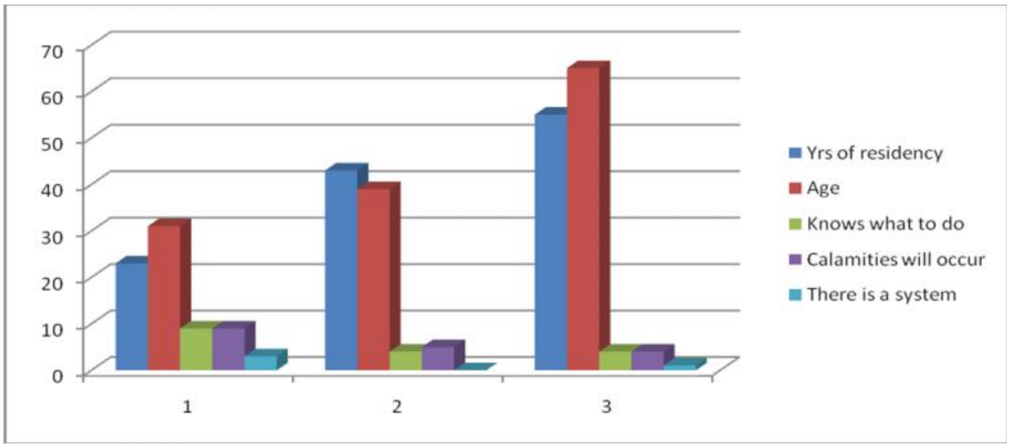


Figure 21 Clusters formed for Mathatirta Village in Nepal showing selected characteristics

Cluster 1 (Migrant Residents) consists of the youngest respondents and with the highest income. These groups also consists of highest number of respondents who have knowledge on what to do in case of calamities and who mentioned that calamity will really occur and have a system to follow in case of calamities. Age of the respondents in this cluster is in average 31 years and they have been living there for 23 years in average. It seems that they have migrated to this place. This cluster has nine respondents who believe that calamities will occur in future and have knowledge of what to do in case of weather related disasters. In this group consist of four respondents who have systems in case of disaster.

Cluster 2 (Young Native Residents) consists of respondents with middle age, medium number of years of residency and medium income. It has less number of respondents who have only less knowledge on what to do in case of calamity and who feel that calamity may occur and none of them have system to follow in case of the disasters. This cluster consists of respondents with age group of about 40 years. Years of residency are higher than the age of the respondents, which show that they were born in the place and not migrated to the place. Only about five respondents have idea what to do in case of disaster and think that disaster may occur in future. None of the respondents of this cluster reported that they have a system in case of disaster.

Cluster 3 (Old Native Residents) has respondents with the oldest age and has been in the area for the longest time than the others. Small percentage of this group is knowledgeable on what to do in case of calamity and mentioned the probability of occurrence of a calamity in future. On the average, respondents in this cluster are of 65 years and lived there for about 55 years. Only four people in this cluster responded that they know what to do in case of disaster. The only one respondent in this cluster reported that there is a system to follow in case of calamity and majority reported that there is no system in case of disaster.

From the characteristic on disaster perception, it seems that cluster 1 is least vulnerable group. This group has some perspective on adaptation in future disasters. Also, in terms of physical strength this group is least vulnerable. Among three clusters, cluster 3 seems to be most vulnerable both in terms of physical strength and perception on disaster.

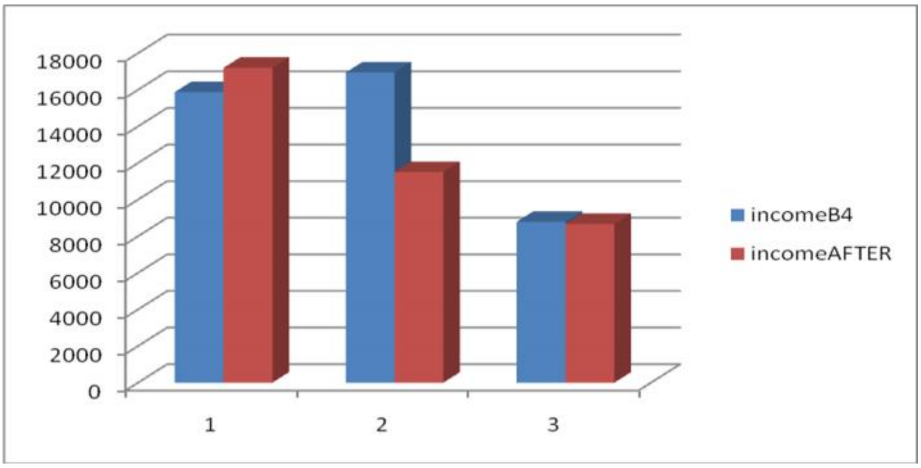


Figure 22 Differences in income of three clusters in Mathatirta, Nepal showing income distribution before and after the calamity

Figure 22 presents the average income status of the three clusters before and after the disaster. Cluster 1 is the highest income group after disaster while cluster 2 is the highest income group before disaster. Cluster 3 is the least income group before and after the disaster. Income of respondents from Cluster 1 has increased after disaster while income from Cluster 2 has decreased drastically after disaster. Income of cluster 3 has not changed after and before disaster. This shows that the disaster has affected the cluster 2 the most. Therefore, in terms of financial coping capacity cluster 2 seems to be the most vulnerable to disasters and cluster 1 is least vulnerable to disasters in future. The cluster results thus reveal that cluster 1 is least vulnerable and cluster 2 is most vulnerable both in terms of disaster awareness and income status.

Vietnam

The cluster analysis conducted using household survey data from the case study in Vietnam identified four cluster groups (cluster 1-4). The characteristics of these four cluster groups are presented in Table 7. Several variables were used to come up with vulnerable clusters. The combination of the following variables came up with four clusters: Area planted to cash crop; Area planted to food crop; Landslide risk (1- high; 2- medium; 3- relatively low; 4- no risk); Erosion risk (1- high; 2- medium; 3- relatively low; 4- no risk); Number of crops planted; Age of the respondent; Educational attainment of the respondent; Major occupation; Minor occupation; and Total labor force available for agriculture.

Table 7 Characteristics of the different clusters in the case study area in Vietnam

Variables	Cluster				all	X^2
	1	2	3	4		
No of households	27	18	22	13	90	-
Education	10.19	6.78	9.06	6.54	8.58	.007**
Age of HH head	47.37	25.22	37.81	55.92	41.38	.000**
Area planted to cash crop	2.9	2.078	1.878	1.715	2.201	.534
Area planted for food	0.17	0.54	0.43	0.45	0.38	.210
HH income (Mill VND)	139	127	91	75	110	.052*
No. of crops planted	2.67	3	2.5	2.8	2.7	.351
Landslide risk (no risk)	11	4	7	4	26	.351
Erosion risk (medium and low)	10	3	7	5	25	.538
Local organization membership	20	11	24	9	64	.155
Presence of goverment programs	7	2	2	3	14	.252
Presence of private programs	-	-	-	-	-	-
Family know what to do I case of land slide	10	4	2	1	17	.001**
Systems	-	-	3	2	5	.115
Presence of additional occupation	3	1	11	-	15	.425
Probability of occurrence of flood	14	7	17	5	43	.343
Probability of occurrence of typhoon	1	3	5	2	11	.421
Probability of occurrence of landslide	17	9	2	9	63	.052*
Probability of occurrence of mudslide	-	2	4	1	7	.379
Probability of occurrence of increasing water level	4	-	5	-	9	.534
Percent loss due to landslide	17.22	16.44	17.25	20	17.46	

Results from the cluster analysis revealed that the clusters are significantly different in terms of age and educational attainment of the respondents, household income, family's knowledge on what to do in case of land slides and the probability of occurrence of landslide. Figure 23 presents these four clusters with their major characteristics including the area of cash and food crops, level of education, age of household head and household income level. The description of the typologies of the four clusters is as follows:

Cluster 1 (large commercial farm) - the highest income group, highest educational attainment; with highest area planted to cash crops; lowest area planted to food crops; Majority of the respondents stated they have low erosion and no landslide risk; However, of the three clusters, they mention that there is the probability of a landslide but the family knows what to do in case this happens.

Cluster 2 (diversified farm) – the youngest of the four groups; second highest earning group; the group which planted more crops; There is probability of occurrence of flood and landslide.

Cluster 3 (household with non-farm works) - The group with the highest membership in local organization; the second youngest group; with the most number of respondents having additional occupation and the group who perceive the highest probability of flood.

Cluster (small traditional farm) 4 – The group with the lowest income; lowest educational attainment and with the oldest members. There is the probability of occurrence of landslide. This group has the lowest area planted to cash crops.

Among the four typologies, cluster 4 (small traditional farm) was identified as the group of local farmers who are most vulnerable to the effects of climate change such as flooding and landslides. Among the most important reasons for the high level of vulnerability among this group of farmers are low income level and knowledge, and limited land area for cultivation. The constraints to all farmers group for dealing with flooding and landslides risk in the case study area include the lack of information and knowledge about the land slides risk, lack of effective risk mitigation measures, weak of institutional and structural link for supporting local farmers dealing with landslides risk. It was revealed from the survey that besides the formal supporting network from the government, informal social networks could provide an important supports to farmers, particularly the small and poor farmers to cope with flood and land slides risks related to climate change.

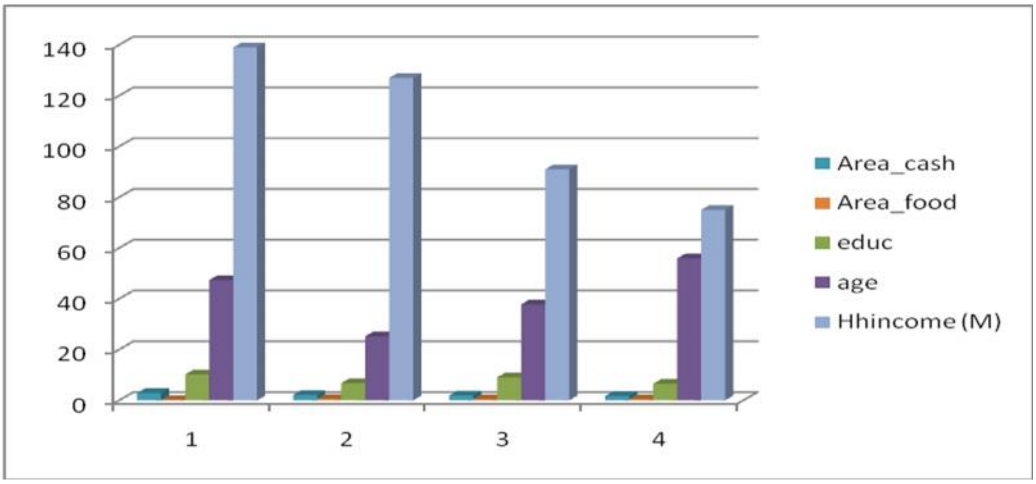


Figure 23 Characteristics of the different clusters identified in the case study area in Vietnam

Philippines

In the Philippine case study, the four typologies of the Infanta, Quezon residents are the Low Vulnerable Upland Farmers (Cluster 1), Low Vulnerable Lowland Non-Farmers (Cluster 2), High Vulnerable Coastal Farmers (Cluster 3) and High Vulnerable Coastal Non-Farmers (Cluster 4). The Low Vulnerability Upland Farmers and the Low Vulnerability Lowland Non-Farmers were considered low in terms of vulnerability. On the other hand, Coastal Farmers and Coastal Non-Farmer were regarded as highly vulnerable groups.

Adaptability was high among all four clusters except for the residents in Low Vulnerable Lowland Non-Farmers. Each cluster group was described by their ecological setting, demographical characteristics, and vulnerabilities and by their adaptation Table 8.

Table 8 Typologies of residents in the case study in the Philippines

TYPOLOGIES OF INFANTA, QUEZON RESIDENTS			
Low Vulnerable Upland Farmers (Cluster 1)	**Low Vulnerable Lowland Non-Farmers (Cluster 2)**	**High Vulnerable Coastal Farmers (Cluster 3)**	**High Vulnerable Coastal Non-Farmers (Cluster 4)**
Socio-economic Characteristics o Ecological characteristics is upland o Family members are engaged in Farming before and after the disaster o Family members are also into firewood gathering and salesmanship o Household size is 6 o No other household members o Average educational attainment of household members are currently or graduated in high school o Have not experienced flood/landslide before 2004	**Socio-economic Characteristics** o Have a household size of 4 o Have one to two children per household or none o No other household members o Average educational attainment of household members are currently or graduated in high school	**Biophysical Characteristics** o Most farmers has at least one parcel in farms o Most reported farm size code is one hectare o The soil relief is level to nearly level o Soil drainage is moderate Parent material is alluvial material in composition **Socio-economic Characteristics** o Ecological characteristic is coastal o Family members are engaged in agriculture before and after the disaster o Perception that flash floods is caused by man o The main reason of joining organizations is because of its utility o Membership in organizations is limited to one o Household size ranges from 4 to 7 o Number of children ranges from 2 to 5 o Most residents are from 41 to 50 age group o Most household heads are males o More household heads are married o No other household members o Average education attainment of household members are currently or graduated in elementary, and currently or graduated in high school	**Biophysical Characteristics** o Most farmers has at least one parcel in farms o Most reported farm size code is one hectare o The type of farm land terrain is lowland irrigated o The soil relief is level to nearly level o Soil drainage is moderate o Parent material is alluvial material in composition **Socio-economic Characteristics** o Ecological characteristic is coastal o Family members are engaged in livestock-raising, firewood gathering, charcoal-making, forest products gathering, and laundry service o Majority of the household head's job is in copra production o The livelihood of residents before and after are composed of two combinations of aforementioned jobs excluding OFW and charcoal-making o The main reason of joining organizations is because of its utility o Household size ranges from 5 to 7 o Number of children ranges from 2 to 3 o Most household heads are male o More household heads are married o No other household members o Average education attainment of household members are currently or graduated in elementary, and currently or graduated in high school o Most farms are owned

Cluster 1 was named the Low Vulnerable Upland Farmers because majority of the residents in the cluster were from the upland community and was farmers. These people are geographically located on the highest portion of the municipality. The upland has strong hilly and mountainous portions compared with the other areas of the community. The vegetation in the upland area is composed heavily of timber and fruit bearing trees. Upland rice farms and vegetable plantations were also found in small portions of the community. Moreover, the community has a relatively conducive climate for planting trees and upland crops. Compared with the lowlands and the coastal areas, the upland area is farther to its distance from the political center of the municipality. Their basic livelihood of households highly depends on upland resources particularly from forest and by-forest products. Most residents were engaged in coconut and fruit production. Alternatively, the accessibility of the residents to forest by-products was evident in the community because a portion relies on firewood-gathering. The firewood gathered was usually for home purposes. There were a high proportion of families with six members. Literacy rates are high among residents who have earned or currently in their basic and secondary level of education.

Cluster 2, the cluster of Low Vulnerable Lowland Non-Farmers is segregated on the flat plains of the community of Infanta, Quezon. They are considered lowland because the elevation of the area was not steep as compared to the upland. Strategically they are far from the shore unlike the coastal community. Prior to the 2004 disaster, most residents of the Low Vulnerable Lowland Non-Farmers were engaged in agricultural livelihoods such cereals and vegetable farming and copra production. Nowadays, a number of households are now into business, charcoal-making and fishing. The transformation of Cluster 2 agricultural to a non-agricultural community was brought about by the 2004 disaster. The debris that the flash floods and mudflows left after the disaster marked the degradation of the soils' condition in the lowland area. What used to be fertile grounds for agriculture are now turned into spatial non-productive lands. The highlights of the salient socio-economic characteristics of the Low Vulnerable Lowland Non-Farmers' cluster were limited as compared with the other three clusters. Compared with the Low Vulnerable Upland Farmers' cluster, the household size of families in Cluster 3 group is relatively smaller. The household size of four members usually has two to three children. There were more literate residents in this cluster in terms of secondary education. In addition, most parents in the lowland community agree that secondary education is all they can afford for their children due to the household's economic instability.

Cluster 3 residents were mainly from coastal areas so they were referred to as High Vulnerable Coastal Farmers. Majority of its residents were farmers primarily engaged in agriculture before and after the 2004 disaster. The socioeconomic characteristics of the group were high in terms of household size that ranges between four to seven members. The household size also reflects the number of children per household. The number of children per households ranges in between four to seven. The numbers of children in this cluster also determines that the vulnerability of households were also high. Traditionally, the male plays the more significant role in the household among residents in this cluster. There was a high concentration of partnership in terms of marriage that contributes on establishing traditional family roles in the community. The members of the family among the High Vulnerable Coastal Farmers' group have high literacy in terms of education in the elementary and high school level. This also attributes that they have a high level of information on various scales in determining and preparing for disasters and its impacts. One of the highlights of the cluster is that they have a high concentration of residents who were members of organizations which have been quite helpful for the majority of the respondents and their families.

Cluster 4, the High Vulnerable Coastal Non-Farmers, have similar background as the High Vulnerable Coastal Farmers in terms of the ecological setting, demographic characteristics, vulnerability and adaptation. One of the highlights that made the Cluster 4 or the High Vulnerable Coastal Non-Farmers different compared with Coastal farmers is livelihood. The residents of the fourth cluster were primarily engaged in livestock-raising, firewood-gathering and copra production. The combination of livelihoods mentioned were predominant to most residents who have dual jobs. Cluster 4 have less significant number of farmers but more of these farmers owns their farming lands. The level of vulnerability was also the same with the High Vulnerable Coastal Farmers except that they were food and water sufficient. Aside from that, they were not lenient for the help that they can get from groups or organization because they heavily depend on themselves and people around them.

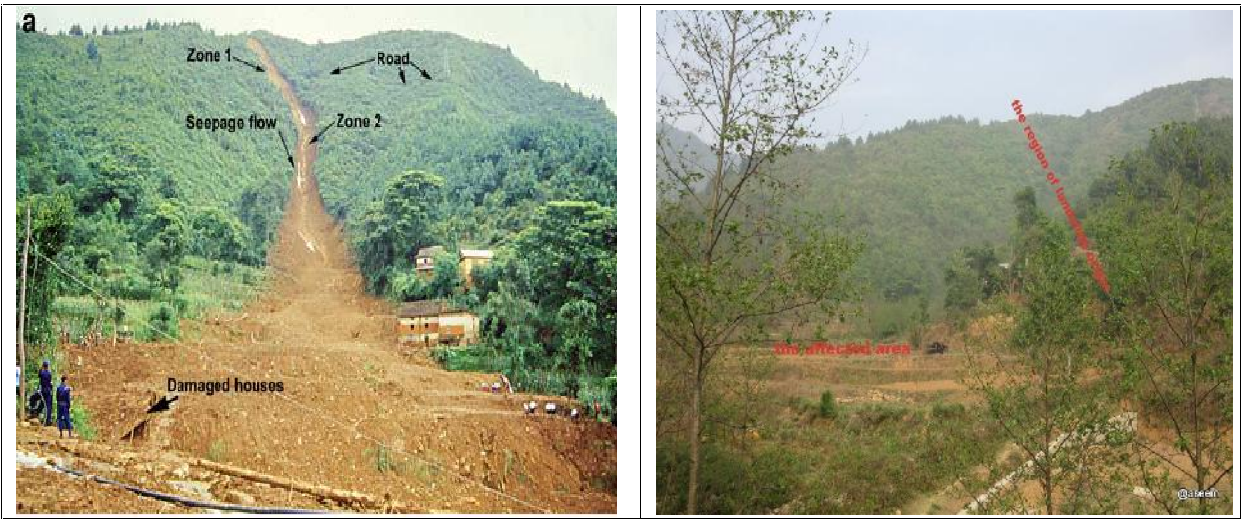
4.2.2 Disaster Experience

In this section, we highlight the disaster experiences of the respondents in Nepal and the Philippines to reveal some interesting examples of adaptation measures to landslide impacts and risks. Because of the relevance of the assessment of disaster experience in the application of agent-based model, we provide here more detailed experiences in the cases study in the Philippines.

Nepal

The general impression made by the locals during group meeting and household survey was that the people of the area were not prepared for any kind of disasters. Landslide due to heavy rainfall in July 2002 was a great shock for them. They had believed that the area is safe and no risks of the disasters. After the disaster, the most affected people were not only suffered from the loss of their relatives and properties but also remained scared when heavy rainfall occurs. Mr Indra Rimal, 62 years, who lost 7 kiths in that disaster cried during the interview (even after 8 years of the disasters occurrence) and said that its all due to the god and no one can control. But he also added that the impacts could be minimized if disaster preparedness program were carried out at local level. Unfortunately there were not any such programs. According to the local people one of the most prevalent problems in their community is natural disasters specially erosion and landslides in upper ridge. The people in the lower part in the valley considered flood as the most serious disaster in the region while remaining respondent consider landslides as the most problematic stress. Maximum number of respondents agreed that the increasing extreme rainfall events are responsible for the disasters.

The victims did not receive any specific and significant help from governmental and non-governmental agencies other than some emergency relief materials immediately after the disaster. Local people think that disasters are unpredictable and it is unpreventable, only damage and life of loss be minimized by preparedness. They want to have preparedness programs but could start by themselves and want governmental and non-governmental support. The community gave suggestions/recommendations to government organizations, local organizations and non-governmental organizations to conduct frequent workshops, interaction and talk programs on disaster preparedness at local level to exchange the ideas and information. They think that this will fill the gap among the concerned organizations stakeholders and the community peoples. Most of the people think that government agencies should take initiatives but, they also admit that, is not taking the disaster issue seriously and is not of the government priority. They think that the government should be responsible for formation of appropriate policy and allotment of budget for disasters. The community suggested to INGOs/NGOs to work out in implementing awareness activities at community level. The local people should also actively participate in the preparedness and awareness programs and should use the knowledge gained through these activities in practical life. Figure 24 shows the improvement in vegetation in the landslide-affected areas of 2002 within almost eight years. However, there are also small landslides in the Matatirtha Village Development Committee (VDC), which shows that there is still lack of preventive mechanism.



(a) July 2002
(Source: Dahal et al. 2009)

(b) April 2009
(Source: Field visit)

Figure 24 Affected area of landslide event in Matatirtha, Nepal

Mountainous terrain, fragile geology and extreme monsoon climate makes Nepal vulnerable to landslide and flash flood. The problem is further exacerbated due to the increasing population. A mountainous VDC, Matatirtha that witnessed landslide calamity in 2002 and population growth due to the urban expansion in the Capitol of the country was selected for the case study of vulnerability assessment. The biophysical characteristics showed that the southeasterly and easterly aspects with an average slope of 42 degrees are vulnerable to the landslides. Also, though forest protects from rain erosion, during heavy rains forested area are more vulnerable. The VDC has been experiencing an increasing number of small landslides after 2002 despite of improvement of vegetation in the area and the local people felt that regular information sharing and awareness programmes is necessary to reduce the impact of landslides in future.

Philippines

The farmers in the Philippine case study with their different profiles have different stories to tell about their experiences in the landslide events in 2004. We gathered these experiences not only because they are relevant for analyzing the adaptation after the landslide disaster but also because they are useful in developing decision rules for the agent-based model. Following is a summary (Table 9) and the discussion of the disaster experiences of each of the four clusters of farmers in the Philippines.

Cluster 1: Low Vulnerable Upland Farmers

The Low Vulnerable Upland Farmers have never experienced disasters prior to the 2004 flash floods and mudslides in their village. Moreover, the chances of exposure to vulnerability are high because the cognition to adaptation was never experienced. In contrast with the aforementioned, the Low Vulnerability Upland Farmers have only suffered from limited disastrous impacts after the 2004 flash flood and mudslides. Among these inconveniences are limited lack of water, destruction of inaccessible roads and homelessness. This group of farmers has never experienced traumatic impacts like self-pity and loss of hope. Therefore, the Low Vulnerable Upland Farmers were regarded cluster with low vulnerability. Behind the fact that the Low Vulnerability Upland Farmers have experienced the 2004 disaster, most of them believes that a similar disaster will likely occur. Thus, the 2004 disaster had given them a preview on how to be ready, cope up and survive for another tragedy.

Table 9 Landslide disaster experience and adaptation strategies in the Philippines

TYPOLOGIES OF INFANTA, QUEZON RESIDENTS			
Low Vulnerable Upland Farmers (Cluster 1)	**Low Vulnerable Lowland Non-Farmers (Cluster 2)**	**High Vulnerable Coastal Farmers (Cluster 3)**	**High Vulnerable Coastal Non-Farmers (Cluster 4)**
Post Disaster Experience o Have not experienced lack of water o Have experienced destruction of main roads o Have not experienced mud all over the house o Have experienced homelessness o Have experienced hypertension after the disaster o Sometimes experience loneliness during rainy days o Never self-pitted during rainy days o Never lost hope during rainy days o Believes that another disaster may likely to occur **Emergency Preparedness and Adaptation Strategies** o Have sufficient food o Have sufficient drinking water o Have sufficient drinking water for the community o Have food available in times of emergency o Have an easy access of emergency assistance o For hunger is the purpose of the assistance o The source of assistance mostly came from groups/organizations o The use of batingaw/kampana/siren is the most systematic way of informing them in a probable occurrence of disaster o Stayed in evacuation centers o Have reconstructed their homes in another place within the village o Will evacuate in case of a sudden erosion of nearby mountains o Being alert and family consensus is the best house procedure o Provision of warnings is the best municipal procedure	**Emergency Preparedness and Adaptation Strategies** o Have sufficient food o Have sufficient drinking water o Have no sufficient drinking water for the community o Have food available in times of emergency	**Pre Disaster Experience** o Have not experienced hypertension **Post Disaster Experience** o Have not experienced hypertension o Have experienced lack of water o Have experienced lack of drinking water o Have experienced destruction of main roads o Have experienced mud all over the house o Have experienced scrubbing of mud all over the house o Half of them both experienced and not experienced homelessness o Half of them both experienced and not experienced sufficiency in food o Half of them both experienced and not experienced availability of food in times of emergency o Frequently experiences fear during rainy days o Frequently experiences loneliness during rainy days o Half of them frequently and the other half sometimes experiences self-pity during rainy days o Frequently experiences fear during typhoons o Believes of another similar disaster occurrence will happen **Emergency Preparedness and Adaptation Strategies** o Have adapted to typhoon o Have adapted to increase in water level in nearby rivers o Have sufficient drinking water o Have no sufficient drinking water in the community o Have easy access on emergency assistance o The purpose of assistance is for clothing and hunger o The source of assistance mostly came from groups/organizations o The most systematic way of informing them about a disaster is through the BDCC/MDCC o Stayed on built new houses o Reconstructed their homes in the same place o Family/Neighbors cleaned the house after the disaster o Will evacuate in case of an immediate flood and water level increase o Will evacuate in case of a	**Post Disaster Experience** o Have experienced lack of water o Have experienced lack of drinking water o Have experienced destruction of main roads o Have experienced mud all over the house o Have experienced scrubbing of mud all over the house o Have experienced homelessness o Have not changed residence because they do not have other place to stay o Have adapted to typhoon o Have adapted to increase in water level in nearby rivers o Have sufficient food o Have sufficient drinking water o Have insufficient drinking water in the community o Have sufficient food available in times of emergency o Have an easy access on emergency assistance o The purpose of assistance is for clothing o The source of assistance mostly came from other people o Frequently experiences fear during rainy days o Frequently experiences loneliness during rainy days o Half of them frequently and the other half sometimes experiences self-pity during rainy days o Never experiences loss of hope during typhoons o Believes of another similar disaster occurrence will happen o Family/Neighbors cleaned the house after the disaster o Will evacuate in case of an immediate flood and water level increase o Will evacuate in case of a sudden erosion in nearby mountains o Believes that LGU programs are helpful

		sudden erosion in nearby mountains o Believes that LGU programs are helpful o Most private sector programs are from the national/local civic groups o Evacuation is the best house procedure o Provision of warnings is the best municipal procedure o Most residents remembered the November 2004 flash flood/landslide	o Most private sector programs are from the national/local civic groups o Alertness is the best household procedure o Provision of warnings is the best municipal procedure o Most residents remembered the November 2004 flash flood/landslide

Unlike the level of vulnerability of the Low Vulnerability Upland Farmers, they are regarded as a group with high adaptability. This is common for the majority of the residents in the cluster because they have the capacity to sustain themselves during and after disaster. According to the Low Vulnerable Upland Farmers, they were found to be sufficient in food, water and other assistance during. This group was also confident that they have a security of assistance coming from groups and organizations and evacuation centers were ready to cater as a temporary shelter.

The Low Vulnerable understood warnings from local community officials and was given orientation on procedures on what to do during emergency such as flash floods and mudslides. The Low Vulnerable Upland Farmers have learned valuable lessons after the 2004 disaster. Most residents who suffered from adverse impacts of disasters have reconstructed their homes by using concrete for building materials.

The case study illustrates specific experiences and adaptations strategy employed by the Low Vulnerable Upland Farmers in Infanta, Quezon.

Case 1: Village Magsaysay in the Before, During and After the 2004 Flash Floods and Mudslides

Magsaysay is considered one of the upland villages in the municipality of Infanta, Quezon. It has a population of 2,021 with 346 households and families. The residents of the village heavily depended on forest products as well as other farm related income. Livelihood is mainly upland rice farming. Charcoal-making in Village Magsaysay are limited to forest timber by-products.

The town proper of Village Magsaysay is about 15-30 minutes of travel. Common transportation is jeepney where one usually waits until it is filled to full capacity. Village Magsaysay is a sleepy town where most of the residents spend their time either doing their regular farming work or doing chores of their family members. The November 2004 calamity is evident, not far from the main road of the Village Magsaysay where visible mountain slopes atop is scarred with landslide marks and the riversides were filled with cobbles and boulders of stones.

As described by the local residents, the wide running river near the village was once deep and teeming with fish and shrimp until flood and landslides when river became shallow. Today, there are infrastructures in process like the road widening and cementing project that will link Quezon and Marikina in the future. The cobbles and boulder stones found alongside of the river was purposively used for the aforementioned infrastructure project by the national government.

According to Mang Marcing, a local resident of the community;

"Tourist spot ang barangay na ito noon... May mga maliliit na kubo dyan sa gilid ng ilog at mayroon ding nagca-camping na mga dayo magdamag." ("The village was a tourist spot before... There were small huts along one side of the river and there are overnight campers from other areas.")

Moreover, these small huts along the riverside served "lambanogs" to tourists and locals while they are singing and dining. In spite of poverty, the local folks find economic gains from local tourists and a combined supplement earnings from upland farming. Most of the residents depended on forest products through random log cutting prior to the 2004 landslide and mudflows. In fact, some of the local respondents can attest that illegal logging was made possible by transporting timbers from the mountain down to the Agos River. This is widely known not only in Village Magsaysay but as to the whole town of Infanta, Quezon as one of the major source why the flash floods and mudslides occurred. It cannot be also denied that almost 50% of the village people relied on logging to augment their income. Due to this, a strict implementation of a local policy that bans illegal logging is now practiced throughout the village.

According to the Village Council of Magsaysay led by Mr. Manalo Miras, there were approximately 70% of the livelihood and 30% in farming that was damaged by the flash flooding and mudslides incidence in 2004. Rebuilding the damages caused by the disaster need consented effort from various groups. It would demand heavy vehicles to uncover and lift the debris that the landslide and mudflow left behind. The disaster impacts brought upon by the 2004 disaster did not only leave damages in terms of livelihood but also major adjustments on the lives of the people being constituents of the upland community in Village Magsaysay, Infanta, Quezon.

Actual and post-disaster experiences on flash floods and mudslides. Although Village Magsaysay is located on the highlands of Infanta, Quezon there were still incidence of flash floods and mudslides. According to the Village Council, the community experienced heavy downpour the whole day which consequently triggered the soil from the upland area to break down and cause a huge landslide. Other residents attested that flooding was also caused by the breakdown of a nearby dam not far from the community. The breaking of the dam was induced by clogged timbers that caused flooding to rage in a fast phase. Some residents recalled that a huge sound similar to a flushing toilet called their attention. Little did they know that the dam had collapsed and the water from the river began to rise. Village Magsaysay was under water for 3 hours from 7:00 until 10:00 in the evening. The flood water began to rise up to levels almost beyond their heads or even their homes. It has been a startling experience for most that resulted to panics for many and deaths for those who were trapped under the rage of flood. Houses that were scattered along the river portions were all washed out (Figure 25), only few families had salvaged a part of their properties and belongings, the overwhelming flood almost washed drowning rescuers. They risked their lives to save the community members, relatives, friends and neighbours. After the disaster, nothing was left standing, their homes, and their livelihoods were all carried away by the mudflow including their hope and faith were overcome by rescue their fear and despair. Years later after the disaster, depression is still observable among their faces every time they narrate their sad stories and personal experiences.

The whole village had no electricity for six months. Communication channels like cellular sites were also down for a couple of months. The people in the community also did not receive relief goods from donors and rescuers due to impassable roads in the "poblacion" or town proper. It nearly took 3 months for the repair of the roads. It was also a huge problem for the community to have water access of both potable and non potable ones. In addition, Brgy. Cpt. Miras admitted that;

"Wala pa ring tuloy-tuloy na pinagkukunan ng tubig, kaya umaasa pa rin kami sa mga Congressman, o ng Mayor, Gobernador... yung aming mga linya ng tubo para maibalik yung dati." ("The water supply is still limited; we are still in hoping for assistance from the Congressmen, or the Mayor, Governor... will able to restore our water way systems.")

Figure 25 The sight of the Ilog River and the scarred mountain portions of Village Magsaysay, Infanta, Quezon in the Philippines

Currently, the water from a reservoir was the last resort that the community had during those times as a temporary source of water. Since 85% of the population of the village has been affected extremely by the disaster, problems with regards to food and health security are experienced by most residents. Relief goods were frequently received by the local folks 2-3 times per weeks. Furthermore, the situation of hunger was still evident for some. The deplorable situation forced the residents to flee out of the village to the nearby communities where there are food, medicines and other necessary relief goods. Bulk relief goods were donated by local and foreign NGOs like the World Vision, ICDAI, ABS-CBN and etc.

Besides the calamity fund that amounted to approximately P51,000 that were utilized for food and rehabilitation of infrastructures, a service provided in terms of response, rescue and rehabilitation by the Armed Forces of the Philippines (AFP) and other volunteer were invaluable. These assistance from the volunteer organizations were highly appreciated by the community and the local government.

Response, rehabilitation and mitigation of Village Magsaysay. After the 2004 calamity, the local village implemented a policy that prohibited the people of Magsaysay to build homes near the river. Brgy. Miras highly emphasized that;

> "May batas sa munisipyo na kung magpapatayo ka ng bahay, kailangan nasa maayos na... hindi pinapayagan magtayo dun sa mapanganib na lugar..." ("There are now municipal policies about building homes, it should be well built... it was also prohibited to build shelters on disaster-risk areas of the community...")

The population that was once at risk was now relocated on areas within the village which they think are safer than to the ones they had before. Some of the residents finally settled in relocation areas outside the village which were provided by NGOs and LGUs.

It was also overwhelming that majority of the people lacked the necessary information in terms of emergency preparedness in times of emergencies. Surprisingly, even the Village Council of Magsaysay do not have concrete plans on addressing disaster incidences. Since the local municipality had devised warning devices and precaution standards for the community to observe and follow, the community residents are far more aware of a local disaster warning in a form of a community bell or "batingting" as called by the locals. The "batingting" gives the local community people a cue on to when they are necessary to move out and secure themselves into safe areas that the village authorities dictates.

Compared with the impacts of the disaster with the other affected villages of Infanta, Quezon the village officials somewhat agree with the village captain's words, saying that;

> "Konti lang po dito kumpara sa kanila, bago ang lahat, ang lugar po sa kanila'y laganap ang tubig, e dito po'y mga tabing ilog lang... at saka yung landslide ay sa mga bahay, matindi sa pagkawala ng bahay, sa kabuhayan at sa pag-aaral ng mga anak." ("The impact here is not as severe as compared to them, their communities were affected more by the flash floods, in here we only have those who lived alongside the river... and the landslides heavily affected the homes, severe homelessness, in livelihood and children's education.")

Regardless of what future disasters might bring the local residents of Village Magsaysay still manages to stay firm on their own land because of the fact that their lives are tied to the benefits that the upland environment gives them which in return made them highly dependent into it.

Cluster 2: Low Vulnerable Lowland Non-Farmers

There were no further highlights in terms of vulnerability to disasters among the famers in cluster 2 because of the diversified experiences of the residents. This is why the Low Vulnerable Lowland Non-Farmers were considered low in terms of vulnerability. There were few adaptive measures employed by the residents that emphasize the characteristics of their cluster. Their emergency preparedness is limited only on having sufficient food and drinking water for the household. Moreover, the community has no capability of providing sufficient drinking water to the majority of its residents. Therefore, the abovementioned reasons are the basis on why the Low Vulnerable Lowland Non-Farmers were regarded low in terms of adaptation.

In order to provide more detailed information with regards to the individual experiences prior, during and after the 2004 disaster, the case of Delia Lasam was highlighted.

Case 2: Elena Tibayan: Never Recovered from Depression After the 2004 Disaster

Elena is a resident for 55 years in Village Ilog, Infanta, Quezon. Farming is her only means of livelihood. She is now living with her family in a house made out of temporary light weight materials because their old house wiped out by the 2004 tragedy which left an indelible mark in their lives.

Their rice farm used to generate an income of P80,000 which was good enough for the whole family. Unfortunately, the 2004 tragedy reduced their 3-hectare land into one and a half (1.5) hectares. Every month, Elena needs to pay the rent of that agricultural land that her family is cultivating. Besidest rice farming, her family manages to sustain their daily needs by firewood gathering as a source of income when harvest is not yet in season.

Experience with disaster. It is hard for Elena to narrate the actual incidence of disaster last 2004 because she and most of her family members were injured. Ten of her relatives were injured and 4 died. She undergoes extreme depression every time the rainy season sets in fearing that a similar disaster might again happen. Most of the houses were torn down, agricultural fields were all covered by mud, and other flood debris caused a lot of inconvenience and accidents (Figure 26). Because of the rapid flow of water, Elena and her family were trapped in their house. Elena remembered losing any hope to survive in that kind of tragedy. Neighbours were all desperately shouting for help. It was a hard time for her to seek immediate help from others because the whole neighborhood was submerged in mud and above head level flood.

It was a tough decision for Elena to have focus on such important matters especially deciding to protect her family. According to her;

> "Hirap magdesisyon, blanko ang isip... nawala ang tuon sa pamilya dahil sa kabuhayan." ("It's hard to decide, the mind was blank... I cannot focus well for my family because of our livelihood.")

Moreover, it was also hard for Elena to protect her properties and livelihood because she did not have any choice but to see it flushed down by the flooding rather than risking her own life to save it. On the other hand, Elena was fortunate because one of her children helped to pay the expenses to re-establish what has been lost in the disaster in terms of generating capital for the livelihood of her family. She had also considered loan from a private agency in order to rebuild the house that was torn down by the disaster.

Due to the fact that much of her properties were lost and some family members had experienced illnesses after the disaster, she had suffered post trauma which includes anxiety, fear, loneliness, self-pity and loss of hope every time the rainy season is experienced. These negative emotions are also in extreme when typhoon is expected to hit their town. She also fears the inconvenience that they have experienced after the disaster, which includes the lack of potable water, electricity and transportation.

Figure 26 Farming grounds before, idle lands now in Village Ilog, Infanta, Quezon in the Philippines

Although Elena had equipped herself with proper knowledge in terms of emergency preparations during disastrous situations, she admitted that the information coming from the media can be different from an actual experience. Her ideas about information on flash floods and landslides were furthered by the fact that the local municipality and non-government organizations provided seminars and symposiums after the 2004 disastrous incidence. In addition, the programs provided by non-government organizations and local government units with regards to seed and seedling dissemination were great help in re-establishing Elena and her family's livelihood.

Disaster preparedness and adaptation strategies. There are still some things that Elena worries about when a disaster inflicts again. These are the unusual disasters that are stressful in terms of its impact. Asked whether she is prepared to face the consequences of disasters such as landslides and mudslides, Elena abruptly said “no” as an answer. In addition, the only thing she could answer in such cases like increase in river flow, typhoon, sudden erosion of mountain soils, and increase in mudflow and landslide is simply “lilisan” or “to evacuate” .

It was very important for her and her family to stick together whenever an occurrence of a disaster is expected. Elena quoted;

> “Pagbaha at malaki ang ilog, pipisan na ang lahat ng miyembro ng pamilya at lilisan.” (“When there is flooding and that the water level in the river rise, the family members will gather to evacuate”.)

This household procedure is reflective on the warnings or procedures given at the village or municipal level. Such systematic procedure given by the local government units such as informing the public of the upcoming occurrence of the disaster is a credible basis for Elena and her family to act in accordance. Elena is also confident that all the members of the family are knowledgeable enough to respond to the signs of warnings that each disaster occurrence stresses.

The aftermath of the 2004 disaster left a difficult situation for Elena and her family. They managed to live in a small temporary built hut made out of the remains of their flushed home as well as debris out of flooding. She also managed to migrate to the nearby village of Pilaway where they managed to reconstruct their new home. Without any funds or help from funding agencies to start with, Elena together with her family dealt with the finances in order to have a new shelter to live and start with. Going back to Village Ilog may have made an impression on her of recurring experiences that happened during the 2004 disaster. She had to pull herself together to counteract the negative feeling that tends to bring her down.

Cluster 3: High Vulnerable Coastal Farmers

The High Vulnerable Coastal Farmers had suffered much in terms of disaster experience. These disaster experiences have brought a lot of discomforts in their everyday living. Among the adverse effects of the November 2004 experienced by its residents were primarily on water and household maintenance problems. In addition, only half of the majority of the residents had suffered from homelessness and food insufficiency. The impacts that the 2004 disaster created post-traumatic stresses on High Vulnerable Coastal Farmers, feelings of fear, loneliness and self-pity were among the personal disturbances that most residents in rainy day seasons and typhoons. Moreover, the abovementioned conditions have led to a common notion among its residents that another similar disaster will happen in the future. Based on disaster experiences, High Vulnerable

Coastal Farmers is highly categorized as one of the most vulnerable group. Behind the fact that the cluster was considered highly vulnerable to disasters, they are also high in terms of adaptability. Confidently, most residents admit that they are highly adaptive to the shocks and stresses that each disaster brings. Besides having the capacity to acquire basic resources like food, water and shelter, the High Vulnerable Coastal Farmers were highly lenient to the help that they can get from organizations.

The aftermath of the 2004 disaster did not prove that recognition in awareness of the disaster risks would mean avoidance from disaster-prone areas. Majority of the residents in High Vulnerable Coastal Farmers cluster have stayed on the same spot where their homes used to stand after the 2004 disaster because their livelihood highly depends on their environment.

Cluster 4: High Vulnerable Coastal Non-Farmers

The High Vulnerable Coastal Non-Farmers' exposure to the 2004 disaster reflects their level of adaptation. Similarly, they also have a same level of adaptation to disasters compared to their farming counterparts. The High Vulnerable Coastal Farmers where likely to stay on the same spot their house used to stand after the disaster. The reason was not because they are tied with their livelihood but for the fact that they do not have any options.

To have a more specific understanding about the Coastal residents, the case of the Lasam was considered.

Case 3: Lasam Family: Resident Since Birth in Infanta, Quezon

Both born and bred in Infanta, Quezon for 51 years, Delia and her husband Oscar had profound experiences in terms of natural disaster occurrences, they live in a small house built in temporary materials like plywood walls, lightweight ceilings and cemented floors, the Lasam Family who were together that time on the actual interview still manages to welcome and accommodate a friendly smile amidst the impoverished conditions that the family experiences. Oscar and Delia lives with their two sons, Judel and Jomel. The other elder children of had their own families and homes situated not quite far from the house of their parents. Since Delia admitted that her preoccupation is to manage their family household, her husband solely to shoulder the daily expenditures as a carpenter, an occupation he shares with 28 year old son Judel. Carpentry is a seasonal job, so during off season Oscar and his son, rely on fishing as an alternate source of income. Another son, 23 year old Jornel contributes to the family income by transporting copra products and other heavy loads at a nearby seaport. The nature of the jobs is reflective on how they have attained their education. Both Oscar and Delia have primary education while their sons Judel and Jornel had secondary school diplomas. Both Judel and Jornel are obliged to contribute to family income at an early age. Furthermore, this is also the same fact why Judel and Jornel remained single because of the financial situation of the family. Inspire of these measures in income there is a relative contentment as evident from their everyday life.

Experience with the 2004 disaster. Not all families are open in disclosing their experiences with disasters especially when casualties or loss of lives was incurred. In the case of the Lasam family, lives have not been lost due to their presence of mind and their quick to response to the current situation in November 2004 flash floods and mudslides tragedy in Infanta, Quezon. Needless to say, the risk of being vulnerable in terms of flooding and mudslides is much expected on the geographical position of the Lasam family. Their house is situated in between the river of Ilog and the coast of the Pacific Ocean thus, making them prone to effects the of overflowing of the river as well as the impacts of high tide on worst case scenarios.

Available and access of knowledge or information about proper procedures and necessary precautions amidst disastrous or calamitous situations was never an option for the family. It was only available when the disaster had happened. The local government as well as national and international NGOs has provided the people information that will enable them to withstand the effects of disaster. Nonetheless, it can be accounted that the Lasam's previous experiences with disasters of flooding and mudslides might have contributed to a degree in adaptability to survive. Delia noted that there has been flooding that happened before although it was not as powerful and overwhelming as compared to the November 2004 calamity. As far as Delia could recall, there were similar flash flood experiences during the years 1998, 1980 and 1965 but the floods were just knee-deep and reaching waistline as maximum depth. According to the testimony of Delia's son Jornel, the November 2004 incidence was characterized quick but has reached to the ceilings of the Lasam's house.

It was about midnight when the family is asleep, the gush of water was felt flowing below their beds, and a couple of more minutes have also led to an increase in water flow and elevation. Most of the decision making matters subdivided into individual conscious efforts to protect their house, properties and even their lives due to panic-induced situation. During the actual flash floods and mudslides it is not only saving the lives of the family members that are the main concern, Delia noted that;

> "Pagkain, lutuan, at iba pang appliances ang inuna basi sa kahalagahan" ("Food, cooking utensils and some appliances were given priority based on the value")

An important parameter of is to place the item to a safe area like the roof far from flood waters. Furthermore, Jornel added;

> "Niligpit ang gamit at inilagay sa bubong." ("Picked up the things and placed them on the roof.")

The main consideration is whether the item is important for survival like food and the cost of the appliances like the electric fan and the television. On the actual incidence of the disaster, others' help was indispensable because of the fact that all the residents suffer the same fate and none of the nearby neighbours have these two floored houses. The only secured place to go is to go to temporary immediate shelters. The Lasam family have no immediate relatives nearby. The most practical alternative solution was to get financial loans to restore the house. Relocation is not a viable alternative because the only property they have is laid where the house is situated.

The difficulties of the family during that post-disastrous situation were made easier because of the availability of programs from NGOs of both local and international organizations. Most of the programs offered housing projects and medical missions. Seemingly, all of the programs implemented and exercised by the NGOs were deemed helpful to them because they could not even recollect what efforts of the local and national government provided assistance of the same level.

Delia narrated that during the disaster they experienced mild fever and frequent colds and coughing. Moreover, the impact of the disaster also made a mark neurosis on Delia. The post-traumatic experiences such as frequent feelings of anxiety and loneliness whenever rainy days are at season, or occurrence of a typhoon is at hand visit their place. There were other discomforts that they experience for the family after the 2004 disaster such as the lack of the basic needs for daily survival like food, water and shelter, being homeless and not to mention floor scrubbing and house cleaning.

Disaster preparedness and adaptation strategies. Sources of post-disaster stresses are limited by food and clothing, and temporary homelessness. With nothing left to recover in terms of household properties as well as wreckage debris from their washed out home, the Lasam family had spent a huge amount of effort to replenish and clear out unnecessary debris and mud accumulations in order to pave way of rebuilding a new shelter. They are left without any choice but to rebuild their house from timber products that are still available from the debris (Figure 27). The lack of options to move away from the disaster prone Village of Pinaglapatan, the Lasam family was fortunate enough to receive assistance from other people during rehabilitation phase of their life. The carpentry skill has been useful in rebuilding the family's house.

Figure 27 Timber products used for charcoal-making and house doors in Village Pinaglapatan, Infanta, Quezon in the Philippines

Coping with the stresses and pressures in November 2004 disaster in Infanta, Quezon had brought upon the individual lives of the Lasam family, these learning experiences had enabled them to become more responsive to the warnings and precautions that a probable future disaster may inflict. On the other hand, insufficiency over certain possession to have in the midst of disaster is also a disadvantage for the Lasam family to have like food, a place for security and even a flashlight. Although household, community and municipal wide safety procedures are available for the Lasam family to rely on, they are still not certain of what might transpire on the next probable occurrence of a natural disaster.

All of the members of the Lasam family are now more aware of the procedure in cases of another flash flood like packing up their personal belongings and placing them on a high elevated place. Since their house is built on semi-lightweight structure, it is a responsibility for the men in their family to secure their house by tying it into a tree before they consider fleeing on a safer zone. In elaboration, Delia explained;

> "Mag-impis ng gamit... itali ang bahay sa puno." ("Secure the necessary belongings and secure the house by tying it to the tree.")

It is also important for them to stay together during the disaster so that each member of the family will be highly monitored. Moreover, a cue for them to evacuate out of the community is by a village based customized bell that will be enabled to reproduce a sound as a sign of an upcoming worst disaster. In addition, Jornel noted the manner of rescue and response to the disaster that the local municipal procedure has, he claims that;

> "May napuntang maghahakot ng tao." ("Someone will pick up the people.")

Likewise, a municipal truck will be on standby to pick-up the people and transport them to designated rehabilitation centers of the municipality.

Delia as the one being responsible of speaking in behalf of the family highly assured that her family is knowledgeable about the procedures and precautions set by the local village and municipal units because of the local government's persistence of informing the public. Furthermore Delia agrees that the likelihood of a similar disaster may take place once more in the municipality or at the village of Pinaglapatan for as long as there are predominant lumber harvesting and destruction of forest reserve in their town.

4.3 Agent-based model: Philippine Prototype

The aim of this section is to discuss how the outputs of the cluster and narrative analyses can be used as input to the agent-based model in assessing vulnerability to landslide impacts. The prototype application of the model in the Philippine case study reveals the usefulness of carrying out actual soil analysis in the area to collect samples of soil variables that affect landslide character. Hence, in addition to the social behavioral model, we discuss here physical behavioral model. The agents in the model are thus human (i.e. residents and farmers) and land (refer to Figure 8 and Figure 9).

4.3.1 The human agent

The human agents in the agent-based model are the residents in the clusters with specific profiles. The model assumes that the agents in each cluster behave differently when confronted with disaster such as landslides. Their adaptive behavior is influenced by their profile, which define their socio-economic characteristics.

Majority of the residents in Cluster 1 group have an average of six family members while, Cluster 2 group have at least 4 household members. Cluster 3 and Cluster 4 groups have household sizes that range from four to seven and five to seven members respectively. Non-relative members were not common among all four cluster groups. The number of children per household in Chapter 1 group was primarily two or four, Cluster 2 group 0-2, Cluster 3 group 3-6 while Cluster 4 group 2-3. The age of the household head is between 41 to 50 years who married males. Cluster 2, 3 and 4 groups were identified to have High Literacy groups are in clusters 2, 3 and 4 groups in basic education. Conversely, Cluster 1, 3 and groups were found to be highly educated in secondary education.

The Cluster 1 group has not experienced disasters before the 2004 tragedy in contrast with Cluster 4 group. About half of the residents in Cluster 3 have experienced disaster before November 2004. These two clusters, Cluster 3 and 4 groups both experienced disaster particularly the one that occurred in November 2004. In spite of the changes brought by disasters, the people did not suffer. The following were some of the discomforts they experienced; hypertension, lack of water (for drinking or not), destruction of main roads, mud all over the house, scrubbing mud all over the house; some emotional discomforts were fear, loneliness, self pity rainy days; frequently fears but never losses hope during typhoons. On the other hand, members in Cluster 1 group did not experienced severe physical and emotional distress but were affected destruction of main roads and feeling of loneliness during rainy days occasionally. Cluster 3 frequently losses hope during rainy seasons. In general, all four cluster groups have experienced homelessness after the 2004 disaster.

In terms of emergency preparedness and adaptation strategies (Table 10), Clusters 3 and 4 were found with the following characteristics; have adapted to typhoons and river water overflow; have an easy access on emergency assistance; for clothing was the purpose of the assistance; have found LGU programs effective; have received help from national/local civic organizations; aware of the preventive measures coming from the municipality in times of disasters; have found reliability of information through village or municipal disaster coordinating council in times of disasters; will evacuate when river water over flow is manifesting; families or neighbors cleaned the house after the disaster and; believes that another similar disaster like the 2004 tragedy will happen.

Among the distinct characteristics of Cluster 1 residents in terms of emergency preparedness and adaptation strategies towards disasters were the following: Sufficient drinking water, easy access on emergency assistance, collaborative household decision-making in times of disasters, attentive to signs of warning (batingaw, kampana, siren and the like), would head for evacuation centers during disasters, had reconstructed their homes within village limits but in safer areas but, believes that the likelihood of a similar disaster like the 2004 disaster may or may not happen. Equally, Cluster 2 had the following characteristics in lieu with adaptation. Had no sufficient food for emergency purposes and in times of disasters, being alert was the only house procedure known and, had built new homes in the same place where they had been affected by the 2004 disaster. Compared with the other three clusters, Cluster 4 residents was able to find assistance mostly from other people and had not changed residency because they did not have other place to stay.

Table 10 Level of adaptive behavior to landslide related conditions of Infanta residents in the Philippines

Emergency Preparedness and Adaptation Strategies	Clusters			
	1	2	3	4
Adaptation to Typhoon				
Yes	M	M	H	H
No	L	L		L
Adaptation to Increase in Water Level in Nearby Rivers				
Yes	M	M	H	H
No	L	L	L	L
Sufficient Food				
Yes	H	H	H	H
No	L	L	H	M
Sufficient Drinking Water				
Yes	H	H	H	H
No	L	L	M	L
Sufficient Drinking Water for the Community				
Yes	H	L	M	M
No	L	H	H	H
Have Food Available in Times of Emergency				
Yes	H	H	H	H
No	L	L	H	M

Table 11 reveals that Cluster 1 and Cluster 3 residents purposively needed the assistance after the 2004 disaster to address hunger and this assistance were predominantly facilitated by groups and organization within or outside the community of Infanta, Quezon. In addition, Cluster 3 and 4 residents were taught more to be alert in the household whenever disasters occur. The last three cluster groups were found insufficient to have enough drinking water for the community. In addition, the first three cluster groups will evacuate when landslides occur. In general, all four cluster groups have sufficient food and drinking water in times of emergencies or disasters.

To summarize, the four typologies of the Infanta, Quezon residents are the Low Vulnerable Upland Farmers (Cluster 1), Low Vulnerable Lowland Non-Farmers (Cluster 2), High Vulnerable Coastal Farmers (Cluster 3) and High Vulnerable Coastal Non-Farmers (Cluster 4). Each cluster group was described by their ecological setting, demographical characteristics, and vulnerabilities and by their adaptation. The Low Vulnerability Upland Farmers and the Low Vulnerability Lowland Non-Farmers were considered low in terms of vulnerability. On the other hand, Coastal Farmers and Coastal Non-Farmer were regarded as highly vulnerable groups. Adaptability was high among all four clusters except for the residents in Low Vulnerable Lowland Non-Farmers.

Table 11 Emergency preparedness and adaptation strategies of Infanta residents in the Philippines

CHARACTERISTICS	CLUSTER GROUPS			
	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Easy Access on Emergency Assistance				
Yes	H	M	H	H
No	L	L	L	L
Purpose of Assistance				
Clothing	L	L	H	H
Hunger	H	M	H	L
Source of Assistance				
Government/Officials	L		L	L
Other people	L	M	L	H
Groups/Organizations	H	L	H	M
Helpfulness of LGU Programs				
Yes	M	M	H	H
No		L	M	L
Private Sector Programs				
International		L	L	L
National/Local Civic	M	M	H	H
National/Local Media	L		L	
National/Local Religious			L	
House Procedures				
Alertness	H	M	M	H
Food preparation	L	L	L	L
Family decision	H	L	L	L
Alertness to warnings	L		L	
Evacuate	L		H	
Pray		L	L	
Secure properties	L	L	L	
Municipal Procedures				
Provide warnings	H	M	H	H
Radio/BARCOM		L	L	L
People initiated	L	L		
Information from NGO and LGU		L	L	L
Provide vehicles		L	L	L
Systematic Ways of Informing the Public				
Batingaw/Kampana/Siren	H	L	M	L
TV/Radio	L	L	L	L
Village Disaster Council/MDCC	L	L	H	H
Signs of Nature	L	L	L	M

4.3.2 The land agent

The land agents in the agent-based model are the different land uses linked to specific soil profiles. The land use maps before (2002) and after (2008) the landslide event in 2004 in Infanta, Quezon are presented in Figure 28 and Figure 29. An unsupervised image classification was done for both aster image of 2002 and 2008. This image classification served as the basis for the supervised classification (Please refer to section 3.3 for the methods used in preparing the maps). The results of the unsupervised image classification were interpreted as:

1. Annual crops
2. Coconut mixed with crops & shrubs
3. Dense vegetation
4. Grasslands mixed with shrubs

5. Built-up
6. Bare soil
7. Fish pond & salt beds
8. Water bodies
9. Clouds
10. Clouds shadows
11. Clouds and surface reflection

The figures reveal that the land use in Infanta, Quezon has changed significantly after the landslide disaster. The locations of the built-up areas in year 2002 is quite different from those in year 2008, which shows the magnitude of impacts of the landslides in terms of habitat displacement. The water bodies did not only extend in terms of length and width, but also shift in places that used to be cultivated.

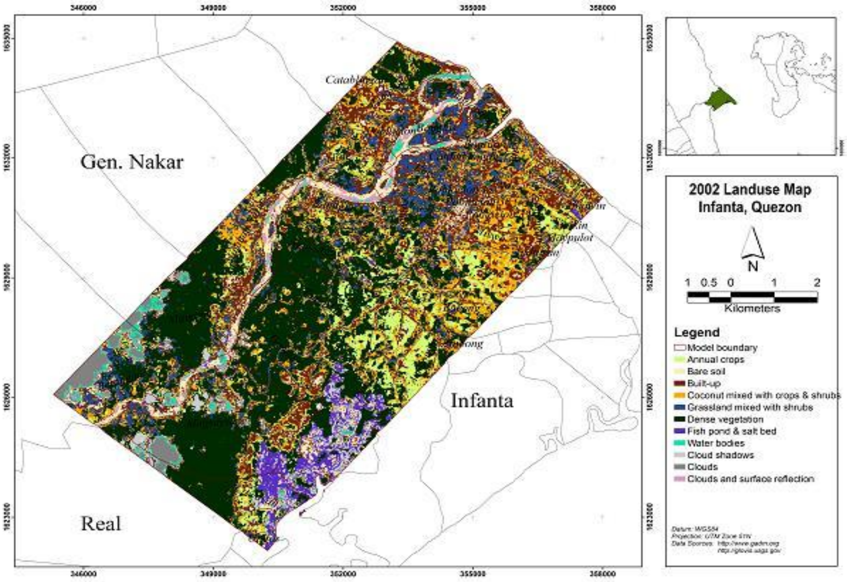


Figure 28 Landuse map derived from Aster satellite image of the case study site in Infanta, Quezon in the Philippines for the year 2002

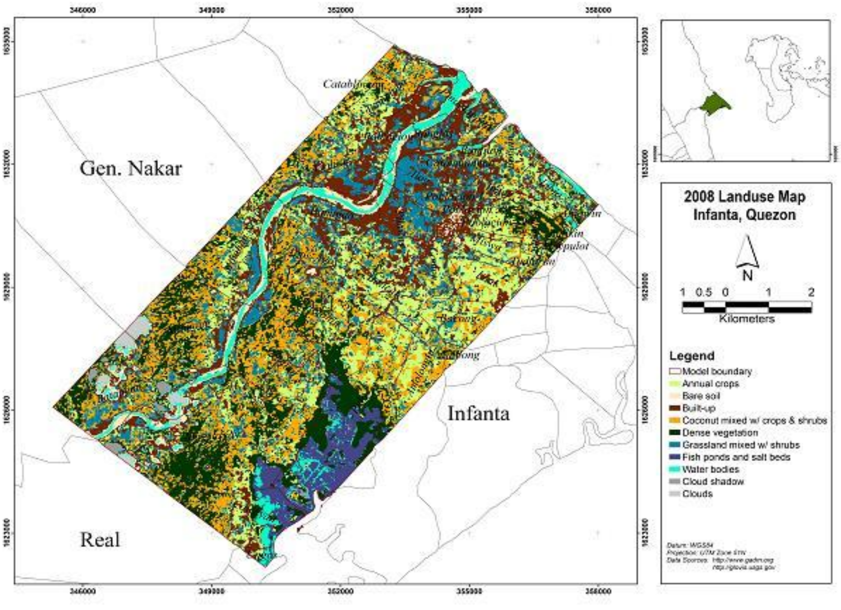


Figure 29 Landuse map derived from Aster satellite image of the case study site in Infanta, Quezon in the Philippines for the year 2008

Using soil analysis from the case study area, we describe the land agent through landslide characterization. The soil of the landslide areas in Village Magsaysay was characterized based on selected soil properties, which are presented in Table 12. Table 13 show the description and soil profiles of the sampling sites. The soils in all sampling sites generally are deep to very deep (more than 1m) and red clayey soils except for sampling site MS2 (Table 12). MS2 sampling site has clay soil texture from the surface up to 75cm depth. However, beyond 75cm, the texture becomes silty clay to clay loam (Table 12). Cation Exchange Capacity (CEC) values range from 16 to 45 cmol(+)/kg soil indicating low to medium activity of clay. CEC provides a measure of the amount of exchangeable cations an active surface is capable of adsorbing. It also primarily depends on the activity of the predominant clay mineral. Higher CEC means that the soil has very active clay and vice versa.

Table 12 Soil characteristics of landslide sampling sites in Village Magsaysay, Infanta, Philippines

Sampling site	Soil depth (cm)	CEC cmol(+)/ kg soil	Sand (%)	Silt (%)	Clay (%)	Textural Grade	Liquid limit, w_L (%)	Plastic limit, w_P (%)	Plasticity Index (PI)[1]
MS1	0-22	25.3	17	36	47	Clay	73.84	54.26	19.57
	22-47	16.0	9	29	62	Clay	87.37	54.34	33.04
	47-93	15.8	14	39	47	Clay	76.80	52.10	24.70
	>93	33.4	19	42	39	Sandy clay loam	72.58	50.06	22.52
MS2	0-40	33.4	20	43	37	Sandy clay loam	65.84	42.03	23.80
	40-75	36.1	23	44	33	Clay loam	68.36	45.37	22.99
	75-103	44.6	20	51	29	Sandy clay loam	66.32	42.47	23.85
	>103	37.5	33	43	29	Clay loam	67.31	43.84	23.47
MS3	0-25	24.9	18	32	50	Clay	67.49	49.49	18.00
	25-55	26.8	13	27	60	Clay	81.82	51.24	30.58
	55-102	25.5	15	29	56	Clay	81.13	59.57	21.56
	102-146	36.4	21	42	37	Clay loam	78.26	59.19	19.07
	>146	20.7	23	40	37	Clay loam	70.51	53.99	16.53
MS4	0-15	27.1	23	36	41	Clay	69.86	45.79	24.06
	15-52	17.4	22	34	44	Clay	68.95	46.44	22.51
	52-78	26.3	23	31	46	Clay	67.28	45.15	22.13
	>78	27.1	22	34	44	Clay	60.79	42.15	18.64

Note: [1]PI = $w_L - w_P$

Table 13 Description of the landslide sampling sites in Infanta, Quezon in the Philippines

Sampling site	Description
MS1	crops (e.g. pineapple, coconut) mixed with shrubs and trees; very large crack observed which could be a potential creeping landslide, crack extending more than 10m generally facing SW direction, deep red clayey soil
MS2	road cut, many large roots, gravels and stone starting at about 0.5m depth
MS3	landslide mass (about a year old) revegetated by grasses and shrubs, very deep red clayey soil with many gravels and rocks at depths beyond 1.6m
MS4	kaingin area (about 1 year old) planted to cassava and banana; surrounded by numerous trees and shrubs; very deep red clayey soil more than 2m, very rough topography; about 500m from Agos river

Soil consistency or Atterberg's limit on the plasticity of the soil is directly affected by the presence of organic matter (Baver, 1956). However, many researchers found that soil plasticity not only depend on the presence of organic matter, but also on the size, quantity and type of predominant clay mineral, water content and type of exchangeable cations (Skemption, 1955; Baver, 1956 and Holt, 1967). From the results of soil analysis, plasticity index (PI) of the soil in the study area increases with increasing amount of clay particles (Table 12). This conforms to the findings of Skempton (1955) and Baver (1956) that as the percentage clay fraction increases, the PI also increases. Plasticity index soil can be used to assess the probability of a soil to swell. The observed PI indicates that the soil in Brgy. Magsaysay has low to moderate expansion potential or shrink-swell tendencies. The moderately high liquid and plastic limit values also suggests that the soil in the area requires moderate amount of moisture before it begins to act as plastic. Therefore, the probability of mass movement or landslide to occur may range from low to moderate which also supports the findings of the Mines and Geoscience Bureau (MGB) based on their published landslide hazard map.

4.3.3 Agent-based Prototype

The information on human and land agents were used to implement the agent-based model. Figure 30 shows a screenshot of the interface of an implementation of the Prototype model in Netlogo. The setup button in upper-left corner is used to initialize the simulation, the go button to its right is used to start the simulation. There are five display buttons on the left of the interface that can be clicked to display maps of elevation, landuse, slope, soil type and political boundaries. The system used the GIS extension in Netlogo to load the data from GIS maps.

In the middle of the interface are combo-boxes that are arranged like an upper diagonal part of a matrix. They represent the AHP parameters that can be set dynamically to compute for the weights of the effect of the bio-physical parameters such as rainfall, elevation, landuse, slope and soil type. Each combo-box has 17 weight preferences, integers 1 to 9 and their reciprocals. A weight preferences 1/9 means the lowest weight preference, 1 means equal weight preference and 9 is the highest weight preference. For example, the value set for rf-vs-elev or the weight preference for rainfall versus elevation is four (4), it means that the rainfall will have more weight at rank four (4) than elevation in computing for the bio-physical hazard. In turn, it has also implicitly set the weight preference for elevation versus rainfall with rank of one-fourth (¼), this is the reason why there is no need for a combo-box for elev-vs-rf. The values set for the first row is four (4) and the remaining rows are set to one (1), this means that rainfall is expected to be given higher weight compared to the other bio-physical parameters. The result of the AHP computation is shown in the monitors to the right of the AHP parameters. The monitor rf-wt has a value of 0.5, it means that rainfall will contribute to 50% of the computed bio-physical hazard the rest of the parameters will represent the remaining 50% each having 0.125 or 12.5% contribution. The AHP parameters can be tweaked depending on the user’s preference.

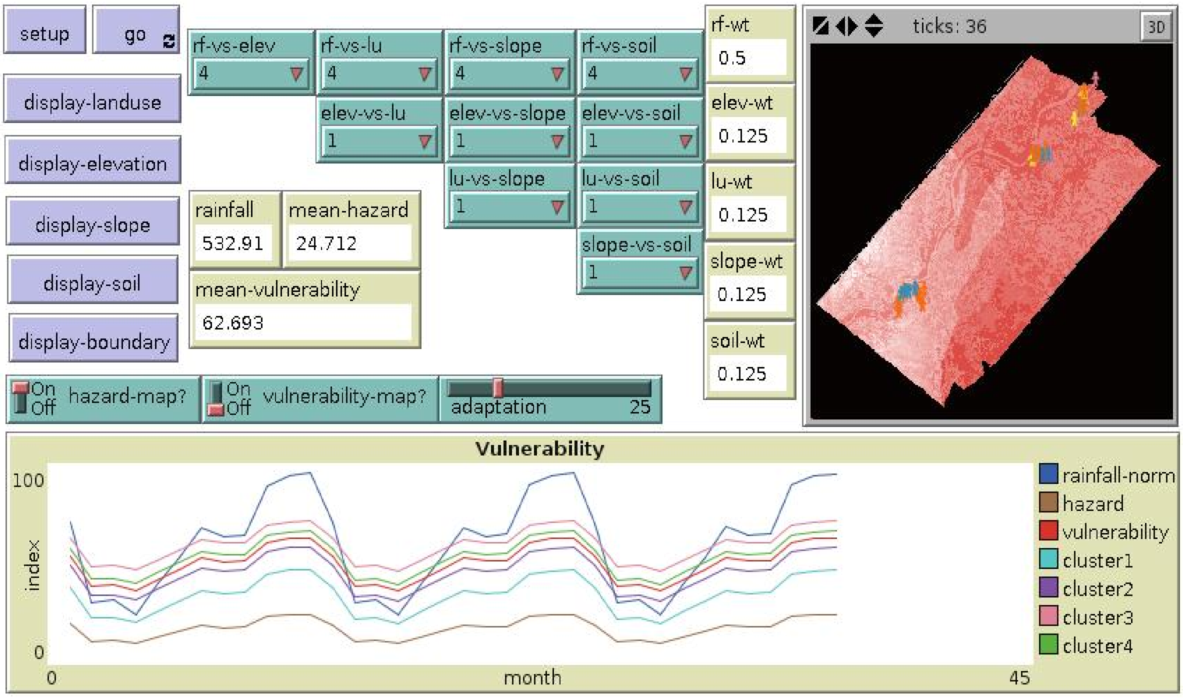


Figure 30 Netlogo interface of the agent-based model in Infanta, Quezon in the Philippines

The upper-right portion of the interface shows the visualization of the map of the case study. It can be used to display maps of bio-physical parameters, in set it displays the hazard map which is updated in real-time as the simulation goes. It also shows the location of the households respondents.

The lower portion of the interface shows a graph that plots some parameters and computed results of the simulation. The blue line represents the normalized value of rainfall between 0 to 100. The x-axis of the plot is based on the monthly rainfall data. A 71-year monthly total rainfall data was created based from IPCC data (http://worldclim.org/) for current year (normal: 1970-2000), 2020, 2050 and 2080. Given an n-sample of monthly rainfall total for the ith month $M^i = \{m_{t(1)}, m_{t(2)}, \ldots, m_{t(n)}\}$, where t(j) is the jth year where observed data for i exists, for all j from 1 to n, a simple linear regression was done on M^i. The resulting line, $m_{t(k)} = b + c * t(k)$, where b is a bias rainfall total, c is the rate of rainfall per year, m is the interpolated rainfall for month i on the t(k)th year. The same process was repeated for all M^i, where i ranges from January to December to generate the interpolation line for all months. The brown line represents the computed bio-physical hazard and the red line represents the average vulnerability of all households. The rest of the remaining lines represent the average vulnerabilities of the different clusters.

The other components of the interface are switches used to toggle the hazard and vulnerability maps, the slider for adaptation and monitors for other variables. The user may also tweak these components.

5 Conclusions

While the different methods of vulnerability, i.e. mapping, profiling and agent-based modeling, can be applied separately for vulnerability assessment, combining them provides added value in terms of focusing case studies only in hotspot areas that need urgent attention, understanding behaviors on adaptation of people with different vulnerability profiles, and developing scenarios on adaptation strategies based on actual disaster experiences. However, due to large amount of data required to apply these complementary approaches, application of these methods can be limited at the local level. Moreover, it requires an interdisciplinary research to capture the dynamic interplay between the socio-economic and biophysical systems.

Scientific findings of studies like this using ABM tools and GIS will be a vital input for decision makers in the improvement of existing policies and mitigation measures related to landslide. However, further study should be done in landslide vulnerable countries in Asia e.g. utilizing remote sensing techniques. These will require expertise and significant budget to carry-out such advance studies to achieve better assessment and correct policies for flood-related landslides in Asia Pacific Region. Nonetheless, this is an important research focus because, as the project results show, the biophysical condition affects the level of vulnerability and adaptation of an individual or a group. Most of the populations especially in rural areas highly depend on the benefits that the environment provides. Their livelihoods that being tied up with the soil. The biophysical information should be linked to the socio-economic environment, which provides the foundations for the populations' capacity to survive and sustain before and after the disaster.

6 Future Directions

- Replicate and validate the results of the study to other flood-related landslide vulnerable areas in the participating countries;
- Conduct an in-depth multi-disciplinary assessment of the geophysical, socio-economic and climate factors to landslide occurrences;
- Improve and validate with ground data the prototype ABM landslide model; and
- GIS and remote sensing inventory studies to map landslide locations.

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Appendix

Conferences/Symposia/Workshops
Southeast Asia Geography Association 2008 International Conference: Disasters, Vulnerabilities and Adaptive Strategies of Southeast Asian Communities (.pdf format is provided)
Assessment of Vulnerability Of Communities And Understanding Policy Implications Of Adaptation Responses To Flood-related Landslides in Infanta, Quezon (.pdf format is provided)

SEAMEO Innotech, Diliman, Quezon City
June 3-6, 2008

Funding sources outside the APN

Department of Science and Technology

Module: Agent Based Model Module

The agent-based model (ABM) Module as described in the table below was prepared and used in the kick-off workshop of the VALE project because it introduces the main activities that are required to develop and operationalize the agent-based framework, which is one of the important deliverables of the project. The overall objectives of the ABM Module are for the partners to understand the relationship between the conceptual and modelling framework within the context of an agent-based systems and the data they have to collect as well as the analysis required to prepare the data for the application of ABM framework in their respective case study. While the project through the ABM Module allows the development of the capacity of the partners to understand the development and application of ABM framework in real word situation, it is not intended to train them to develop and implement the codes for the ABM computer programs, which require a high level of technical computer knowledge. The ABM Module has however contributed to develop their knowledge on how survey data can be prepared, analysed and used to provide an in-depth understanding of the vulnerability and adaptation of the farmers and residents in landslide prone areas in their countries.

Description of the ABM Module for the VALE Project

Module Components	Module Objectives	Module Description	Module Materials/Equipment
Module 1: Concepts	Develop understanding for building conceptual framework for agent-based model	▪ Introduce the concept underlying the behaviour and actions of agents in a modelling framework ▪ Discuss in details the different components of an agent-based system including social, economic and biophysical ▪ Explain how the different ABM components interacts in a process-based environment ▪ Description of the relevance of developing scenarios for global environmental change in relation to the impacts on landslides	Powerpoint slides, Literature
Module 2: Applications	Provide examples of the ABM framework in a real situation	▪ Present case studies for the applications of ABM in vulnerability to droughts in the Philippines, sustainability of ecosystem due to policy changes in Belgium, diffusion of malaria vector due to climate changes	Netlogo movie files, Clusters and typologies, Brainstorm ideas, Draft VALE framework

		in France, carrying capacity of coastal areas due to sea level rise in England, and migration and abandonment impacts on rural development in Portugal ▪ Identify the data (i.e. survey, GIS maps, scenarios) required to run an agent-based model relevant to the research questions and case study areas ▪ Discuss the analysis (i.e. cluster techniques) to parameterise the data and the interpretation of these parameters for the agent-based model ▪ Explain the data requirements, framework components and case study characteristics for the VALE case study areas in the Philippines, China, Nepal and Vietnam	
Module 3: Hands-on	Provide exercises on framing and coding agent-based model	▪ Provide examples of simple Netlogo programming codes to understand how the framework relate to the agent-based modelling environment ▪ Simple exercises on how to code in Netlogo software to understand the interaction between the survey data and GIS maps in a modelling environment	Computer, Netlogo programming codes