Flood vulnerability assessment on a commune level in Vietnam

Bachelor thesis about the application of a flood vulnerability assessment to communes of the Ca river basin in Nghe An province in Vietnam

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Jelmer Veenstra (s1006177)
Bachelor Civil Engineering
University of Twente, The Netherlands

Supervisor: Dr. Marcela Brugnach
Department of Water Engineering and Management
University of Twente, The Netherlands

Supervisor: Dr. Nguyen Tien Giang
Department of Hydrology
VNU University of Science, Vietnam

UNIVERSITY OF TWENTE.

This is a Bachelor Thesis for the study of Civil Engineering at the University of Twente in Enschede, The Netherlands. The assignment was carried out from July until October 2013 at the VNU University of Science in Hanoi, Vietnam

Preface

My internship was carried out at the VNU University of Science in Hanoi, Vietnam. At this university, a research is currently carried out with three main targets, namely (1) building the scientific basis to assess the damages caused by the floods, climate change and the exploitation activities, (2) assessing the socio-economic effects, caused by flood damage in the context of climate change and the exploitation activities and (3) proposing measures to create a sustainable socio-economic development plan for Central Vietnam. My internship and this thesis are a part of this project, but will focus on the things I did myself. This research is focused on the assessment of the flood vulnerability of the Ca river basin on a commune level, but it can also be carried out in other areas.

During my stay in Vietnam I met many new people. I would like to thank my supervisor Mr. Giang for his time and help, even though he was always busy with his work. Mr. Hung, thank you for your help and clear view. By doing my research at the VNU University of Science in Hanoi I worked on a part of their project, without it I wouldn't have had the chance to go to Vietnam and to get this insight in the working methods of South-East Asia. I also had the chance to work with Vietnamese students. Ngoc and Kha, thank you for helping me with software problems. Especially I would like to thank Nhu and Da for being supportive, open to a good conversation and taking me around Hanoi.

I would also like to thank my supervisor in The Netherlands, Marcela, for her support and open and calming view on problems. I would also like to thank Hanneke and Michel for their thorough feedback on my thesis and Lisanne for supporting (and even promoting) studying abroad and especially being there for me when I needed it.

This thesis marks the end of my Bachelor studies Civil Engineering. I am looking forward to continuing in the Civil Engineering master track of the University of Twente and hope to get a chance to go abroad again.

Enjoy reading about applying flood vulnerability assessment on communes in Vietnam.

Jelmer Veenstra
Enschede, October 2013

Summary

To make it possible for governments and people in communes to respond to floods, there is a need to know to which extent a commune is vulnerable to floods.

Flood vulnerability consists of the three factors exposure, susceptibility and resilience. These factors consist of indicators which assess different characteristics of vulnerability. Flood vulnerability can be displayed with a vulnerability score for its separate factors or as a combined flood vulnerability index (FVI) to display the overall flood vulnerability of an area or commune.

For this research a set of 22 indicators is developed. The goal of the indicators is to require only data that is feasible to collect in the field with a questionnaire. All the relevant characteristics are assessed, but as a part of indicators that are feasible to assess. Also, the indicators discriminate to a reasonable degree between different levels of vulnerability.

To collect the data for twenty of these indicators, a questionnaire is developed in this research, with a question for every indicator. There were questionnaires held in Vietnam about flood vulnerability before, but there were several problems while doing this. By developing a new method of asking questions and providing answers to the people, this questionnaire tries to improve the results. Still, there are some disadvantages, vulnerability of people remains difficult to assess.

The questionnaire data of these twenty indicators is collected in the Nghe An province during the research. This data is available in excel and can be combined with the flood danger and land use data. Unfortunately, there is no weighing data collected, and there were some difficulties with collecting the data in the field.

The data for the two other indicators, flood danger and land use, is already available, but it was not yet ready to put it in an FVI equation. The land use had to be divided into groups with the same vulnerability score. The flood modelling data consisted of depth, velocity and duration data, which had to be combined into a flood danger map with different vulnerability scores.

The questionnaire, land use and flood danger data can be combined into maps of the factors of vulnerability. By giving a vulnerability score to every commune, it is clear which communes are more vulnerable than others. The factors can also be combined into the FVI and visualized with a map or a graph.

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1. Introduction

Of many occurring natural disasters, floods are the most common and the most damaging to human lives (Balica, Development and Application of Flood Vulnerability Indices for Various Spatial Scales, 2007; Kha, Anh, & Son, 2011; Wang, Li, Tang, & Zeng, 2011). To reduce the amount of flooding, or the damage it does, there are structural (e.g. dams and dikes) and non-structural measures (e.g. forecasting and educating). To be able to decide how and in which areas or communes to respond to floods with flooding measures, governments need to know how vulnerable different communes are. Therefore, there is a need for an assessment of the flood vulnerability of the communes, with a vulnerability score for every commune as a result. A flood vulnerability score, or Flood Vulnerability Index (FVI), is a representation of all the characteristics of a commune that are related to flooding. The FVI consists of indicators which each assess one or more of these characteristics. Reducing a complex concept as vulnerability into an FVI, makes vulnerability of different communes easy to interpret and to compare. This helps the government decide where to respond to flood vulnerability. The focus of this research is the vulnerability of people and the characteristics that are directly relevant. For example their commune, their preparedness and their income, but not indirectly related characteristics like long term changes in their environment.

1.1 General research area

For the people in Vietnam, floods are mostly harmful. For example, in the aquaculture it causes the nets to drain and the shrimps to get out. Also, the velocity of the water often does much damage to crops and houses. (United Nations OCHA: Reliefweb, 2011). Many areas in Vietnam are vulnerable to flooding, one of them is the Nghe An province.

The Nghe An province is the downstream part of the Ca river basin, a large international river basin that begins in Laos. The province is located in the northern central region of Vietnam and is marked red on the map in Figure 1.

The Nghe An province has 1 city, 2 towns and 17 districts, which are shown in Figure 2. The province has 437 communes, which are part of and subordinate to one of the districts. The province has a population of 2,9 million with 1.7 million in labor force. The percentage of people working in the agriculture, forestry or aquaculture sector has decreased (28,47% in 2010) and the proportion of people working in the industry sector (33,44% in 2010) and services sector (38,09% in 2010) has increased. Of the 16,490 km^2 of surface, 11.955 km^2 is forest and 2.070 km^2 is agricultural land. The landscape of the province inclines in the Southern East direction, where the Truong Son mountain range is located. The Nghe An province plays an important role in the transport system of Vietnam, with several provincial roads, the highways no. 7, 15, 48 and 46 and 124 km railway including 94 km of the North-South route from Hanoi to Ho Chi Minh City. Nghe An province also has an airport and a harbor. The province has many rivers and lakes, which account for a sufficient water supply, but also for the main power supply. (Vietnam Invest Network Corp., n.d.)

Figure 1 - Nghe An province

Figure 2 - Districts of the Nghe An province (Vietnam Invest Network Corp., n.d.)

1.2 Problem definition and research questions

There is a need to know to which extent a commune is vulnerable to floods. However, it is not clear how to put an existing theoretical vulnerability assessment into practice for communes in Vietnam. Moreover, it is not clear which vulnerability characteristics are important for these communes.

There is land use and flood modeling data available for the Nghe An province at the VNU University of Science. The local offices of each commune can also provide some other statistical data about the commune, but it is not sufficient for a complete vulnerability assessment. This is mainly because there is no data available about vulnerability characteristics as preparedness, social cohesion and awareness, which might be relevant characteristics when assessing flood vulnerability of people, but also because the availability and level of detail of data differs per commune. For this reason there is a demand to collect more flood vulnerability data, in addition to using the land use and flood modeling data.

For this research, the following questions are tried to be answered in an attempt to solve the problems:

- Question 1: What is flood vulnerability in general?
- Question 2: How is vulnerability defined and used in other studies and what does it consists of?
- Question 3: Which indicators are needed to assess the characteristics of vulnerability?
- Question 4: How to bring an existing theoretical vulnerability framework into practice to assess flood vulnerability of communes in Vietnam in a scientifically sound and also feasible way?
- Question 5: What data is already available and what data still needs to be collected?
- Question 6: How to make all the data easy to interpret and compare?

1.3 Research goals and workflow

To be able to apply the theoretical flood vulnerability to communes in Vietnam, these questions will be answered in this research. In this sub-chapter the goals and the workflow (Figure 3) of this research will be defined. The numbers of the goals are consistent with the numbers of the research questions.

Main goal: Make theoretical flood vulnerability assessment applicable for the communes in the downstream part of the Ca river basin in Nghe An province in Vietnam and bring parts of this assessment into practice. This main goal is reached with the sub-goals.

- Sub-goal 1: Get acquainted with the concept of vulnerability and its assessment methods
- Sub-goal 2: Define flood vulnerability (chapter 2)
- Sub-goal 3: Identify the indicators to assess characteristics of vulnerability (chapters 3)
- Sub-goal 4: Develop a questionnaire to collect the data that is not yet available (chapter 4)
- Sub-goal 5: collect the available land use and flood modeling data, and the not yet available data (chapter 5)
- Sub-goal 6: Make flood vulnerability of different communes easy to interpret and comparable, by combining the data. (chapter 5)

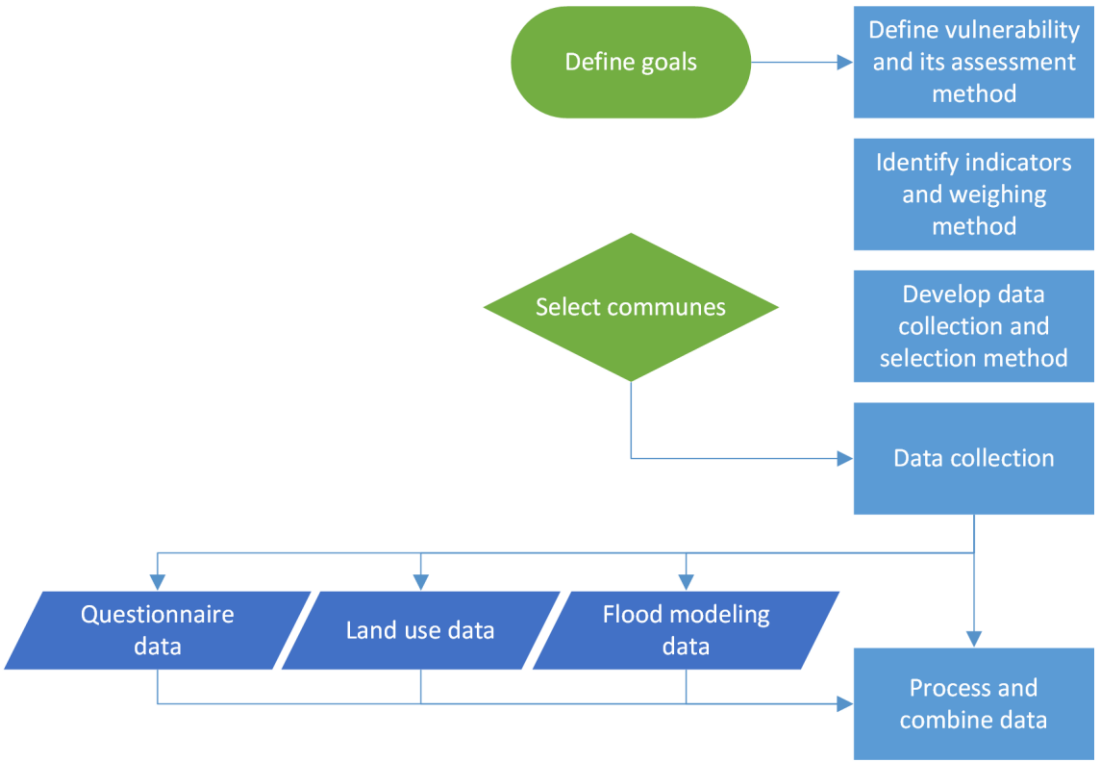

Figure 3 - Workflow

2. Conceptualizing vulnerability

In the past decennia, many definitions of flood vulnerability are published in literature. The practical working definitions of vulnerability and its factors will be defined in this chapter. These practical definitions make it possible to group indicators into the factors and thus to assess the factors separately. This separate assessment of factors makes it possible to assess which of them contributes the most to the overall vulnerability. Definitions from literature are used to create these working definitions. Furthermore, this chapter also elaborates on the calculation of the FVI.

2.1 Definition and factors of vulnerability

Vulnerability is an important concept in human-environment research, its conceptualization has developed over time and reflects contribution from a wide range of disciplines. As a result there are competing and often contradictory definitions, but with a common thought, the potential for loss or for being harmed (Hebb & Mortsch, 2007; Cutter, 1996). An elaboration of the definition of vulnerability is given in this sub-chapter.

Years ago, regularly only the biophysical exposure was mentioned in vulnerability research. An example is the definition of Terry Cannon (1990), where vulnerability is described as a measure of the degree and type of exposure to risk generated by different societies in relation to hazards.

Numerous studies found this only-physical way of thinking too simplistic. Because, for example, with communication, education and preparation, people can minimize their vulnerability, so vulnerability is not merely external to people (Cardona, 2003; Seventh Framework Programme, 2011; Chambers, 2006/1989). Studies which neglect this do not address vulnerability adequately (Preston, Yuen, & Westaway, 2011). Cutter (1996) agrees, as this study defines vulnerability as a hazard of place (in a particular geographic region) which encompasses physical risks as well as social response and action.

Hebb & Mortsch (2007) state that it is important to not only identify high risk areas, but also identify vulnerable populations and identify what makes them vulnerable. Also, they say that this non-physical part of vulnerability became more important in literature over the years. They define vulnerability as the degree of exposure and the capacity to cope and recover or adapt. In this definition, three factors of vulnerability are mentioned. One factor consists of the hazard itself and the objects in danger (e.g. exposure to hazards, the geographical location). Another factor consists of the preconditions of being harmed (e.g. the conditions that make populations more vulnerable, before the hazard occurs). The third factor encompasses the capacity to cope, adapt or recover from the hazard. Many other studies also define vulnerability as a function of exposure, susceptibility and resilience, for example Cardona (2003), Smit & Wandel (2006), Balica et al. (2012), Balica (2007), Blaikie et al. (2003/1994), IPCC (2001), Pelling (2003), Messner & Meyer (2006) and Villagrán de León (2006).

The similarity between all of these studies, is that they agree on the three factors that define vulnerability. Sometimes they use other names for factors, but the main principle is the same, flood vulnerability consists of the factors exposure, susceptibility and resilience. In this research, flood vulnerability will be defined as “the function of the factors exposure, sensitivity and resilience of a system”.

2.1.1 Exposure

According to Balica (2007), exposure is defined as the predisposition of a system to be disrupted by a flooding event due to its location in the same area of influence. Also, exposure can be understood as the values that are present at the location where floods can occur. These values can be goods, infrastructure, cultural heritage, agricultural fields or people. Exposure is the extent to which property is located in flood risk areas and is generally described as patterns and processes which estimate its intensity and duration. Messner & Meyer (2006) also define it as the various elements at risk, similar as Fuchs et al. (2011), who define it as the relationship of elements at risk to the hazard.

In all these studies, exposure contains a hazard or flood, a system or its physical elements at risk in the same area as the hazard and affection, or disruption by this hazard. Therefore, the working definition of exposure in this research is: “the predisposition of a system or its elements to be affected by a flood due to its location in the same area”.

2.1.2 Susceptibility

Susceptibility is often described as the potential of a system to be harmed by a hazardous event as flooding, caused by some level of fragility, relative social or economic weaknesses or disadvantageous conditions. (Seventh Framework Programme, 2011; Cardona, 2003; Balica, Development and Application of Flood Vulnerability Indices for Various Spatial Scales, 2007). For creating a working definition for this thesis, it is important to make a clear and easy to understand distinction with resilience, because this helps putting indicators in the right factor. The working definition of susceptibility in this research is therefore: “the preconditions of being harmed due to disadvantageous conditions, before the area floods”.

2.1.3 Resilience

Resilience is referred to as adaptive capacity or resistance, and often also used as lack of resilience (internal vulnerability, defenselessness). Resilience is the ability of a system to adjust to changes or threats, to avoid, mitigate or absorb potential damage or harm, to cope with the consequences without loss or to even take advantage of opportunities (IPCC, 2001; Pelling, 2003; Chambers, 2006/1989). Balica (2007) summarizes the different characteristics of resilience as ‘maintaining significant levels of efficiency in its components’. And Cardona (2003) summarizes the many characteristics of lack of resilience as ‘the limitations of access and mobilization of the resources’, similar to Balica (2007).

In all the studies, resembling terms like enduring, coping capacity, mitigation or absorption and avoidance are important. These things are only needed when an area is actually flooding, or in the recovery period after a flood. This fact will be used to make an easy to understand distinction with susceptibility. In this research, resilience will be defined as: “the capacity of a system to endure, adapt and mitigate, during and after floods”.

2.2 Properties and calculation of the FVI

Assessing vulnerability, and in this case, setting up an FVI is a complex task. Because when reducing complex information about characteristics into indicators, and indicators to factors and an index of just one number, there is a certain loss of information. However, reduction of complexity is necessary and is also done with the Gross National Product and the Human Development Index, both widely used and accepted. (Germanwatch, 2004)

The quantifiable factors of the FVI all have their own indicators, for example income, flood depth and quality of infrastructure. Because the vulnerability characteristics of every area are different, the vulnerability and thus the FVI also differs per commune (it differs in space). Furthermore, the FVI changes in time, because the area changes. For example by building new houses close to the river, flood measures, better education or a higher river discharge.

All FVI equations have factors for exposure to hazard, sensitivity or susceptibility of the people, and their resilience or coping capacity to the hazard.

Vulnerability is the result of the combination of the factors exposure, susceptibility and resilience:

$$FVI = Exposure\ [¤]\ Susceptibility\ [¤]\ Resilience$$

Where [¤] is the relation between the three factors.

Exposure and susceptibility both have a positive influence on vulnerability, and resilience has a negative influence on vulnerability. Resilience can have a positive effect on vulnerability if it is defined as lack of resilience. Lack of resilience will be used, because this way it is easier to process and display the data. This results in two possible equations, one with a summation and one with a product.

Villagrán de León (2006) gave the preference to the risk equation, but defined the relation between vulnerability and its factors as:

$$FVI = \frac{Exposure \times Susceptibility}{Resilience}$$

Where resilience could also be defined as 1 / lack of resilience:

$$FVI = Exposure \times Susceptibility \times Lack\ of\ resilience$$

Balica (2007) did research in developing the FVI for different levels of detail, river basin, sub-basin and urban area. She defines vulnerability as the following equation for all the levels of detail, with the same three factors:

$$FVI = Exposure + Susceptibility - Resilience$$

The Seventh Framework Programme (2011) defined the FVI as follows, with the factor resilience defined as 1 / lack of resilience:

$$FVI = Exposure + Susceptibility + lack\ of\ coping\ capacity$$

Depending on the used equation, the indicators will have to have a different format, but the result of the FVI is the same. The goal of the equation of the FVI, is to compare different communes to each other in overall vulnerability, but also in its separate factors exposure, susceptibility and resilience. Also, it should be possible to visualize these separated factors, as in Figure 4 (Birkman, 2007) and Figure 5 (Preston, Yuen, & Westaway, 2011). For these reasons, a summation relationship is more useful. Also, it is preferred if the resilience is negatively formulated, and a higher score causes the vulnerability to be higher, conform other factors. Therefore, the FVI equation used in this research is as follows:

$$FVI = Exposure + Susceptibility + Lack\ of\ Resilience$$

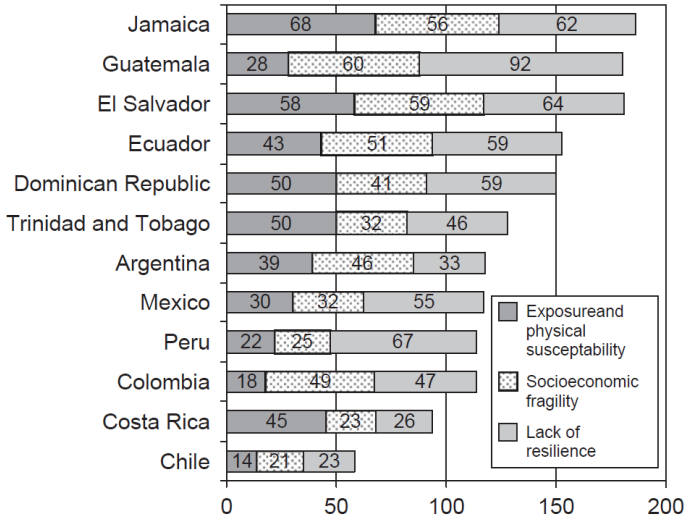

Figure 4 - Example of the separate vulnerability factors combined into overall vulnerability

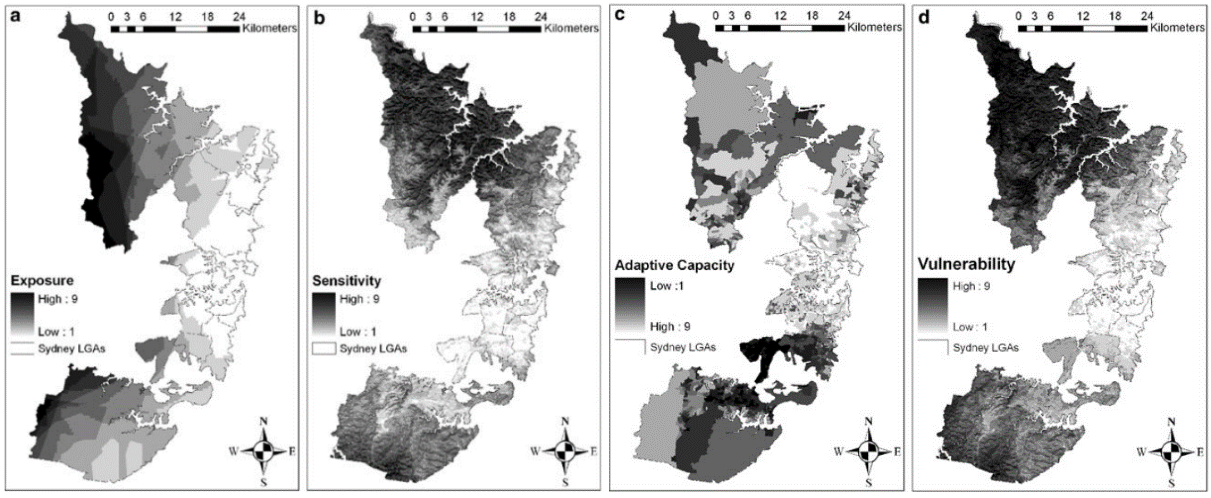

Figure 5 - Example of vulnerability (d), and its factors separated in (a), (b) and (c)

When choosing the preferred equation, the indicator format will have to follow this choice. With the chosen equation, the indicators have to be measured on a scale from 0-100% (or 0-1, like Balica et al. (2012)). Then, the indicators have to be combined into 0-100% factors by averaging their total according to their individual weight. These factors are then summed up according to the equation, each with an equal weight. The result is a 0-100% number for vulnerability, the FVI.

3. Vulnerability indicators

Numerous studies mention many different vulnerability indicators which assess many characteristics, numerous examples of studies will be given in this chapter. Not all these indicators are relevant for this research. Indicators are collected from different studies. Subsequently, a selection of relevant indicators is made, some will be discarded and some similar indicators will be merged into one indicator. The resulting set of indicators will be feasible to assess in the communes with the questionnaire approach. At the end of this chapter the weighing method of the indicators will also be described.

3.1 Method of selecting indicators

In the process of selecting indicators, a goal needs to be formulated. This goal is the basis for defining a list of characteristics (or state) of a system that need to be assessed in the research. There is a close link between the characteristic of the system and the indicator. The starting point is the formulated goal, which is needed for a set of indicators that is scientifically sound. This set of indicators is used to assess flood vulnerability characteristics. The main interest is always assessing the characteristic, but there is a close link with the indicator, because the quality of the indicator is determined by its ability to indicate the characteristic of the system. (Birkmann, 2006)

The goal of the indicators is to require only data that is feasible to collect in the field with a questionnaire. All the relevant characteristics are assessed, but as a part of indicators that are feasible to assess, so there is no data loss. Also, the indicators should discriminate to a reasonable degree between different levels of vulnerability. (UNCHS (Habitat), 2001)

3.2 Discarding irrelevant characteristics

In some other studies environmental characteristics are assessed. For example endangered species, loss of natural cover, sea water level, distance from sea, percentage of land area above or below sea level, earthquakes, tsunamis, slides (Aall & Norland, 2005). This research has its focus on vulnerability of people and directly related characteristics. Environmental characteristics do not influence people's vulnerability to flooding directly, so they will not be assessed extensively. The only environmental characteristics that are used are assessed in the flood danger modelling and are therefore part of the flood danger indicator. Sea related characteristics for example, could be relevant for the flood danger indicator, but flood danger is already modeled and the data is available.

3.3 Merging characteristics into a set of indicators

After discarding irrelevant characteristics, the remaining characteristics are merged into a set of 22 indicators displayed in Table 1. The indicators correspond to the goals set in chapter 3.1.

Other studies have their own set of indicators. Sometimes the indicators in these studies correspond with the indicators from this study, but sometimes they use only one characteristic as an indicator. Resources that use these indicators or a characteristic of an indicator are displayed in Table 1 with numbers from 1 to 9.

The numbers correspond with the selection of literature with indicator overviews that are used in this research:

1. (Balica, 2007) and (Balica, 2012)
2. (Balica, Wright, & van der Meulen, 2012)
3. (UNCHS (Habitat), 2001)
4. (Kha, Anh, & Son, 2011)
5. (Bowen & Riley, 2003)
6. (Fekete, 2009)
7. (Aall & Norland, 2005)
8. (Vári, Ferencz, & Hochrainer-Stigler, 2013)
9. (Elena-Ana, Costache, Dan, Dogaru, & Sima, 2013)

	Indicator	1.	2.	3.	4.	5.	6.	7.	8.	9.
Exposure	Population in flood prone area	x	x	x	x	x	x	x		
	Cultural heritage	x	x	x						x
	Water and sedimentation quality	x		x		x				
	Land use (map and data)	x		x	x	x				
	Flood danger (map and data)	x	x	x	x			x		
Susceptibility	Mobility/health of people	x	x	x			x	x		x
	Warning system	x		x	x					
	Awareness	x	x	x	x					x
	Spatial planning		x	x	x			x		
	Flood protection measures	x	x	x	x			x		
Lack of resilience	Shelters	x	x	x			x			
	Preparedness	x	x	x				x	x	x
	Recovery time	x	x	x					x	x
	Social security	x		x		x			x	
	Past experience	x		x					x	x
	Availability of drinking water	x		x		x				x
	Income/employment	x		x		x	x	x	x	x
	Infrastructure	x		x				x		x
	Energy Supply	x		x						
	(Tele)communication	x		x						
	Emergency service	x		x	x			x	x	
	Financial flood support	x		x	x					

Table 1 - Considered indicators on a commune level

For each indicator from the set there is a sub-chapter which describes examples of characteristics (sometimes used as indicators in other studies) that are merged into one indicator. The order of the indicators in this chapter corresponds with the set of indicators displayed in Table 1 and with the order of the questions in the questionnaire in chapter 4 and appendix A. Most of the indicators will be assessed with the questionnaire, except for 'land use' and 'flood danger', because these cannot be assessed with a questionnaire, but are very important for flood vulnerability.

3.3.1 'Population in flood prone area'

Characteristics as population number, density, growth rate (urban and rural), population in inundation area, proximity to inundation, proximity to river (Aall & Norland, 2005; Balica, Development and Application of Flood Vulnerability Indices for Various Spatial Scales, 2007) will be merged into the 'Population in flood prone area', because this is the indicator relevant for the direct vulnerability of

the people. The indicator will assess whether the people are affected by every small flood in their commune (they live in a highly flood prone area) or not even by extreme floods (they do not live in a flood prone area).

3.3.2 'Cultural heritage'

The indicator 'Cultural heritage' consists of cultural heritage, religious places like churches and pagodas and historical sites and monuments. When assessing this indicator, it is about the presence of any cultural heritage that will be irreversibly damaged by a flood and about the importance of for the people in the commune.

3.3.3 'Water and sedimentation quality'

Characteristics that request a lot of detailed data are for example, SO^2 concentration, toxic industries, pesticide/fertilizer use, wastewater, number of spills, waste treatment (Aall & Norland, 2005). But also characteristics as oil spills, fertilizer use, POP, poisoning (Bowen & Riley, 2003). They all influence the quality of the water or sediment left behind after a flood. Therefore these characteristics will be merged to the indicator 'Water and sedimentation quality'. This indicator assesses the effect of the flooding water on the area, if it will be good for the crops and safe for humans and animals, or if it is poisonous for everything in the area.

3.3.4 'Land use (map and data)'

Land use could consist of characteristics like natural reservations, forest, forest change rate, unpopulated area, uncontrolled planning zones, vegetated area, over used areas, percentage of urban/rural areas, cadaster survey (Balica, 2007). These characteristics will be merged into the indicator 'Land use (map and data)'.

The land use data is already available (Nghe An Ministry of Natural Resources and Environment, 2010), it is important for vulnerability and it is not feasible to collect it with a questionnaire. Therefore, land use characteristics will not be assessed with the questionnaire.

In previous modeling researches in the Thach Han river basin in Vietnam, the different land uses were also assessed and visualized on a map, and divided into groups with a vulnerability score from one to five. (Kha, Anh, & Son, 2011). In this research, the land use map will be analyzed and the land uses will be divided into groups that all have a vulnerability score. These scores can be combined with the questionnaire and flood danger vulnerability scores.

3.3.5 'Flood danger (map and data)'

When assessing the danger of a flood, many characteristics are important. For example, flood duration, velocity and depth, degraded area, river discharge, topography (e.g. slope), (heavy) rainfall, return periods of floods, soil subsidence, ground water level, drainage system quality (Balica, 2007), dry/wet periods, length of waterline (Aall & Norland, 2005). Because the characteristics of flooding, and its danger, is important for vulnerability, they will be merged into the indicator 'Flood danger (map and data)'.

The flood modeling data (depth, velocity and duration) of the Nghe An province is already available (Anh, 2012), it is important for vulnerability and it is not feasible to collect it with a questionnaire. Therefore, flooding characteristics will not be assessed with the questionnaire.

In previous research, the flood danger of the Thach Han river basin is assessed, in this research, flood depth, velocity and duration data from models made by the VNU University of Science (2011) was combined into a flood danger map by Kha et al. (2011), with vulnerability scores for every level of flood danger. This same method of combining flood depth, velocity and duration will be applied in this research to create a flood danger map. Every level of flood danger will get a vulnerability score, which can be combined with the questionnaire and land use vulnerability scores.

3.3.6 'Mobility/health of people'

The characteristics disabled people, handicapped people, percentage of children, percentage of >65 people as mentioned by Balica et al. (2012) and Tapsell et al. (2002), people with special needs (Aall & Norland, 2005; Balica, Development and Application of Flood Vulnerability Indices for Various Spatial Scales, 2007), percentage of (single) female households (Fekete, 2009; UNCHS (Habitat), 2001; King & MacGregor, 2000), human health and life expectancy index (Balica, 2007; UNCHS (Habitat), 2001) can be merged into to the indicator 'Mobility/health of people'. The indicator will assess the ability of people to move or flee if necessary and help the immobile people.

3.3.7 'Warning system'

The indicator 'Warning system' indicates the speed of the flood warning or forecast, but also the quality and accuracy of the details about the overall danger or the depth, velocity or duration of the upcoming flood. The communication penetration rate (Balica, 2007) is also a characteristic that is merged into the indicator.

3.3.8 'Awareness'

'Awareness' consists of the actual awareness of the people in the commune and of a training they did or things like manuals or instructions which causes the people to know what to do when the area floods.

3.3.9 'Spatial planning'

Indicates the amount of spatial planning, for example using a flood danger map when deciding which land to use for which purposes.

3.3.10 'Flood protection measures'

Indicates the need for and the provided flood protection measures by the government, for example dams, dikes, pumping stations, drainage systems, levees and reservoirs for water storage.

3.3.11 'Shelters'

Indicates the availability of shelters such as high grounds, hospitals or other places where the affected people can seek shelter during and after the flood.

3.3.12 'Preparedness'

Characteristics like awareness, having a solution, taking individual measures, or having food available in storage all indicate a level of preparedness. These characteristics are merged in this research to the indicator 'Preparedness', this merged indicator is also used by many researchers like Balica (2007), Balica et al. (2012), UNCHS (2001), Aall & Norland (2005), Vári et al. (2013), Elena-Ana et al. (2013).

3.3.13 'Recovery time'

Indicates the amount of time needed for recovery to the previous efficient state. It consists of recovery of infrastructure, communication lines, businesses, jobs and houses.

3.3.14 'Social security'

Indicates the social security and cohesion of a commune, possible help from friends and commune members, but also the level of trust in institutions and each other.

3.3.15 'Past experience'

Past experience makes it easier for people to come up with solutions to avoid or cope with floods. Education is also often seen as a vulnerability indicator. A linear connection between education level and vulnerability could be arguable. It is more plausible that practical and logical thinking, which often increases because of education, makes people less vulnerable in the same way as past experience. The characteristics education, literacy rate and past experience (Balica, 2007) are merged in the indicator 'Past experience'.

3.3.16 'Availability of drinking water'

In Vietnam, tap water can be connected to a water system in a city, but in the countryside people often use water from a river or the mountains. This tap water is almost never drinkable, so drinking water comes from bottles or by cooking the water from the tap. Drinking water is important to survive, characteristics like access to drinking water, quality of water supply, population without access to sanitation or water (Balica, 2007) are therefore merged to the indicator 'Availability of drinking water'.

3.3.17 'Income/employment'

Characteristics as unemployment, high/middle/low income, expectancy of employment (Aall & Norland, 2005; Balica, Development and Application of Flood Vulnerability Indices for Various Spatial Scales, 2007; Fekete, 2009; UNCHS (Habitat), 2001) and GDP (Gross Domestic Product) per capita, population under poverty (Balica, 2007; Bowen & Riley, 2003; Fekete, 2009), damage to business, damage to income can be merged into the indicator 'Income/employment'. This indicator assesses the possible loss of income and the time it takes to get it back.

3.3.18 'Infrastructure'

Indicates the remaining quality of the infrastructure after a flood, and the remaining possibilities to use it for supplying or evacuation.

3.3.19 'Energy supply'

Indicates the remaining quality of energy supply possibilities after floods by sources as electricity, gas, coal and wood.

3.3.20 '(Tele) communication'

Indicates the remaining quality of (Tele) communication after floods and the possibilities to contact others and get help from them.

3.3.21 'Emergency service'

Indicates the quality and speed of emergency service, help or support from institutions after floods. For example, searching for people in need, rescuing and taking (health) care of people, providing food and other help, cleaning the area.

3.3.22 'Financial flood support'

Indicates the financial flood support of the government and insurance, but also the possibility to get money in other ways, for example borrowing it from others.

3.4 Weighing indicators

Not every indicator is equally important for the flood vulnerability of an area. Many vulnerability studies use equal weights for every indicator (Kha, Anh, & Son, 2011), because the authors assume equality of the indicators or because they cannot find a better weighing method (Dwyer, Zoppou, Nielsen, Day, & Roberts, 2004).

According to Dwyer et al. (2004), there are two alternative approaches applying weights to indicators. One of the approaches uses objective methods, focusing on quantitative methods. The other approach investigates the subjective application of weights based on a researchers' local knowledge, experience and intuition. He states that this approach is qualitative and can vary according to the perspective, but should not be dismissed, because it can be appropriate in some situations. This expert method is widely used, for example by the European Commission (2011). This 'Handbook for the improvement of vulnerability assessment' also uses expert knowledge to refine their indicator list, case study relevancy, hazard relevancy and data availability. The expert method is also used for weighing indicators for a social vulnerability index (Villagrán de León, 2006).

For this reason, the knowledge from experts and local offices will be used to weigh the indicators. Their opinion about the importance of every question or indicator to a commune will be asked. They can give a number of importance for every question or every indicator, on a 1-5 scale, next to every question on the questionnaire. Relative weights of each indicator will be applied when processing the data. The questions of the questionnaire are split up in the factors exposure, susceptibility and lack of resilience. These factors are weighted equally, and the indicators can be weighted relative to every factor or to the overall vulnerability.

This expert approach is feasible to carry out in combination with a questionnaire, and fits the practical purpose. The experts can extensively review the developed scenarios, and give their expert opinion about the weight of the indicators, because they are able to see which characteristics every indicator has to assess, because they will be described in these scenarios. Unfortunately, there is no weighing data collected when the questionnaire was carried out in the communes, so this data is not available. Equal weights will be assumed.

4. Practical data collection method, questionnaire

This chapter elaborates about the reason of using a questionnaire, problems with different questionnaires uses at the VNU University of Science and a description of the questionnaire used in this research.

4.1 Questionnaire approach for commune level

When assessing vulnerability there is data required about many different characteristics, but a complete database with data about each of these characteristics is rarely available. If it would be, selecting and weighing of indicators could be done with a statistical analysis of available data, for example by testing for multicollinearity among indicators and for a dominant indicator for a characteristic of the commune (Cutter, Boruff, & Shirley, 2003). This statistical analysis is also useful to analyze the relevancy of different characteristics according to their analyzed weight.

Often there is a problem with collecting all the detailed information of all the individual characteristics, which could be another problem. In the communes in Vietnam, there was a selection of detailed information available at the local offices of the communes. For example about the age of people, the amount of cattle, damage with particular floods etc. Still, some important variables are not available in these statistical databases, for example preparedness to the flood, social relations, and trust. For this reason, an approach based on questionnaire surveys is used, instead of using statistical data. (Vári, Ferencz, & Hochrainer-Stigler, 2013)

This questionnaire is used to collect the data for the vulnerability indicators. The flood modeling and land use data is already available. Because vulnerability has many characteristics, many indicators can be assessed. If a questionnaire is too long, it is not feasible to use. Therefore there is a selection method needed for the indicators. This selection is done by discarding and merging indicators in chapter 3. The method is based on the fact that a questionnaire is used. The actual questionnaire is developed based on this set of indicators. The questionnaire will be used to collect data for all the indicators, except for land use and flood danger.

4.2 Problems with previously used questionnaire methods

When using the questionnaire method, there is a limit of questions, because more questions will cause people to refuse to fill it in. Vulnerability has many characteristics to assess and that conflicts with this limit of questions.

It is often difficult to assess all the possible characteristics of vulnerability, because some of them demand highly detailed information. This information is often not available on for example a commune level. Also, it is hard to determine their individual importance and their relation with other characteristics.

For example, the age of people, it is easy to ask this question in a questionnaire. But it is difficult to determine which age group is more vulnerable and also which ages are grouped together (e.g. group 0-10 or 0-15 year olds together and give them the same vulnerability score). Also, this interacts with other characteristics of vulnerability to define the mobility of people, the vulnerability characteristic

which you actually want to assess. An elderly person may not be vulnerable because of age, but only if this is combined with living alone, having a disability and not having a car. This statement is also supported by Dwyer et al. (2004). Mobility is also an effect of many characteristics, of which some may only be relevant in one or few communes. When forgetting or not assessing some of these characteristics, this results in a wrong vulnerability assessment and a wrong FVI. Also, it is difficult to decide how important every characteristic is and how they interact.

Another example can be found in the coping options of the people. In previous questionnaires, questions about this topic always had options. Do you have a boat to flee, do you wait on your roof, or do you have food in storage. In different situations, different options make you less vulnerable. If the surrounding area is flooded, but a house is still habitable, a food storage would make people the least vulnerable. If a house is completely under water or damaged because of the velocity of the flood, a boat would be make people the least vulnerable, and food preparation is not important anymore, because the supplies are destroyed.

A third example is the form of the data that is created with some previously used questions. Because every option needs to be assessed, many options are given with questions about for example the way the government helps the communes. There is always a need to put in a blank answer, to let people fill in for example all the supportive things the government does. It is hard to assess all these different answers and to decide which one is more important.

There is a need to solve the problems in these three examples, in order to assess vulnerability in a scientific way. The next two sub-chapters will propose a solution to these problems with questionnaires. The questionnaire will be developed with these methods.

4.3 Method, part 1: Merging indicators

Many characteristics are merged into the set of indicators chapter 3. Merged indicators make it possible to asses a lot of characteristics, with little data loss and with a moderate number of questions. This way, it remains feasible to assess all the relevant characteristics with a questionnaire. These indicators are assessed with extreme scenarios in the questionnaire. These scenarios make it possible to assess the relevant characteristics of flood vulnerability in a feasible way, but without the problems and inaccuracies that occurred with the previously used questionnaire methods.

A merged indicator can only be measured qualitatively and subjectively, but it resolves problems with combining indicators that assess only one characteristic, as described in chapter 4.2. Merging the indicators which assess similar characteristics resolves this problems and the merged indicator can also be easily assessed in every commune. Merged indicators which would solve the first two of the three example problems would be ‘mobility’ and ‘coping capacity’.

4.4 Method, part 2: Extreme scenarios

Merged indicators have to be able to contain a large amount of data of all the characteristics of flood vulnerability which they must assess. That is where the second part of the method comes in, the extreme scenarios.

Every (merged) indicator is answered by one question. Instead of using methods like, ranking, rating or regular scaling (with extreme terms, feelings or words) of possible answers, a semantic differential with a scale from 1-5 is used. The extremes of these scale consist of a scenario, one which describes low vulnerability and results in a lower FVI and one which describes high vulnerability and results in a higher FVI. This extreme scenario method is also used in cultural research, such as Chirkov et al. (2005). Furthermore, according to Peng & Nisbett (1997) it is considered to be the most criterion valid method for assessing values among the methods ranking, rating and scaling. The scenario method can reduce noise, because the interpretation of meaning of value terms and problems as relativity of social comparison based judgments and deprivation-based preferences (Peng & Nisbett, 1997). Also, with regular scaling, people interpret the used term by using their last relevant memory, instead of thinking about the extensive scenario the researcher had in mind when he made the questionnaire. An important condition for the validity of the data and the benefits of the method to apply, it is important to develop extensive and detailed scenarios.

With the chosen semantic differential approach with the two extremes, the merged indicators will extensively assess all the relevant characteristics and the data loss is minimal.

4.5 Questionnaire questions

The set of indicators developed in chapter 3, with their corresponding numbers (I#) and one question for every indicator is displayed in Table 2. These questions are developed according to the method described in this chapter. The entire questionnaire, including the extreme scenario answers and weighing column, is presented appendix A.

	Exposure	
I#	**Indicator**	**Question in questionnaire**
1	Population in flood prone area	Does your family live in a flood prone area?
2	Cultural heritage	Is there cultural heritage that could be damaged by floods?
3	Water and sedimentation quality	What is the effect of the flood water quality and its sediment for the area?
4	Land use (map and data)	-
5	Flood danger (map and data)	-

	Susceptibility	
I#	**Indicator**	**Question in questionnaire**
6	Mobility/health of people	Are you and your family able to evacuate, in case of a flood?
7	Warning system	Do you get a flood warning/forecast?
8	Awareness	Are you aware of the risk of floods?
9	Spatial planning	If you would use or buy new land, do you use flood maps for spatial planning?
10	Flood protection measures	Does the district/commune government provide protection measures?

	Lack of resilience	
I#	**Indicator**	**Question in questionnaire**
11	Shelters	Are there any place where you can seek shelter during and after flood?
12	Preparedness	Are you prepared for floods?
13	Recovery time	Are you able to recover to the previous efficient state?
14	Social security	Does your family get help from your friends and commune-members in case of a flood?
15	Past experience	Are you experienced in flooding of your commune?
16	Availability of drinking water	Is there enough drinking water available after a flood?
17	Income/employment/business	Would you lose your income/job/business in case of a severe flood?
18	Infrastructure	Is it possible to use the remaining infrastructure after the flood?
19	Energy Supply	Is energy available after flood?
20	(Tele)communication	Are you able to connect or get help from people from other communes thanks to telecommunication?
21	Emergency service	Do you get any help from the government or other institutions after the flood?
22	Financial flood support	Do you get financial flood support?

Table 2 - Developed questions for questionnaire

5. Results and analysis

In this chapter the results of the research will be displayed, it contains data that is collected in order to assess the characteristics of vulnerability with help of the set of indicators.

First, the questionnaire research area and the average questionnaire data is displayed. Next, the data of the vulnerability factors is displayed separately and the factor exposure is also split up in questionnaire, land use and flood modeling data. In further research, this data can be combined into overall vulnerability maps and graphs like Figure 4 and Figure 5 in chapter 2. Because not all data is accurate and because there is no weighing data available, this is not yet done in this research.

5.1 Adjusted questionnaire research area

The area selection for the questionnaire was done by the project team. Because this was only a test run for the questionnaire, it was only carried out in a small selection of the communes. The initial idea was to select twenty communes and ask twenty households in each commune to fill in the questionnaire. In practice, some adjustments were made. For example, the questionnaire is eventually carried out in 23 of the 166 communes in six districts in the south of the Nghe An Province, in the downstream part of the Ca river basin. Also, there is a varying number of questionnaires per commune, as shown in Table 3. Almost all the selected communes are located next to the main branch of the Ca river, this is visible in Figure 6 on the next page.

Commune	District	Number of questionnaires
Lưu Sơn	Đô Lương	28
Đà Sơn	Đô Lương	20
Trung Sơn	Đô Lương	16
Thuận Sơn	Đô Lương	5
Thanh Hưng	Thanh Chương	11
Thanh Văn	Thanh Chương	6
Đồng Văn	Thanh Chương	9
TT Nam Đàn	Nam Đàn	20
Nam Thượng	Nam Đàn	19
Nam Tân	Nam Đàn	21
Nam Lộc	Nam Đàn	21
Khánh Sơn	Nam Đàn	20
Nam Kim	Nam Đàn	20
Nam Trung	Nam Đàn	20
Nam Cường	Nam Đàn	22
Hưng Long	Hưng Nguyên	20
Hưng Lam	Hưng Nguyên	17+19
Hưng Phú	Hưng Nguyên	34
Hưng Châu	Hưng Nguyên	23
Hưng Nhân	Hưng Nguyên	28
Bến Thủy	Vinh	22
Hưng Hòa	Vinh	21
Phúc Thọ	Nghị Lộc	24
23	6	466

Table 3 - Surveyed communes in Nghe An province

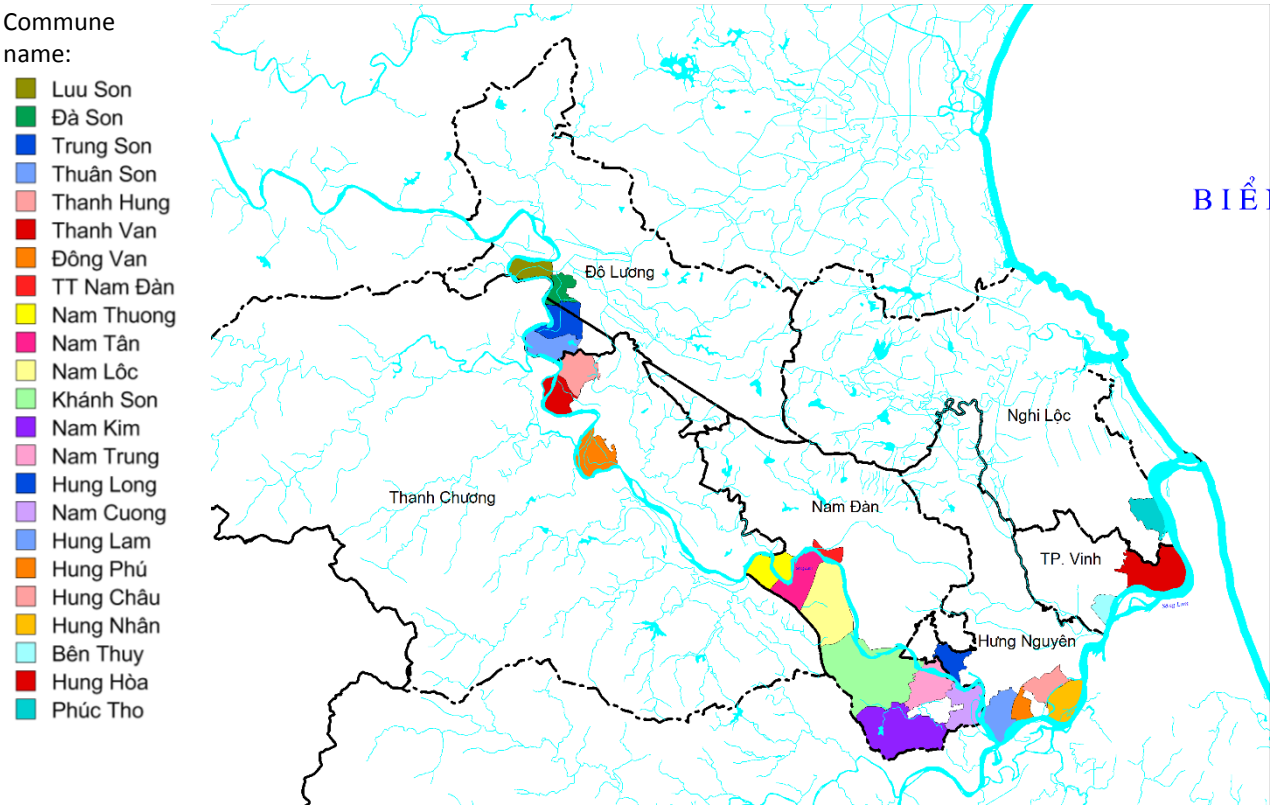

Figure 6 - The 23 communes (in six districts) in the south of the Nghe An province where the questionnaire was carried out

5.2 General questionnaire data

The data collected with the questionnaire is displayed in Table 4 on the next page, this is an overview the average scores of all the answers per commune, made with Microsoft Excel. The color codes ranges from 1 (white) to 5 (dark red), corresponding with the 1-5 answering scale provided in the questionnaire. These scores are also displayed on a map in Figure 7 on the next page. The scale of the questionnaire data is directly convertible to a vulnerability score.

The average scores for all the communes in the questionnaire dataset are similar. They have a range from 2,18 to 2,93 and a standard deviation of only 0,2. The results are quite similar, because all the communes are next to the river. Also, there is no weighing data collected with the questionnaire, so all the indicators had to be weighted equally.

	Exposure			Susceptibility					Resilience															
Commune	**I1**	**I2**	**I3**	**I6**	**I7**	**I8**	**I9**	**I10**	**I11**	**I12**	**I13**	**I14**	**I15**	**I16**	**I17**	**I18**	**I19**	**I20**	**I21**	**I23**	min	max	avg	stdev
Lưu Sơn	3,18	2,07	2,89	2,61	2,50	2,41	2,82	2,68	2,57	2,64	2,57	2,75	2,89	2,68	3,07	2,36	2,61	2,43	3,00	3,39	2,07	3,39	2,71	0,31
Đà Sơn	3,90	2,35	3,10	2,50	2,70	2,05	2,40	2,40	2,60	2,80	2,85	2,45	2,45	2,00	2,90	2,40	2,40	2,25	2,90	3,20	2,00	3,90	2,63	0,44
Trung Sơn	3,81	2,67	3,13	1,93	2,34	1,77	2,29	2,67	2,53	1,94	2,88	2,06	1,69	2,81	3,33	3,19	2,81	3,00	2,81	3,88	1,69	3,88	2,68	0,62
Thuận Sơn	3,00	2,60	3,00	2,80	3,20	3,00	2,80	2,80	3,40	3,80	2,20	2,60	2,60	3,20	3,20	2,80	2,80	3,20	2,60	3,00	2,20	3,80	2,93	0,35
Thanh Hưng	2,73	2,00	2,82	3,10	2,50	2,55	2,80	2,27	3,00	2,55	2,64	2,55	3,18	1,91	3,55	2,27	1,91	2,27	2,45	2,45	1,91	3,55	2,57	0,42
Thanh Văn	2,83	2,17	1,67	1,33	2,33	1,83	2,67	1,83	2,00	3,33	2,00	1,67	2,17	1,83	2,50	2,00	2,00	1,83	2,83	2,67	1,33	3,33	2,18	0,49
Đồng Văn	3,33	2,44	3,11	2,22	2,22	2,33	2,22	2,11	2,44	2,89	2,44	2,00	2,33	2,00	3,00	2,89	2,44	2,78	2,11	2,78	2,00	3,33	2,51	0,39
TT.Nam Đàn	1,95	1,30	2,25	2,65	2,23	1,85	2,20	2,65	2,60	2,65	1,80	2,55	3,05	1,85	2,35	2,05	1,79	1,95	2,75	3,90	1,30	3,90	2,32	0,57
Nam Thượng	3,21	2,16	2,79	1,79	1,47	1,58	2,68	2,63	2,21	2,21	2,42	1,47	1,79	1,53	3,37	2,42	1,42	2,79	2,00	2,53	1,42	3,37	2,22	0,59
Nam Tân	3,00	2,14	2,57	1,67	1,83	2,05	2,19	1,86	2,95	2,24	2,62	2,24	2,05	1,81	3,67	2,33	2,38	2,19	2,90	3,00	1,67	3,67	2,38	0,51
Nam Lộc	3,43	2,05	2,52	2,00	2,24	1,86	2,48	2,76	2,71	3,62	3,05	2,43	2,19	2,33	3,38	2,29	2,05	2,00	2,76	2,81	1,86	3,62	2,55	0,51
Khánh Sơn	3,70	2,35	3,05	1,75	2,25	2,15	2,35	2,70	2,25	2,30	2,80	2,45	2,05	1,90	3,70	2,90	2,60	2,30	2,75	3,30	1,75	3,70	2,58	0,54
Nam Kim	3,10	2,00	2,25	1,85	2,10	2,45	2,05	2,80	2,70	2,00	2,40	2,20	2,85	2,55	3,25	2,35	2,60	2,20	3,05	3,40	1,85	3,40	2,51	0,45
Nam Trung	4,30	3,45	3,40	2,00	2,38	2,00	2,40	3,00	2,75	2,25	2,80	2,05	2,20	2,80	3,50	2,75	3,20	3,20	3,00	3,15	2,00	4,30	2,83	0,60
Nam Cường	4,59	2,36	2,77	1,95	1,82	1,73	2,45	3,05	2,86	2,36	3,64	2,55	1,95	3,00	4,18	3,18	2,95	2,45	2,36	3,27	1,73	4,59	2,78	0,75
Hưng Long	4,70	1,70	2,60	2,45	1,90	1,60	2,15	3,05	2,70	2,05	2,80	2,25	1,50	2,05	3,55	2,35	2,45	2,05	2,70	3,35	1,50	4,70	2,50	0,75
Hưng Lam	3,69	2,34	2,58	2,44	2,54	2,22	2,47	2,50	3,14	2,34	3,28	2,50	2,31	2,50	3,39	3,28	3,00	2,64	2,92	3,25	2,22	3,69	2,77	0,43
Hưng Phú	4,41	1,70	2,65	2,09	1,81	2,06	2,09	3,24	2,26	2,70	3,30	2,09	1,88	2,18	3,64	2,53	2,35	2,03	2,24	2,44	1,70	4,41	2,48	0,68
Hưng Châu	3,74	2,13	2,52	2,74	1,83	2,13	2,52	2,30	3,09	3,39	2,87	3,30	2,22	1,70	3,17	2,48	2,35	1,87	3,00	3,57	1,70	3,74	2,65	0,60
Hưng Nhân	4,36	3,46	3,43	2,41	2,73	2,57	2,39	2,29	2,07	2,75	3,78	2,25	2,75	2,96	4,07	2,82	3,21	3,25	2,21	2,75	2,07	4,36	2,93	0,64
Bến Thủy	3,59	1,91	2,73	2,41	2,39	2,00	2,36	3,32	2,50	2,36	1,95	2,36	2,55	1,95	2,18	2,00	1,73	1,86	3,05	3,73	1,73	3,73	2,45	0,58
Hưng Hòa	4,19	2,33	2,81	2,19	2,21	2,24	2,52	2,33	2,52	2,71	2,76	2,38	2,43	1,86	3,33	2,62	2,95	2,38	2,57	3,33	1,86	4,19	2,63	0,52
Phúc Thọ	3,33	1,88	2,92	2,54	2,08	2,13	2,42	3,04	2,67	2,50	2,08	2,54	2,63	2,04	3,13	2,38	2,29	1,75	2,63	3,08	1,75	3,33	2,50	0,44
min	1,95	1,30	1,67	1,33	1,47	1,58	2,05	1,83	2,00	1,94	1,80	1,47	1,50	1,53	2,18	2,00	1,42	1,75	2,00	2,44	1,30	3,33	2,18	0,31
max	4,70	3,46	3,43	3,10	3,20	3,00	2,82	3,32	3,40	3,80	3,78	3,30	3,18	3,20	4,18	3,28	3,21	3,25	3,05	3,90	2,22	4,70	2,93	0,45
avg	3,57	2,24	2,76	2,24	2,24	2,11	2,42	2,62	2,63	2,63	2,69	2,33	2,33	2,24	3,28	2,55	2,45	2,38	2,68	3,14	1,80	3,82	2,58	0,38
stdev	0,67	0,49	0,39	0,42	0,38	0,34	0,22	0,40	0,35	0,50	0,51	0,37	0,44	0,48	0,48	0,37	0,48	0,47	0,31	0,42	0,25	0,42	0,20	

Table 4 - First analysis of the questionnaire data, with average scores for every commune

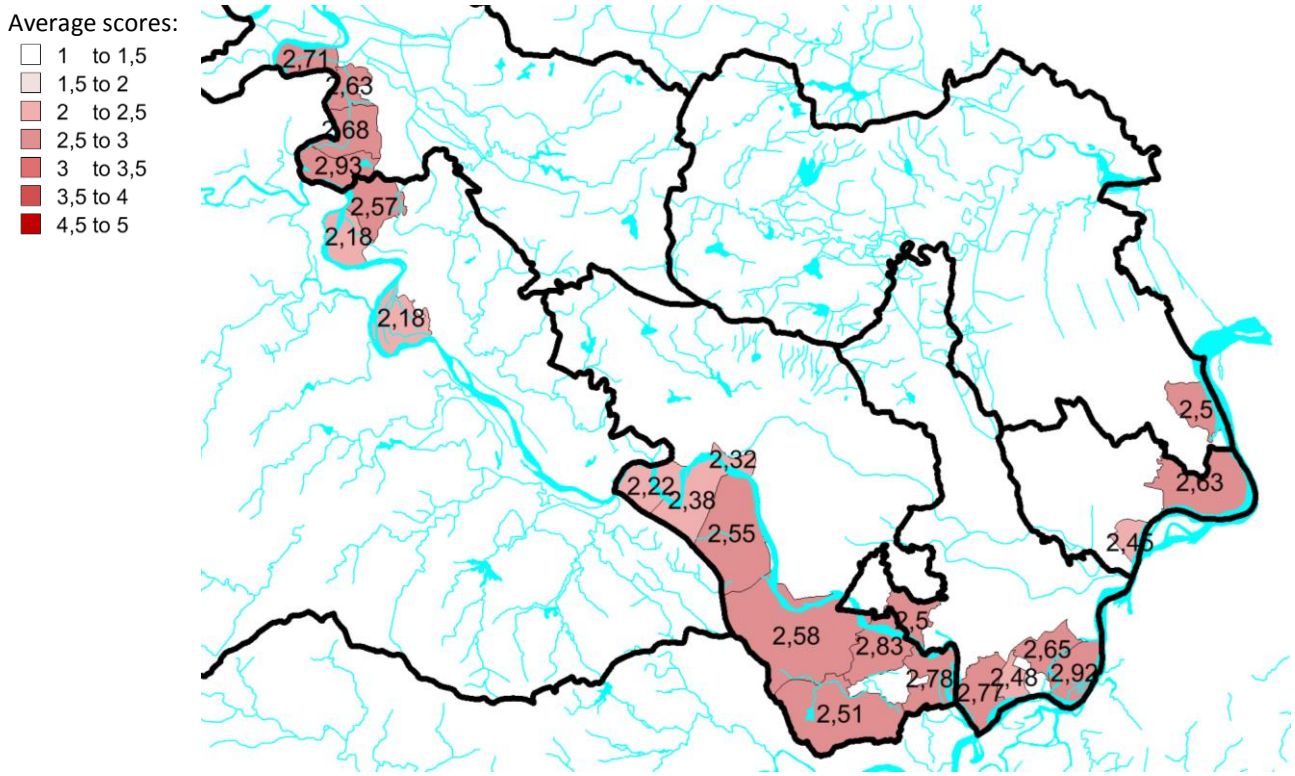

Figure 7 - Original average questionnaire scores for every commune

5.3 Exposure

The factor exposure consists of questionnaire, land use and flood modeling data. The exposure vulnerability scores from the questionnaire must be combined with the vulnerability scores of land use (I4) and flood danger (I5), to give a good indication of the exposure factor of vulnerability of the communes. This can be done by combining the data in Mapinfo when more accurate data and weighing data is available. In this research, only the separate indicators are displayed, because of the unavailability of weighing data and accurate flood modelling data.

5.3.1 Questionnaire data

The excel questionnaire data of every factor is presented in appendix C, the average of the factor exposure is displayed in Figure 8.

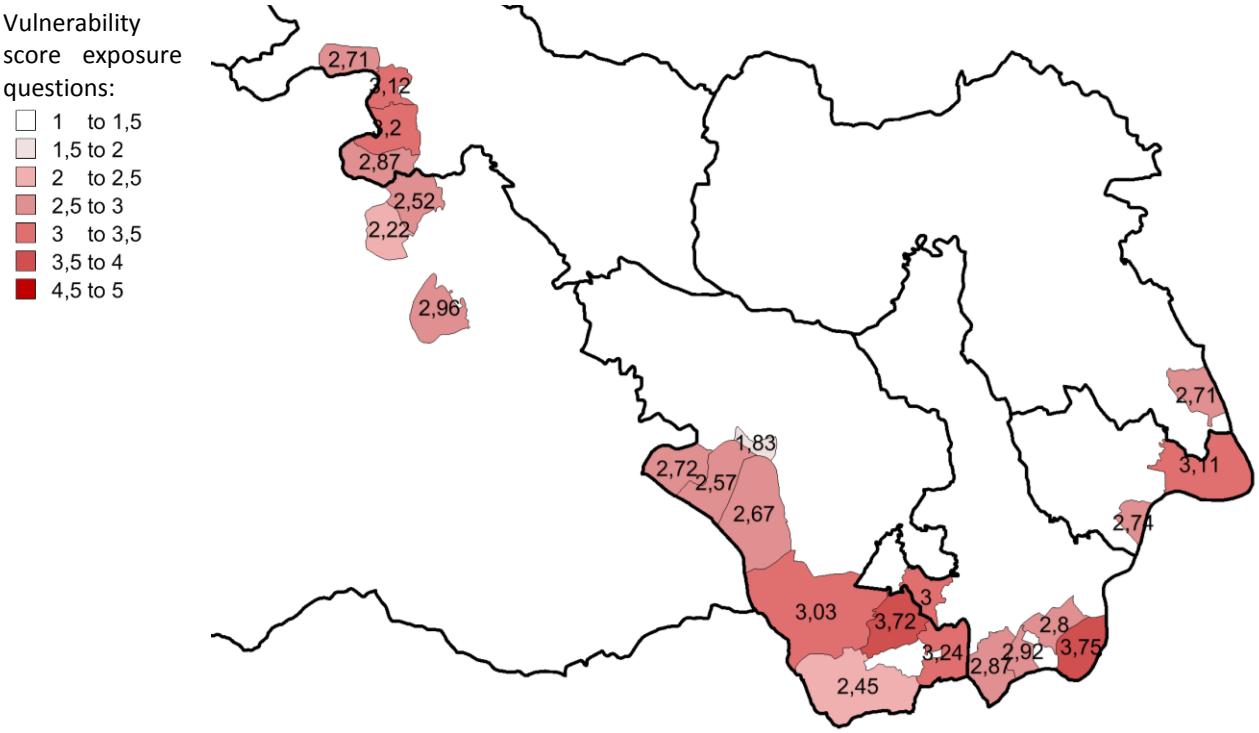

Figure 8 - Average exposure questionnaire scores for every commune

5.3.2 Land use data

To assess the vulnerability of land use, there must be a vulnerability score for each land use. There were approximately fifty different land uses in the original land use data. It is difficult to rank land uses on such a large scale. Therefore, the land uses must be divided in groups. These groups will get a vulnerability score, based on previous research studies.

The most recent available land use is obtained by the VNU University of Science from the government of Nghe An province (Nghe An Ministry of Natural Resources and Environment, 2010). The database is a Microstation file, converted to MapInfo. It was not possible to use the original Microstation data, partly because of an insufficient experience level with this software at the VNU University of Science, but mostly because of the need to combine the land use data with flood danger data, which is only available in MapInfo. Also, the data needs to be combined with the questionnaire data, which was also

imported in MapInfo. In MapInfo there is no distinction possible between some of the approximately sixty different land uses. In the original file, structures and colors were used, but with the conversion to MapInfo the structures disappear. The result is that some of the land uses are grouped together.

To give a vulnerability score to each land use, the approximately fifty land uses in the land use database must be grouped into groups of equally vulnerable land uses. Fortunately, the grouping done by MapInfo is no problem, because these land uses fit together in a logical group. This 'Public/cultural' residual group is not ideal, but it is a reasonable solution. An overview of the original land use data, its colors and the legend, together with the eventual land use groups and which land uses are in which groups, is displayed in appendix B. There are eleven of these land use groups and they are displayed in Figure 9, with ten vulnerability scores.

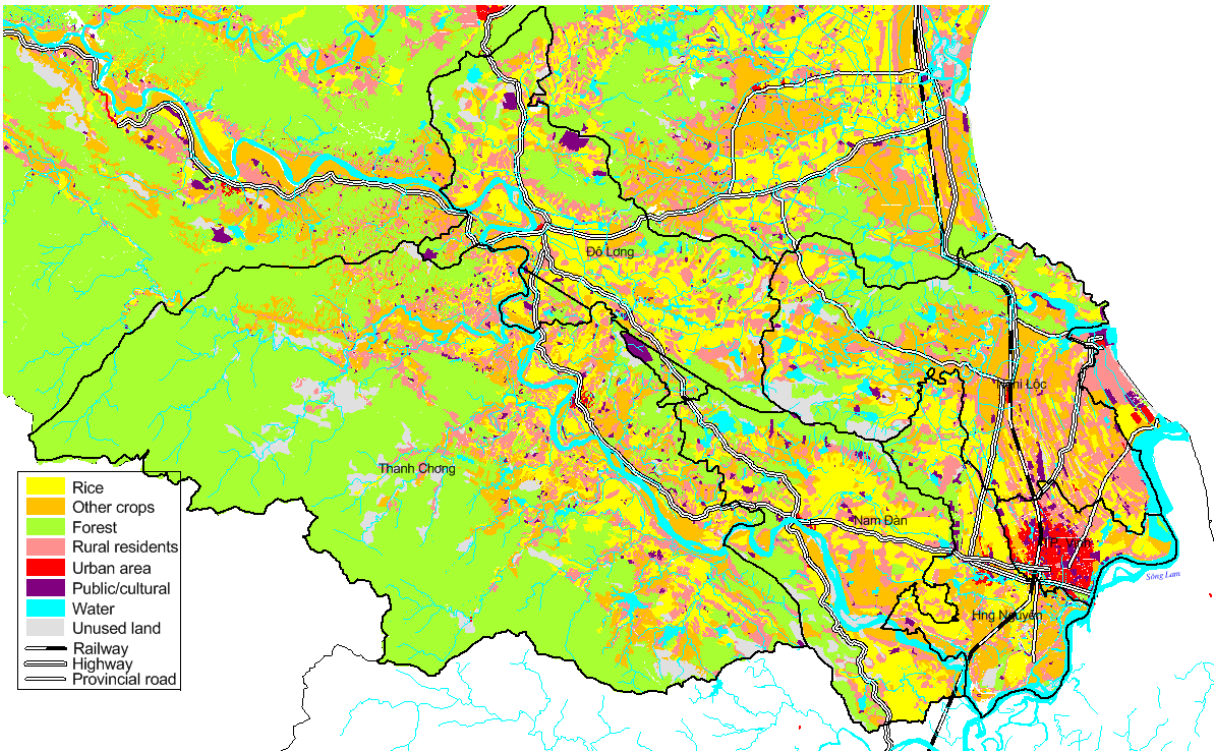

Figure 9 - Land use in the southern part of the Nghe An province

The grouping of land use in this way can be used for all the land use data available in Vietnam, if it has the same subdivision of land uses. If not, this grouping can be used for the entire Nghe An province, and not only for this Southern part. Therefore, this grouping method is also useful for other research.

To decide which land use groups are more vulnerable than others, a previous study about flood vulnerability where land uses were grouped according to damage curves and actual recorded damage (Chen, 2007). One of the results of this study was the order of vulnerability of different land uses, by their average damage. This result, combined with the land use groups from this internship, is displayed in the first and second column Table 5. The land use group 'Public/cultural' is not used by Chen (2007), but the group was needed for the land use data of the Nghe An province, because it was more detailed than the land use data Chen (2007) used and there were many land uses which could not be grouped in the other land use groups.

In previous research, Kha (2011) argued that the land use group was the most important of all, because in his research, it contained both hospitals, communication networks and infrastructure. The rest of the group consisted of land uses that were less important than many others, so it was unusual to give the group a higher score than for example urban land use. Also, in this research, the infrastructure is divided in separate groups with already a high vulnerability score. Hospitals are still a part of the group, but this is only a small part of it. The rest of the group consists of diverse land uses like industry, power plants, mining, defense, graveyards, waste treatment, sports and education. The full content of the land use groups is displayed in appendix B. This diversity makes it difficult to decide on the vulnerability score of the Public/cultural land use group. Because of the many unimportant land uses within the group, it is rated to be less important as rural areas.

The vulnerability score for every land use is displayed in the last column Table 5. The land use map is converted to a vulnerability map by adding the vulnerability scores in Mapinfo and displaying the information on a colored scale, this result is displayed in Figure 10 on the next page.

Land use	Avg damage USD per m^2	Vulnerability score
Railways	12,2	10
Urban	5,53	9
Highway	5,05	8
Rural	2,67	7
Public/cultural	-	6
Provincial roads	1,05	5
Forest	0,84	4
Rice	0,0403	3
Other crops	0,0053	2
Water	-	1
Unused land	-	1

Table 5 - Damage per land use according to Chen (2007), combined with the 11 land use groups

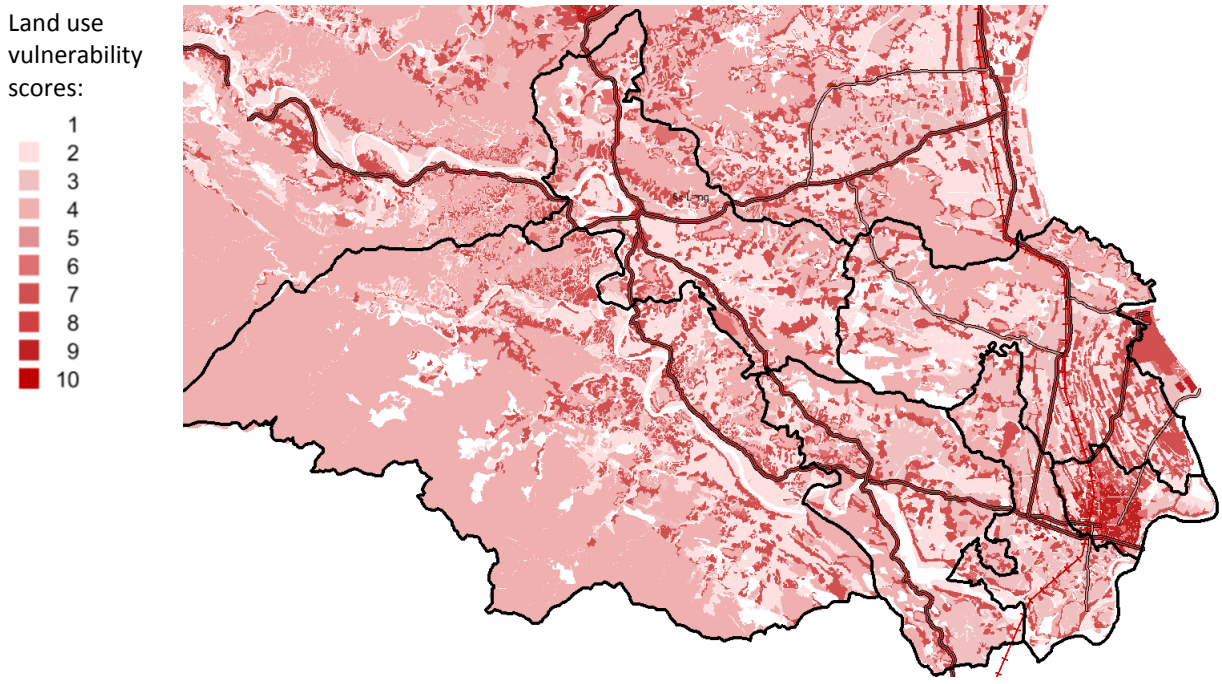

Figure 10 - Vulnerability of the land use in the six districts

5.3.3 Flood modeling data

Flood danger consists of flood depth, velocity and duration. This flood modeling data comes from inundation models made with the program Mike Flood in another research (Anh, 2012) and is available at the VNU University of Science in MapInfo files.

The flood depth modeling has eight intensities, the velocity and the duration have ten intensities (displayed in Table 6). The vulnerability score is added in Mapinfo to be able to calculate the flood danger, the weighted average of flood depth, velocity and duration. The flood modeling polygon maps are converted to grid maps with a grid size of 50x50m. The weighted average is calculated with the Vertical Mapper extension according to the following formula:

$$Flood\ danger = \frac{\frac{1}{8}*depth + \frac{1}{10}*velocity + \frac{1}{10}*duration}{3} * 5$$

Depth	Vscore	Velocity	Vscore	Duration	Vscore
< 0,2m	1	<0,1	1	0,1 - 0,5	1
0,2 - 0,5m	2	0,1 - 0,2	2	0,5 - 1	2
0,5 - 1m	3	0,2 - 0,3	3	1 - 2	3
1 -2m	4	0,3 - 0,4	4	2 - 3	4
2 - 3m	5	0,4 - 0,5	5	3 - 4	5
3 - 4m	6	0,5 - 0,6	6	4 - 5	6
4 - 5m	7	0,6 - 1	7	5 - 7	7
>5m	8	1 - 1,5	8	7 - 9	8
		1,5 - 2	9	9 - 13	9
		>2	10	>13	10

Table 6 - Depth, velocity and duration in the flood modeling data

The result of the Mapinfo calculation of the flood danger from the flood depth, velocity and duration data in Mapinfo is displayed in Figure 11 on the next page.

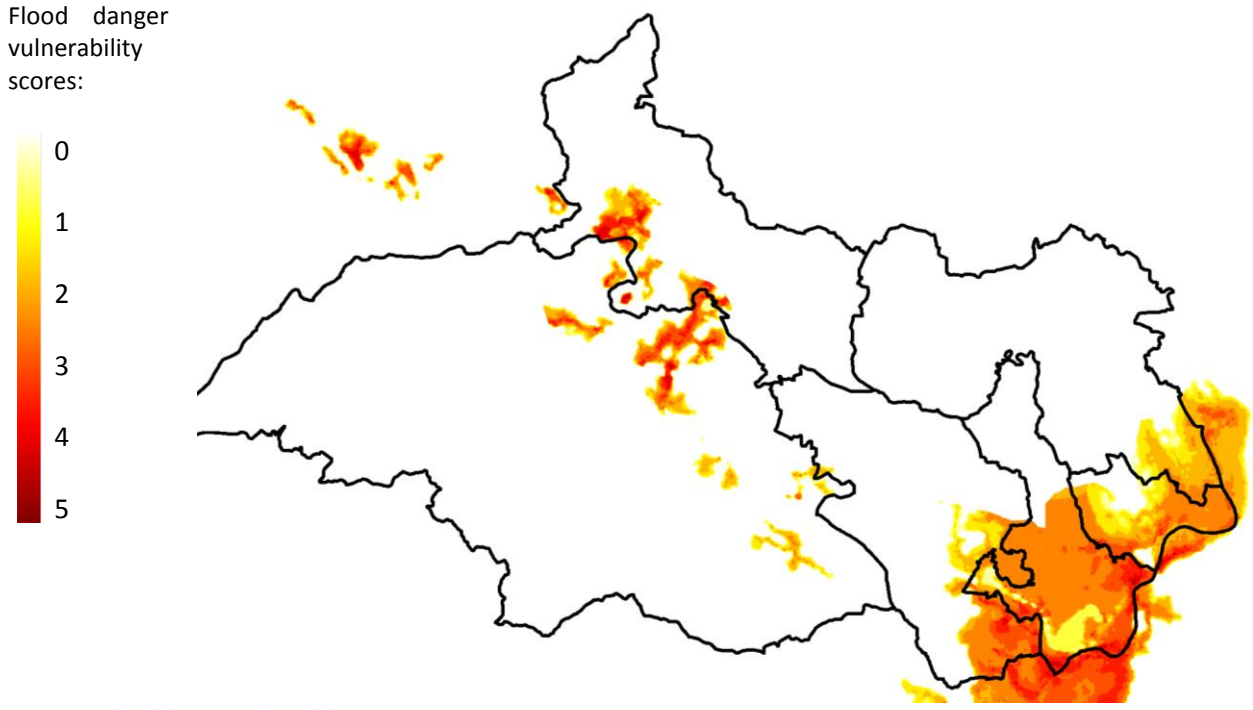

Figure 11 - Flood danger vulnerability scores

5.4 Susceptibility

The excel questionnaire data of every factor is presented in appendix C, the average of the factor exposure is displayed in Figure 12.

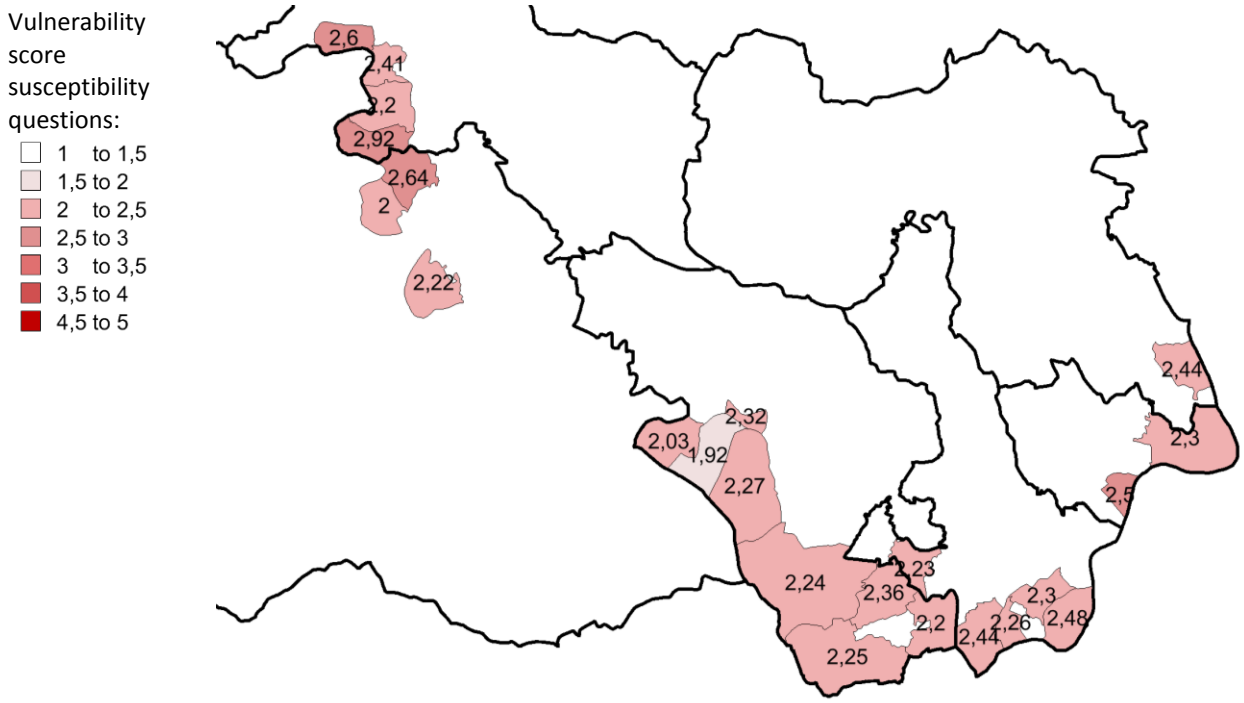

Figure 12 - Average susceptibility questionnaire scores for every commune

5.5 Lack of resilience

The excel questionnaire data of every factor is presented in appendix C, the average of the factor exposure is displayed in Figure 13.

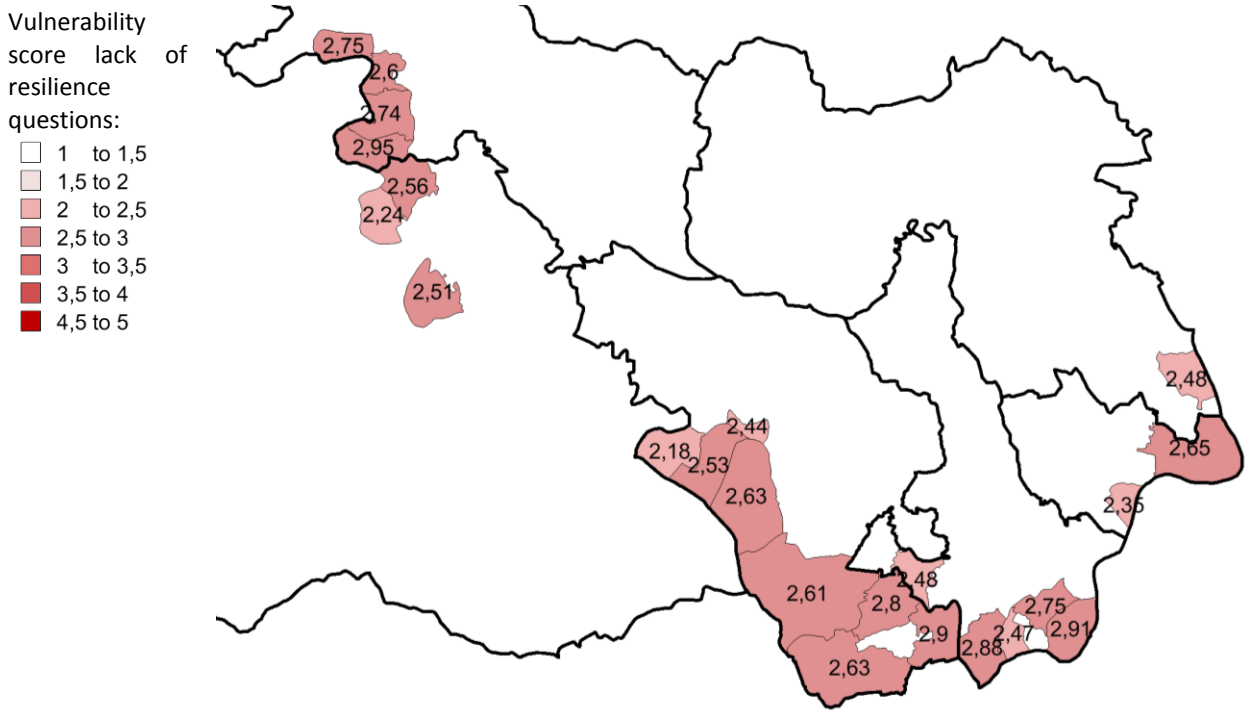

Figure 13 - Average lack of resilience questionnaire scores for every commune

6. Conclusions

The conclusions correspond to the research questions and goals in chapter 1.

6.1 General flood vulnerability

This first goal of this research was to get acquainted with flood vulnerability in general. The conclusion is spread over the rest of the conclusions. Vietnam is quite vulnerable to floods and it is necessary that flood vulnerability research is done for communes in Vietnam.

6.2 Definition of vulnerability and factors

Flood vulnerability consists of the three factors exposure, susceptibility and lack of resilience. These factors consist of indicators which assess different characteristics of vulnerability. The FVI is the combination of the three factors and the factors or the overall FVI can be displayed in graphs or maps, to create an easy to understand indication of the flood vulnerability of different areas.

6.3 Set of indicators

For this research a selective set of indicators is developed. The goal of the indicators is to require only data that is feasible to collect in the field with a questionnaire. Still all the relevant characteristics are assessed, but as a part of indicators that are feasible to assess, there is minimum data loss. Also, the indicators should discriminate to a reasonable degree between different levels of vulnerability. The set is the basis for the questionnaire.

6.4 Data collection method

To collect the data for twenty of these indicators, a questionnaire is developed in this research. There were questionnaires about flood vulnerability held in Vietnam before, but there were several problems while doing this. By developing a new method of asking questions and providing answers to the people, this questionnaire tries to get better and more trustworthy results. Still, there are some difficulties in the field and with the results.

6.5 Data availability and collection

The data for these twenty indicators has been collected with the questionnaire in the Nghe An province during the internship. This data is available in excel and can be combined with the flood danger and land use data. Unfortunately, there is no weighing data collected, and there were some difficulties with collecting the data in the field. Also, there are some improvements needed for the questionnaire and the way the questionnaire is carried out.

The data for the other two indicators, flood danger and land use is already available, but it was not yet ready to put it in an FVI equation. The land use had to be divided into groups with the same vulnerability score. The flood modelling data consisted of depth, velocity and duration data, which had to be combined into a flood danger map with different vulnerability scores. There is a clear result of the vulnerability score of the South of the Nghe An province related to flood danger and land use. This result is not on a commune scale, but even more precise.

6.6 Combining the data

The questionnaire, land use and flood danger data can be combined into maps of the factors of vulnerability. By giving a vulnerability score to every commune, it is clear which communes are more vulnerable than others. The factors can also be combined into the FVI and visualized with a map or a graph. In this research, the results of the FVI were not a goal on itself, but merely developing a method to assess vulnerability. Also, there is room for improvement of the data collection with the questionnaire, and the flood danger data came from models that are not yet finished. For these reasons, the data is not yet combined into an exposure factor, or even in an overall FVI.

7. Discussion

7.1 General research

- With selecting resources and having an opinion about things, the development of the indicator set is influenced. Other people may develop other sets of indicators.
- The research is conducted with low data availability and a questionnaire in mind, “only characteristics that are feasible to assess can be assessed”. This influences the set of indicators.
- This selective indicator set has its influence on the result of the FVI. The results will be different when only using statistical data. Nevertheless, this way other characteristics are assessed, which are important to flood vulnerability of people
- The question about “Flood warning/forecast” was split up in the eventual questionnaire, the results are averaged to get one result for the indicator.

7.2 Questionnaire in the field

- The students that carried out the questionnaire understood the content of the information they needed to ask, but the answer of the people did not focus on the question. This made students confused about what score to tick in the questionnaire. This required ingenuity and agility of the interviewer, but they did not have enough background information about the research and motivation behind the questionnaire to ask more relevant questions and get a relevant answer.
- The questionnaire is mainly directed at objects that are located in flooded areas, so for non-flooding areas there are many questions that are irrelevant and people do not know how to answer the questions. The right thing to do was to give it a score of ‘1’, the lowest vulnerability.
- There were no ranking questions, no open answers for the people to fill in themselves, or a ‘I do not know’ option, all on purpose and motivated in this thesis. The students had difficulties with putting the answer given by the local people on the provided scale.
- The questionnaire is only carried out in 23 communes of the Nghe An province, all next to the Ca river. There were 466 questionnaires in total. This number might not give a good impression of the vulnerability of all the communes in the province. But it would also be less relevant to survey the communes who are not next to or near the river.

7.3 Questionnaire data

- The vulnerability scores of the communes is quite similar to each other. There were only some questions with varying scores. The overviews of each factors in appendix C indicate that the factor resilience contributes the most to this similarity. The factor exposure has the highest standard deviation.

7.4 Weighing

- Weighing data is not collected while carrying out the questionnaire. The weighing scale in the column to the right of the questions on the questionnaire was misinterpreted, namely the same as the answering scale under each question.
- The order of the questions is changed in the eventual questionnaire. Even if there would have been weighing data collected, it would not be possible to weigh only within every factor. The weighing would only be possible within overall vulnerability.

7.5 Land use groups

- The vulnerability score of the 'Public/cultural' land use group is debatable, because the different land uses within the group vary when using common sense. Maybe it is even not desirable to put the land uses into one group.
- All the land use groups have a vulnerability score on an integer scale. The damage data from another study that was used to give a vulnerability score to every land use, is not linear, but the vulnerability score is.

7.6 Flood danger data

- The flood danger data was actually not available yet. The project team was still working on the models and they were not finished yet, but the models were run to produce results for this research nevertheless. As a result, the flood modeling maps are not as accurate as they could be. This will be solved in the future research of the project team.

8. Recommendations

8.1 Questionnaire development and practice

- Some fields were not filled which resulted in a zero or an empty field in the excel results. Make sure people fill in all the answers to get accurate results.
- Also carry out the questionnaire at the local offices (so not only ask for a weighing score). These questionnaire must be slightly different formulated, but with the same idea. Surveying the local offices would give a more representable impression of the entire commune, better than by asking individuals.
- Carry out the questionnaire in more communes of the Nghe An province, with more questionnaires per commune. The questionnaire can also be carried out in the rest of Vietnam.
- The questionnaire carried out in the field had 45 questions. Twenty of these questions are developed in this thesis and the rest is developed by several people from the project team. The questionnaire should have one idea and motivation, and should not be different researches merged into one. A shorter questionnaire gives people the opportunity to put more time in every question and really think about the scenarios.

8.2 Improve scenarios

- Develop better scenarios with help of local knowledge. This was also the original idea, but unfortunately there was no expert meeting to improve the scenarios during this internship. Experts of for example local offices in the communes can be asked to give feedback on the developed scenarios to make them more extensive and also easier to understand for the local people.
- Improve instructions for the students who interview the local people, explain the meaning of and the motivation behind every question, indicator and the assessed characteristics. If they get a non-suitable answer from the local people, they will be able to ask more questions to get a suitable answer.

8.1 Collect weighing data

- Organize an expert meeting to discuss the weight of every indicator or question, the expert approach.
- Weigh indicators within factors instead of as a part of overall vulnerability. To be able to do this, questions must be displayed per factor and it will be important to review if every indicator is indeed in the right factor.
- Weighing can also be done with different methods, for example varying weights for the flood danger indicator, depending on its vulnerability score (Kha, Anh, & Son, 2011)

8.2 Analyze questionnaire data

- Factor averages are interesting, but some individual question results could also be interesting. Also focus on this in further research.
- The standard deviation varies across communes, questions and factors, in further research it could be interesting if all the indicators are indeed relevant and it could be interesting to research why some of the standard deviations are as low as they are.

8.3 Combine data into exposure

- Combine questions (I1,I2,I3), land use (I4) and flood danger (I5) into exposure with Mapinfo
- Make graphs of overall vulnerability, with the factors separated (like the examples in Figure 4 and Figure 5 in chapter 2)
- To make accurate maps/figures of this, it is important to have every indicator in the right factor

8.4 Land use and flood danger research

- Improve or finish the flood modeling research for the Nghe An province rest of Vietnam and combine depth, velocity and duration into a flood danger map like in this and other researches. This can be combined with land use and other exposure indicators into an indicator map.
- Acquire land use data for the rest of Vietnam to be able to group the land uses in groups with different vulnerability scores. This can be combined with flood modeling data and other exposure indicators into an indicator map.

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Appendix A: Developed questionnaire

The questionnaire that is conducted in the Nghe An province had approximately 45 questions. That questionnaire consists of the questions developed in this thesis (Table 7) and of questions developed by other members from the project team of the VNU University of Science. This is because there was a need to collect data for multiple researches within the project where this internship is a small part of. The questions developed by the other members of the project team do not add value to this research. Therefore, only the twenty questions developed in this thesis are shown in this appendix. The numbers in the first column (I#) of Table 7 correspond to the numbers of the indicator set developed in chapter 3.

I#	Exposure			Importance
1	Does your family live in a flood prone area?			Low ○ ○ ○ ○ ○ High
	No, even extreme floods in my commune do not affect me	○ ○ ○ ○ ○	Yes, and every small flood in my commune affects me	
2	Is there cultural heritage that could be damaged by floods?			Low ○ ○ ○ ○ ○ High
	None	○ ○ ○ ○ ○	Yes, a lot, it is also important for me in person and it will be damaged forever	
3	What is the effect of the flood water quality and its sediment for the area?			Low ○ ○ ○ ○ ○ High
	Makes land better for agriculture and is not harmful for people and animals	○ ○ ○ ○ ○	The area needs to be cleaned and cleared of harmful sediment, because it is dangerous for people, animals and crops	
	Susceptibility			
6	Are you and your family able to evacuate, in case of a flood?			Low ○ ○ ○ ○ ○ High
	My family would be able to move/flee if necessary. Or the immobile people in our family (sick, disabled, children, elderly) can get enough help. Or we do not need to.	○ ○ ○ ○ ○	We could not get away in time because of immobility	
7	Do you get a flood warning/forecast?			Low ○ ○ ○ ○ ○ High
	Yes, I receive the warning in time and with accurate information about the danger (e.g. depth, velocity, duration)	○ ○ ○ ○ ○	No, I do not get a warning	
8	Are you aware of the risk of floods?			Low ○ ○ ○ ○ ○ High
	Yes, and I also know what to do because of a training, manual or instruction. Or there is no danger.	○ ○ ○ ○ ○	No, not at all	
9	If you would use or buy new land, do you use flood maps for spatial planning?			Low ○ ○ ○ ○ ○ High
	Yes, I always use flood maps or another method to decide which land is safe to use for different purposes (e.g. buildings, agriculture)	○ ○ ○ ○ ○	No, I do not have a map or other method to use or we do not use it	
10	Does the district/commune government provide protection measures?			Low ○ ○ ○ ○ ○ High
	Yes, protected by district/commune government, they invest enough. For example drainage systems, pumping stations, dykes, reservoirs for water storage. Or it is not needed.	○ ○ ○ ○ ○	No, there are no measures/investments, but we do need it	

	Lack of resilience			
11	Are there any place where you can seek shelter during and after flood?			Low ○ ○ ○ ○ ○ High
	Yes, there are enough high grounds, hospitals or other shelters for all the affected people	○ ○ ○ ○ ○	No	
12	Are you prepared for floods?			Low ○ ○ ○ ○ ○ High
	Yes, we are not in danger or are able to protect ourselves by individual measures, have food in storage or the food supply is not affected by the flood	○ ○ ○ ○ ○	No	
13	Are you able to recover to the previous efficient state?			Low ○ ○ ○ ○ ○ High
	Yes, and this will take little time	○ ○ ○ ○ ○	No, the damage stays noticeable for a long time	
14	Does your family get help from your friends and commune-members in case of a flood?			Low ○ ○ ○ ○ ○ High
	Yes, the commune or people or friends will help me if needed	○ ○ ○ ○ ○	No, my family has to take care of itself	
15	Are you experienced in flooding of your commune?			Low ○ ○ ○ ○ ○ High
	Yes, it happened before and we have had practical education, and this will both help me a lot.	○ ○ ○ ○ ○	No	
16	Is there enough drinking water available after a flood?			Low ○ ○ ○ ○ ○ High
	Yes, there is or we are able to make it ourselves, just like before the flood	○ ○ ○ ○ ○	No, there is normally, but after a flood we have to use non-drinkable water	
17	Would you lose your income/job/business in case of a severe flood?			Low ○ ○ ○ ○ ○ High
	No, I will not lose it or I can get my income back within a week, maybe by switching jobs	○ ○ ○ ○ ○	Yes, and I would lose my income for a long period	
18	Is it possible to use the remaining infrastructure after the flood?			Low ○ ○ ○ ○ ○ High
	yes, the infrastructure is in the same state, we can use it to flee or get supplies	○ ○ ○ ○ ○	No, the infrastructure is damaged or otherwise not useable anymore	
19	Is energy available after flood?			Low ○ ○ ○ ○ ○ High
	Yes, nothing will change in the availability of energy (electricity, gas, coal, wood)	○ ○ ○ ○ ○	No, there was before the flood, but not anymore after the flood	
20	Are you able to connect or get help from people from other communes thanks to telecommunication?			Low ○ ○ ○ ○ ○ High
	Yes, this worked before and will work after the flood	○ ○ ○ ○ ○	No, we don't have telecommunication in our commune/house	
21	Do you get any help from the government or other institutions after the flood?			Low ○ ○ ○ ○ ○ High
	Yes, they search for people in need, support by giving them a boat, food, shelters or other things, and clean the area	○ ○ ○ ○ ○	No	
22	Do you get financial flood support?			Low ○ ○ ○ ○ ○ High
	Yes, I get flood support money from the government or another institution, I have a flood insurance and I can get or borrow money from others	○ ○ ○ ○ ○	No	

Table 7 - Questionnaire developed in this thesis

Appendix B: Land use in MapInfo

In this appendix the land use data is displayed in its original colors in Figure 14 (Nghe An Ministry of Natural Resources and Environment, 2010), together with the legend (Table 8) and the eventual land use groups used in this thesis (Table 9).

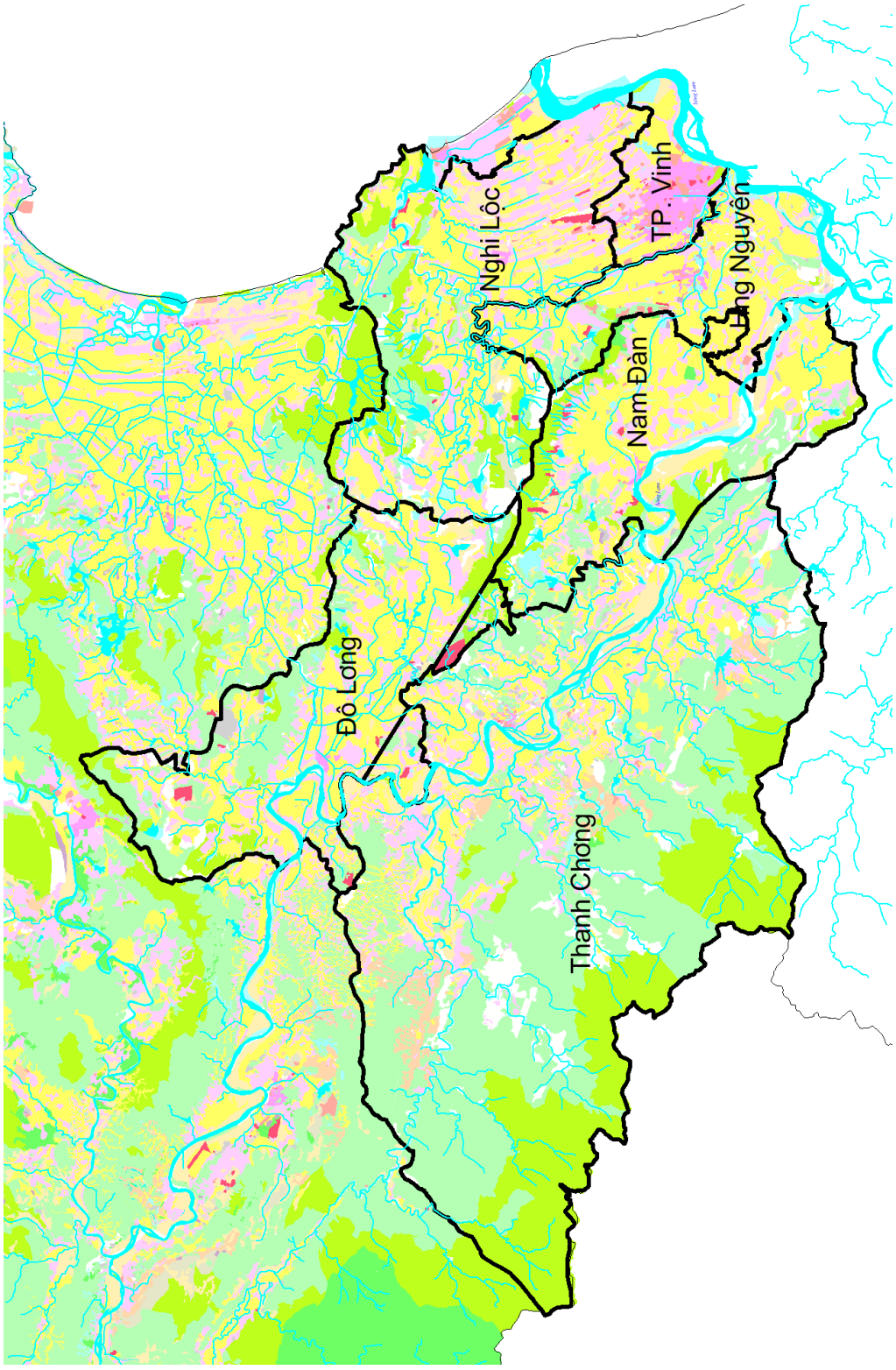
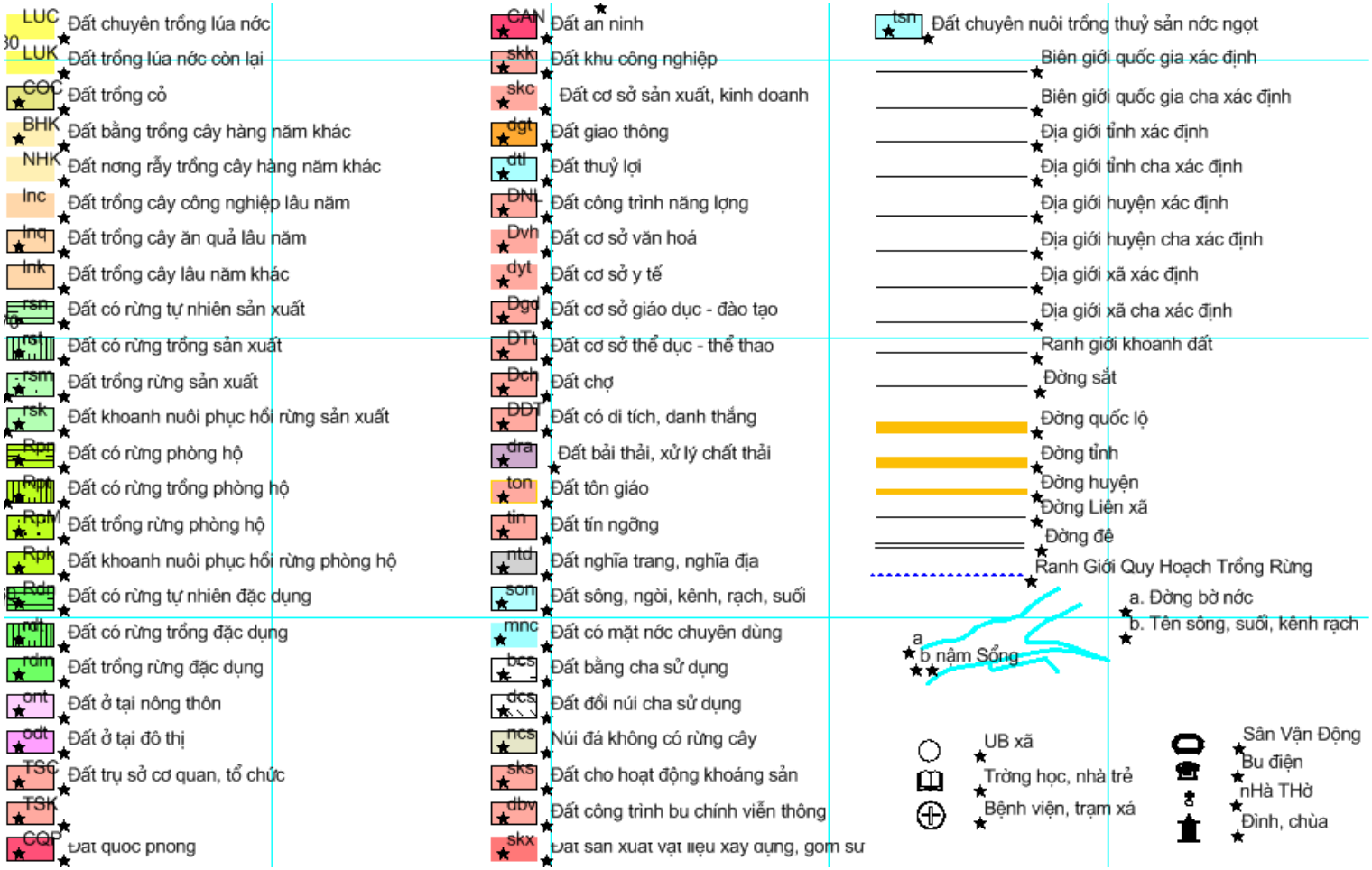


Figure 14 - Land use of the southern part of the Nghe An province

Table 8 - Original land use legend



Color	Vietnamese MapInfo legend	Google translate	Group
Yellow	Đất chuyên trồng lúa nước	Land for growing rice	Rice
	Đất trồng lúa nước còn lại	Paddy land remaining	Rice
Brown	Đất trồng cỏ	Grazing land	Other crops
Salmon	Đất bằng trồng cây hàng năm khác	Land with other annual crops	Other crops
	Đất nương rẫy trồng cây hàng năm khác	Soil cultivation of annual crops other	Other crops
Dark salmon	Đất trồng cây công nghiệp lâu năm	Land perennial crops	Other crops
	Đất trồng cây ăn quả lâu năm	Woodland perennial fruit	Other crops
	Đất trồng cây lâu năm khác	Other perennial woodland	Other crops
Soft green	Đất có rừng tự nhiên sản xuất	Land with natural production forests	Forest
	Đất có rừng trồng sản xuất	Plantation production	Forest
	Đất trồng rừng sản xuất	Production forest land	Forest
	Đất khoanh nuôi phục hồi rừng sản xuất	Forest restoration production	Forest
Light bright green	Đất có rừng phòng hộ	Protective forest land	Forest
	Đất có rừng trồng phòng hộ	Protection forest	Forest
	Đất trồng rừng phòng hộ	protection forest	Forest
	Đất khoanh nuôi phục hồi rừng phòng hộ	Land zoned restore forests	Forest
Dark green	Đất có rừng tự nhiên đặc dụng	Land use natural forest special use	Forest
	Đất có rừng trồng đặc dụng	Forest plantation special	Forest
	Đất trồng rừng đặc dụng	Special-use forest land	Forest
Light purple	Đất ở tại nông thôn	Rural residential land	Rural
Mid-purple	Đất ở tại đô thị	Land in urban areas	Urban
Light pink	Đất trụ sở cơ quan, tổ chức	Land-based agencies and organizations	Public/cultural
	Đất trụ sở cơ quan, tổ chức	Land-based agencies and organizations	Public/cultural
	Đất khu công nghiệp	Industrial land	Public/cultural
	Đất cơ sở sản xuất, kinh doanh	Soil production facilities, business	Public/cultural
	Đất công trình năng lượng	Energy production/factories	Public/cultural
	Đất cơ sở văn hoá	Cultural facilities	Public/cultural
	Đất cơ sở y tế	health facilities	Public/cultural
	Đất cơ sở giáo dục - đào tạo	educational institutions - training	Public/cultural
	Đất cơ sở thể dục - thể thao	fitness facilities - sports	Public/cultural
	Đất chợ	land market	Public/cultural
	Đất có di tích, danh thắng	Land monuments, landscapes	Public/cultural
	Đất tôn giáo	Religious Land	Public/cultural
	Đất tín ngưỡng	Land beliefs	Public/cultural
	Đất cho hoạt động khoáng sản	Land for mining activities	Public/cultural
	Đất công trình bưu chính viễn thông	Land of the telecommunications	Public/cultural
Dark pink 1	Đất quốc phòng	Defense land	Public/cultural
Dark pink 2	Đất an ninh	Land security	Public/cultural
Dark purple	Đất bải thải, xử lý chất thải	Land disposal sites, waste treatment	Public/cultural
Grey-purple	Đất nghĩa trang, nghĩa địa	Land for cemeteries, graveyards	Public/cultural
Light blue 1	Đất sông, ngòi, kênh, rạch, suối	Land rivers, canals, streams	Water
Light blue 2	Đất có mặt nước chuyên dùng	Land with specialized water surface	Water
Light blue 3	Đất chuyên nuôi trồng thuỷ sản nước	Land for freshwater aquaculture	Water
	Đất thuỷ lợi	Land irrigation	Water
White	Đất bằng chưa sử dụng	Unused flat land	Unused land
	Đất đồi núi chưa sử dụng	Unused hills	Unused land
Grey-brown	Núi đá không có rừng cây	Rocky mountains without trees	Unused land

Table 9 - Original land uses and land use groups

Appendix C: Questionnaire data per factor

The average questionnaire scores of every factor are displayed in Table 10, Table 11 and Table 12.

	Exposure				
Commune	**I1**	**I2**	**I3**	avg	stdev
Lưu Sơn	3,18	2,07	2,89	2,71	0,57
Đà Sơn	3,90	2,35	3,10	3,12	0,78
Trung Sơn	3,81	2,67	3,13	3,20	0,58
Thuận Sơn	3,00	2,60	3,00	2,87	0,23
Thanh Hưng	2,73	2,00	2,82	2,52	0,45
Thanh Văn	2,83	2,17	1,67	2,22	0,59
Đồng Văn	3,33	2,44	3,11	2,96	0,46
TT.Nam Đàn	1,95	1,30	2,25	1,83	0,49
Nam Thượng	3,21	2,16	2,79	2,72	0,53
Nam Tân	3,00	2,14	2,57	2,57	0,43
Nam Lộc	3,43	2,05	2,52	2,67	0,70
Khánh Sơn	3,70	2,35	3,05	3,03	0,68
Nam Kim	3,10	2,00	2,25	2,45	0,58
Nam Trung	4,30	3,45	3,40	3,72	0,51
Nam Cường	4,59	2,36	2,77	3,24	1,19
Hưng Long	4,70	1,70	2,60	3,00	1,54
Hưng Lam	3,69	2,34	2,58	2,87	0,72
Hưng Phú	4,41	1,70	2,65	2,92	1,38
Hưng Châu	3,74	2,13	2,52	2,80	0,84
Hưng Nhân	4,36	3,46	3,43	3,75	0,53
Bến Thủy	3,59	1,91	2,73	2,74	0,84
Hưng Hòa	4,19	2,33	2,81	3,11	0,96
Phúc Thọ	3,33	1,88	2,92	2,71	0,75
min	1,95	1,30	1,67	1,83	0,33
max	4,70	3,46	3,43	3,75	0,72
avg	3,57	2,24	2,76	2,86	0,67
stdev	0,67	0,49	0,39	0,42	

Table 10 - Questionnaire data for the factor exposure, average scores for every commune

	Susceptibility						
Commune	**I6**	**I7**	**I8**	**I9**	**I10**	avg	stdev
Lưu Sơn	2,61	2,50	2,41	2,82	2,68	2,60	0,16
Đà Sơn	2,50	2,70	2,05	2,40	2,40	2,41	0,24
Trung Sơn	1,93	2,34	1,77	2,29	2,67	2,20	0,35
Thuận Sơn	2,80	3,20	3,00	2,80	2,80	2,92	0,18
Thanh Hưng	3,10	2,50	2,55	2,80	2,27	2,64	0,32
Thanh Văn	1,33	2,33	1,83	2,67	1,83	2,00	0,51
Đồng Văn	2,22	2,22	2,33	2,22	2,11	2,22	0,08
TT.Nam Đàn	2,65	2,23	1,85	2,20	2,65	2,32	0,34
Nam Thượng	1,79	1,47	1,58	2,68	2,63	2,03	0,58
Nam Tân	1,67	1,83	2,05	2,19	1,86	1,92	0,20
Nam Lộc	2,00	2,24	1,86	2,48	2,76	2,27	0,36
Khánh Sơn	1,75	2,25	2,15	2,35	2,70	2,24	0,34
Nam Kim	1,85	2,10	2,45	2,05	2,80	2,25	0,38
Nam Trung	2,00	2,38	2,00	2,40	3,00	2,36	0,41
Nam Cường	1,95	1,82	1,73	2,45	3,05	2,20	0,55
Hưng Long	2,45	1,90	1,60	2,15	3,05	2,23	0,56
Hưng Lam	2,44	2,54	2,22	2,47	2,50	2,44	0,12
Hưng Phú	2,09	1,81	2,06	2,09	3,24	2,26	0,56
Hưng Châu	2,74	1,83	2,13	2,52	2,30	2,30	0,35
Hưng Nhân	2,41	2,73	2,57	2,39	2,29	2,48	0,18
Bến Thủy	2,41	2,39	2,00	2,36	3,32	2,50	0,49
Hưng Hòa	2,19	2,21	2,24	2,52	2,33	2,30	0,14
Phúc Thọ	2,54	2,08	2,13	2,42	3,04	2,44	0,39
min	1,33	1,47	1,58	2,05	1,83	1,92	0,29
max	3,10	3,20	3,00	2,82	3,32	2,92	0,19
avg	2,24	2,24	2,11	2,42	2,62	2,33	0,20
stdev	0,42	0,38	0,34	0,22	0,40	0,22	

Table 11 - Questionnaire data for the factor susceptibility, average scores for every commune

	Resilience													
Commune	**I11**	**I12**	**I13**	**I14**	**I15**	**I16**	**I17**	**I18**	**I19**	**I20**	**I21**	**I23**	avg	stdev
Lưu Sơn	2,57	2,64	2,57	2,75	2,89	2,68	3,07	2,36	2,61	2,43	3,00	3,39	2,75	0,30
Đà Sơn	2,60	2,80	2,85	2,45	2,45	2,00	2,90	2,40	2,40	2,25	2,90	3,20	2,60	0,34
Trung Sơn	2,53	1,94	2,88	2,06	1,69	2,81	3,33	3,19	2,81	3,00	2,81	3,88	2,74	0,62
Thuận Sơn	3,40	3,80	2,20	2,60	2,60	3,20	3,20	2,80	2,80	3,20	2,60	3,00	2,95	0,44
Thanh Hưng	3,00	2,55	2,64	2,55	3,18	1,91	3,55	2,27	1,91	2,27	2,45	2,45	2,56	0,49
Thanh Văn	2,00	3,33	2,00	1,67	2,17	1,83	2,50	2,00	2,00	1,83	2,83	2,67	2,24	0,49
Đồng Văn	2,44	2,89	2,44	2,00	2,33	2,00	3,00	2,89	2,44	2,78	2,11	2,78	2,51	0,36
TT.Nam Đàn	2,60	2,65	1,80	2,55	3,05	1,85	2,35	2,05	1,79	1,95	2,75	3,90	2,44	0,62
Nam Thượng	2,21	2,21	2,42	1,47	1,79	1,53	3,37	2,42	1,42	2,79	2,00	2,53	2,18	0,58
Nam Tân	2,95	2,24	2,62	2,24	2,05	1,81	3,67	2,33	2,38	2,19	2,90	3,00	2,53	0,52
Nam Lộc	2,71	3,62	3,05	2,43	2,19	2,33	3,38	2,29	2,05	2,00	2,76	2,81	2,63	0,52
Khánh Sơn	2,25	2,30	2,80	2,45	2,05	1,90	3,70	2,90	2,60	2,30	2,75	3,30	2,61	0,52
Nam Kim	2,70	2,00	2,40	2,20	2,85	2,55	3,25	2,35	2,60	2,20	3,05	3,40	2,63	0,44
Nam Trung	2,75	2,25	2,80	2,05	2,20	2,80	3,50	2,75	3,20	3,20	3,00	3,15	2,80	0,45
Nam Cường	2,86	2,36	3,64	2,55	1,95	3,00	4,18	3,18	2,95	2,45	2,36	3,27	2,90	0,62
Hưng Long	2,70	2,05	2,80	2,25	1,50	2,05	3,55	2,35	2,45	2,05	2,70	3,35	2,48	0,58
Hưng Lam	3,14	2,34	3,28	2,50	2,31	2,50	3,39	3,28	3,00	2,64	2,92	3,25	2,88	0,40
Hưng Phú	2,26	2,70	3,30	2,09	1,88	2,18	3,64	2,53	2,35	2,03	2,24	2,44	2,47	0,52
Hưng Châu	3,09	3,39	2,87	3,30	2,22	1,70	3,17	2,48	2,35	1,87	3,00	3,57	2,75	0,61
Hưng Nhân	2,07	2,75	3,78	2,25	2,75	2,96	4,07	2,82	3,21	3,25	2,21	2,75	2,91	0,60
Bến Thủy	2,50	2,36	1,95	2,36	2,55	1,95	2,18	2,00	1,73	1,86	3,05	3,73	2,35	0,57
Hưng Hòa	2,52	2,71	2,76	2,38	2,43	1,86	3,33	2,62	2,95	2,38	2,57	3,33	2,65	0,41
Phúc Thọ	2,67	2,50	2,08	2,54	2,63	2,04	3,13	2,38	2,29	1,75	2,63	3,08	2,48	0,40
min	2,00	1,94	1,80	1,47	1,50	1,53	2,18	2,00	1,42	1,75	2,00	2,44	2,18	0,32
max	3,40	3,80	3,78	3,30	3,18	3,20	4,18	3,28	3,21	3,25	3,05	3,90	2,95	0,36
avg	2,63	2,63	2,69	2,33	2,33	2,24	3,28	2,55	2,45	2,38	2,68	3,14	2,61	0,32
stdev	0,35	0,50	0,51	0,37	0,44	0,48	0,48	0,37	0,48	0,47	0,31	0,42	0,21	

Table 12 - Questionnaire data for the factor lack of resilience, average scores for every commune