Application of GIS and Remote Sensing for Environment and Flood Risk Management in Central Viet Nam

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SUMMARY

This project was carried out to assess and implement new methods or review existing methods of categorising land use in the Mekong areas of Viet Nam. It specifically looks at the links to flooding and the changing uses of the land.

The aims of this project can be summarised as follows:

- To ascertain land use in these areas and how it has changed over the years since 1989.
- To determine if these changes in land use have had an effect on flooding, and, if so, then by how much.
- To establish the reasons for the changes to the land use that has taken place, looking specifically at socioeconomic factors that determine land use changes.
- To identify methods that manage the land effectively and balance economic interests, environmental protection and flood prevention.

The survey of land use showed that the natural forest has been cleared for agriculture in many areas, mainly upland crops on slopes and paddy fields in the flat areas. This leads to degradation of the upland areas as no proper structure was in place to manage it in the long term. This was also due to there being no controls on land use in these areas by the government at the time.

New projects have been mainly aimed at reforestation as this is seen to prevent soil erosion and flooding. Local peoples were given extra incentives to grow trees as a result. This method has also had its negative effects on the livelihoods of local peoples and environment, as well as not working effectively to decrease flooding on a large scale. The research conducted in this field suggests that the increase in flooding is attributed to lowland development and environmental changes. Also many local peoples surveyed said that the flood was a necessary part of their lives, at least in rural areas. It provides nutrient-rich sediment, kills off pests such as rats and insects and forms a natural irrigation system. Urban areas are still badly affected by flooding as they have no use for its benefits as rural agriculture does, and the urban environment are typically indirectly affected and directly damaged by the floods themselves. This link between floods and lowland land use changes mainly applies to catastrophic flooding; low-level flooding has been shown to be greatly affected by reforestation. Also account must be taken of the other benefits of reforestation that are widely documented.

A key method of managing floods effectively is better coordination between lowland and upland areas. Upland areas that are managed badly and that have a degraded environment are seen to negatively affect the lowland areas downstream from them.

The key to long term success for land use in these areas is to find a balance between agriculture, environment and flood prevention. So while forests have limited effect on large scale flooding, they do affect low level flooding and have many other benefits for the environment and economy of the area.

The catastrophic flooding talked about in the report is mainly attributed to global climate change that affects rain fall patterns. Although upland degradation has been shown to be a minor factor in the floods the changed implemented have had too much of a negative effect on the environment and economy of the areas to justify their continuation. This unfortunately is not taken in to account by high level decision makers, and it is still pushed by international agencies, disregarding the knowledge that has been used for centuries by the local peoples to manage these floods effectively.

1. BACKGROUND

In Viet Nam prior to the land reform and the introduction of the doi moi policy, most uplands and forestry lands were ostensibly under collective or state farm management. However, there appears to have been a considerable amount of land that was in fact under open access, with no management regime imposed, because of the state's inability to prevent people from making illegal use of the forest. In addition some of the state lands were managed under the system of communal land management in areas where ethnic minorities had developed traditional systems of land use.

In the shift from state to privately managed forestlands, incentives to protect resources were created. These policies/programs have significant impacts on land cover. Moreover, in the literature of flood disasters, there is a common perception that forest cover in the uplands has a strong relationship with the severity of flooding (see appendix 1 for the detailed argument). Thus, the analysis of the impacts of land use and development policies/programs on land cover and its relation to flood is crucial not only in Viet Nam but also other Mekong countries since floods are frequent disasters, but there is still a lack of awareness or misperception among local and national government officials about the important of improving upland and forest toward flood risk reduction.

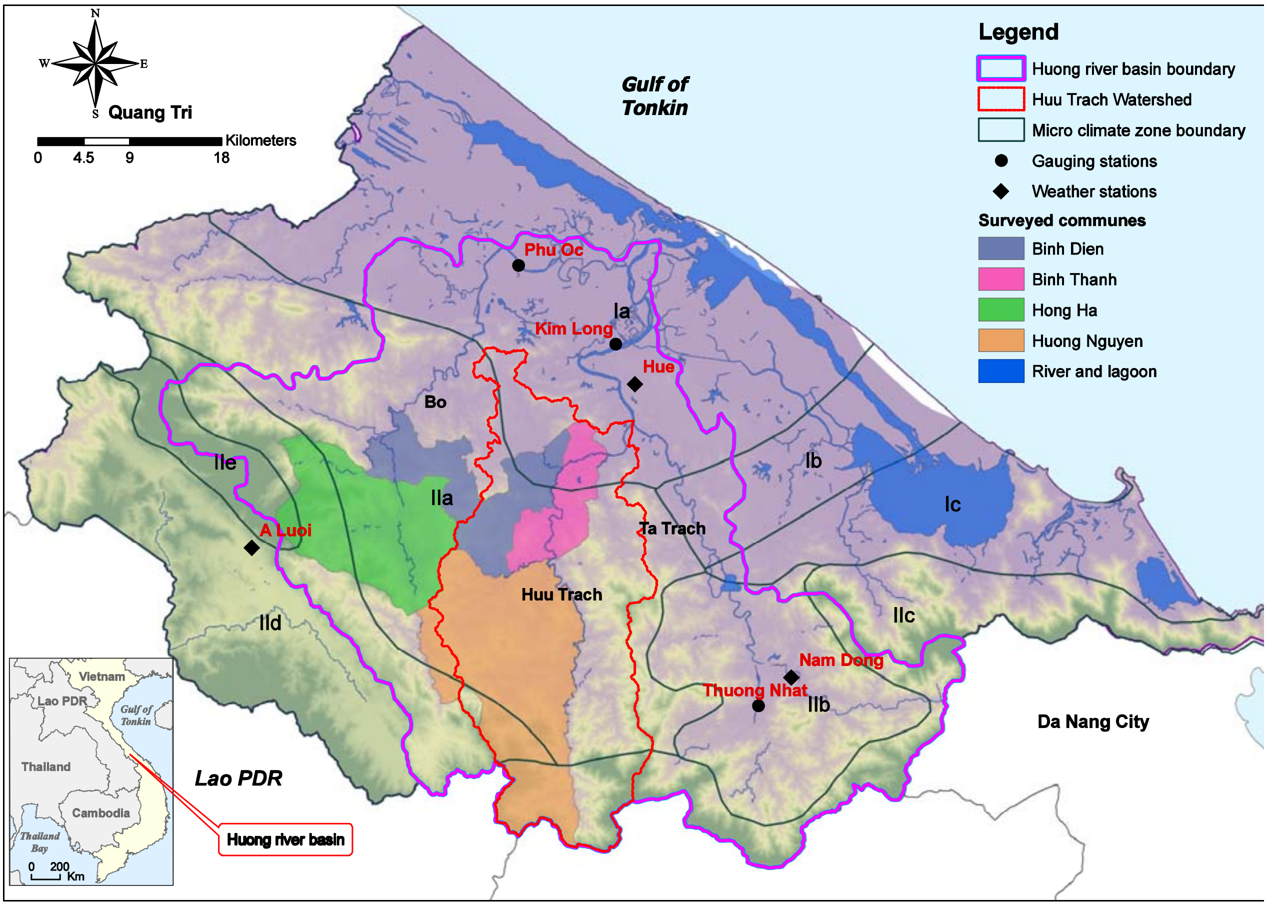
1.1 Characteristics of the study area

The Huong River basin is the largest basin of Thua Thien Hue province (Figure 1). The area of the basin is 2,830 km^2 in which more than 80% of the area is mountainous and hilly with their heights ranging from 200m to 1,708m. The basin, located on the East of Truong Son mountainous range and on the North of Bach Ma range, covers the majority of the province territory. The main flow of the Huong River originates from the high mountain area of Bach Ma range where the altitude is from 900m to 1,200m through Huu Trach tributary. The longest flow originates from the altitude of 1,318m, which runs from South to North, through the Huu Trach tributary with the length of more than 104km. The Huong River basin has three main tributaries named Ta Trach, Huu Trach and Bo. The length of the Ta Trach River is 51km and the area of its drainage basin is 729km^2. The length of the Huu Trach River is 70km and its drainage basin is 691km^2. The Ta Trach meets the Huu Trach at the Tuan confluence. The Bo River is 94km long and the total area of its drainage basin is 938 km^2 and converges with the Huong River at the Sinh confluence.

The Huong River basin has the highest rainfall in Viet Nam, with medium annual rainfall of 2800 mm in coastal areas and 3500 mm in the upper part of the basin. On average, 3500mm of rain falls in the A Luoi area, 3200 mm in the Nam Dong area, and up to 2850 mm in Hue city. Rainy season prolongs from August to December. According to the result of a study by Thua Thien Hue Hydrometeorology Center (TTH PPC 2008), the Huong River basin has two main climatic zones, which consist of seven microclimate zones

(Figure 1). The topography of the basin changes rapidly, with hardly any transition area, from the upstream high mountain down to the plain and large lagoon system. During the rainy season this morphology causes high runoff upstream and large floods and inundations in downstream areas.

Figure 1: Research location and selected weather stations



Source: Author's elaboration

2. PROJECT OBJECTIVES

2.1 Goal and purpose

The goal of this research is to explore the detailed impacts of land use and socio-economic development policies/programs on land cover change and their linkage with flooding by using remote sensing and GIS technique and participatory research approach. The result of this study will be essential to advocate environment management and development communities to integrate flood risk reduction components in their policies and programs.

2.2 Specific objectives of the project

- To identify the impacts of major land use policies/programs on the land cover in the mountainous areas of Thua Thien Hue from 1989 to 2008;
- To examine the relationship between land cover change and the flood disaster in Thua Thien Hue;
- To identify the main socio-economic factors governing the land cover change in the mountainous areas of Thua Thien Hue Province in the period of 1989-2008;
- To develop an integrated approach of environment, development and flood risk management for the context of Huong river basin, Thua Thien Hue province.

3. OUTPUTS

3.1 Impacts of major land use policies/programmes on the land cover and people in the mountainous areas of Thua Thien Hue from 1975 to 2008

Activities

- Gathering secondary data (land use, socio-economic development, disaster management and forest management policies/programs/projects in Thua Thien Hue and research areas);
- Organizing Focus Group Discussion at Binh Thanh, Binh Dien and Huong Nguyen communes;
- Carrying out household surveys, semi-structured interviews with commune and village leaders at Binh Thanh communes (82 households), Binh Dien communes (119 households), Huong Nguyen communes (97 household), and household survey at Hong Ha communes (94 households).

Methodology

To achieve this output, field surveys were carried out in four upland communes of the Huong River basin: Binh Thanh, Binh Dien, Huong Nguyen, and Hong Ha communes (see Figure 1). These selected communes best represented the socio-economic and physical conditions of the uplands. Knowing the inherent shortcoming of the non-random nature of the sampling procedure, prior to the selection of survey communes the investigators conducted a reconnaissance visit to the upland areas to find out economic status, main livelihood activities, and ethnic composition. During such visit, the staff of commune people's committees also informed the investigators about the significant changes in the surrounding landscapes.

In each surveyed commune, transect walks, participatory exercises (mapping, wealth ranking, historical and problem tree) with focus groups, household surveys and interviews of key informants (staffs of commune people's committee, elders, and village chiefs) were carried out. Before administering the questionnaires, the investigators obtained the lists of all households within the commune along with their village location, main livelihood activity, and economic status (divided into three levels: poor, medium, and better off). The samples of households contacted were randomly selected from these lists. The final number of questionnaires gathered was 404 (average 100 per commune). The investigators collected both qualitative and quantitative data. Qualitative data were analyzed using textual analysis, and quantitative data were analyzed using the Statistical Package for Social Scientists (SPSS) software. This output is the result of both primary and secondary data analysis based on the combination of qualitative and quantitative approaches.

Achievements

Impacts of major land use policies/programmes on the land cover in the period before 1989

According to the research of Hue University of Agriculture and Forestry (HUAF 1997), before 1954 natural forests occupied most of the upland areas of the Huong River basin. Upland farmers mainly lived on shifting cultivation, hunting and collecting products from forests. However, because of large forested areas, low population density and long fallow periods, the impact of shifting cultivation on forestry resource was almost insignificant. Damages were instead created by the war of 1967-1968 and 1972-1973, which seriously damaged the upland forests. Subsequently, after 1975 until the late 1980s, the Vietnamese government implemented 'fixed settlement' policies, which provided land and financial support to upland people to build 'fixed houses', while villagers still lived on shifting cultivation. Unfortunately, this cultivation practice and forest exploitation, carried-on without any planning, degraded the quality of forests, often causing soil erosion and landslides (HUAF 1997). For example, after clearing and burning shrubs, due to the absence of vegetative cover, the plots were exposed to severe erosion from heavy-rain.

The New Economic Zone (NEZ) program, which started in 1975, also had significant impacts on land cover in the mountainous areas of Thua Thien Hue. During this program, with the support of local government authorities, people from Hue city, surrounding lowland villages, and the boat people (who lived on the boat along the river and lagoon), came to settle the upstream areas of the Huong River. To survive in this new environment, these new settlers cleared the forest and grew crops in the hills and wet rice in the small valleys and alluvial areas alongside natural springs. Regrettably, without proper training for sustainable long-term use of the abundant land (for example sloping for upland farming), these new settlers, allured by short-term benefits, heavily exploited the upland severely degrading it.

According to the results of the focus group discussions with upland farmers, in this period, no formal rules governed forestland management. Work in the uplands was neither managed nor controlled by the co-operative or a State Forest Enterprise (SFE). Instead, local people had designed their own rules. Everyone was free to clear as much land as he or she wanted; how much land farmers could open up only depended on their will and available labor force. Upland access was not restricted to any individuals or group of people. Furthermore, logging activities, and over harvesting of forest products heavily contributed to degrade the forest.

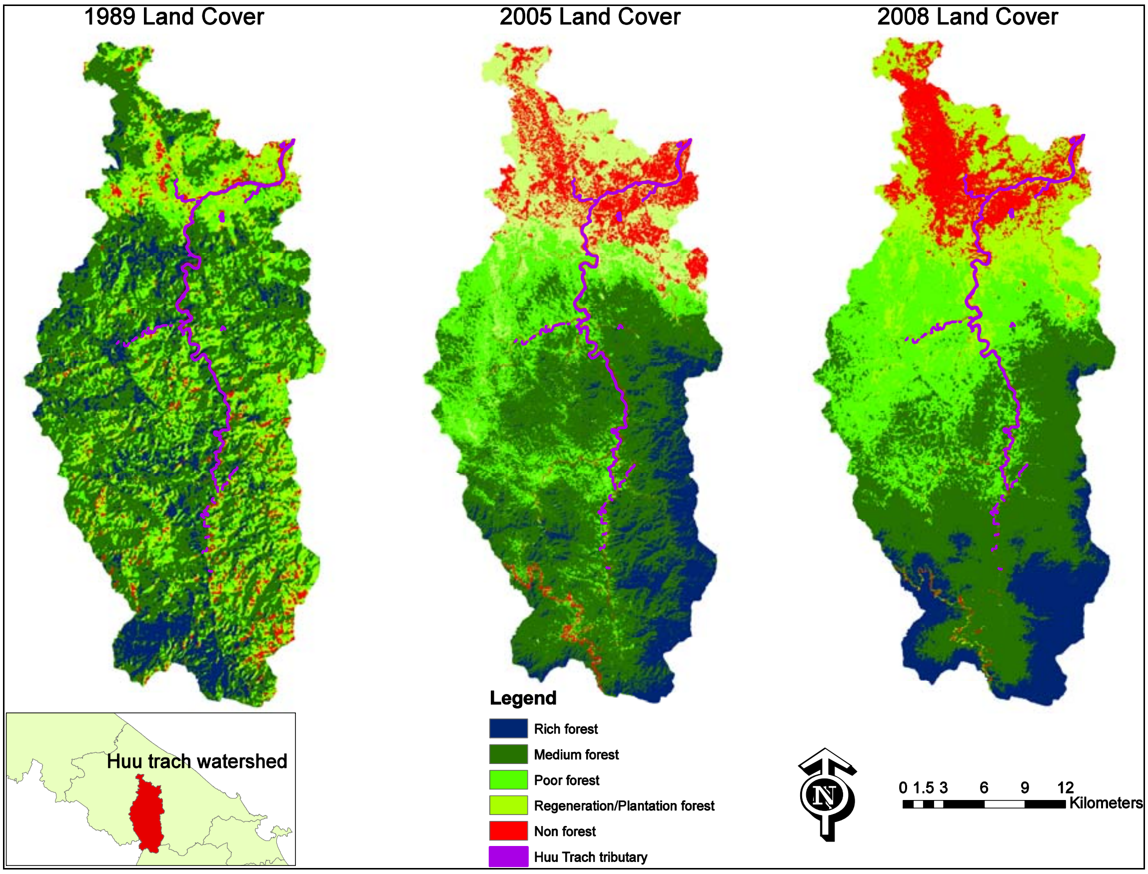
Impacts of major land use policies/programmes on the land cover in the period after 1989

During this period many reforestation programs were launched in the Huong river basin. They included the United Nations World Food Program (WFP – often identified by the acronym PAM), the ‘fixed cultivation and settlement’ program, the government program 327 and more recently the Five Million Hectares Reforestation Program (5MHRP). Vietnamese decision makers started perceiving flood risk reduction as one of the most important “environmental services” of the forest. Consequently, with the establishment of the 5MHRP, in 1998, the Vietnamese government focused its environmental policies on reforestation of the hill slopes and bare lands. This watershed management policy prioritized comprehensive forest cover, and one of the stated aims was to reduce the severity of natural disasters (The Government Socialist Republic of Viet Nam 1998). Forest management of major areas in the uplands was allocated to the Watershed Management Boards under the Thua Thien Hue provincial Department of Agriculture and Rural Development. Between 1994 and 2000 the Boards organized the planting of a major part of the hill land, mainly with acacia. Agricultural production has gradually been transferred to the river valleys instead of the hill slopes, in order to protect the forest. As a consequence the forest cover types have been significantly altered during this period (see Figure 2).

Impacts of major land use policies/programmes on upland people

The land use policies and programs in the uplands have significant impacts in the livelihoods of the upland people; particularly to some extent they increased the vulnerabilities of the uplanders to flood risks. For example, shifting cultivation, practiced by ethnic minority groups was pointed out as the major cause of flood risks, and consequently banned. To leave space to reforestation programs the total amount of land available for agricultural purposes decreased with time. The end result was an increased competition over agricultural land among the villagers. The only land that could be used for agriculture cultivation was the upper river valley floodplains (obviously exposed to flash floods – see Figure 3). Ironically, these forestry programs and policies in the attempt to reduce flood risk have in fact intensified the vulnerabilities of the upland people to flood disasters. The lack of access to the hill slopes was perceived both by households and commune authorities as the main constraint for recovery from the 1999 floods (Beckman 2006). Today households and commune authorities are not longer encouraging shifting cultivation, yet they argue that erosion control and flood protection is workable with agro-forestry production on the slopes. Namely, environmental and livelihood needs can be met without increasing flood vulnerability.

Figure 2: Land cover in Huu Trach watershed in 1989, 2005 and 2008



Source: Author's analysis and calculation from satellite images

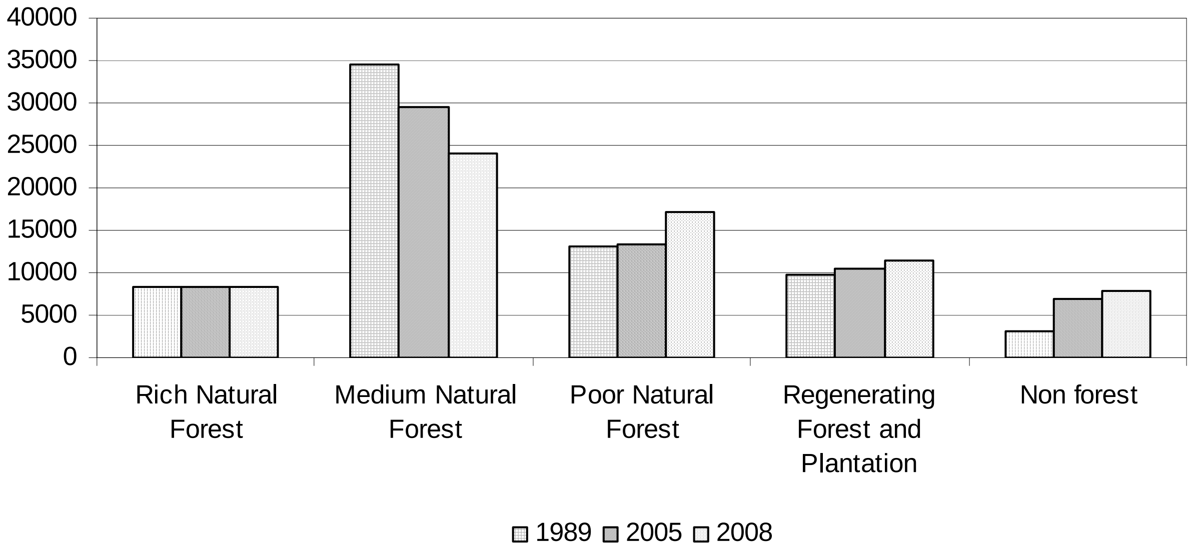
Figure 3: 'At risk' agriculture area in the valley at Hong Ha commune

Source: Author's elaboration from DEM and QuickBird Image

Furthermore, by ignoring the value of indigenous practices, these modern policies have considerably disrupted existing local management systems, and thus increased the vulnerability of the upland people. For example, the forestland allocation policy in the decision 327 (Council of Ministers, Socialist Republic of Viet Nam 1992) has instituted a land use system where all land is either state-owned or private with no consideration of traditional common land use practices. A visible serious consequence of this policy in the uplands was riverbank erosion. Up to the 1980s, when forestlands were still under common property, people had been planting bamboo along the river to protect the riverbanks from erosion. Upland dwellers also used to plant bamboo and indigenous forest species for protection of agricultural and residential areas. However, when the forestlands became controlled by state forest enterprise or retailed to households, the incentives for community forestry initiatives decreased. Today, the riverbanks are largely without protective bamboo planting.

In addition, the role of the communities was minor in the new regime for protecting watershed forests. Participation to the forest management program was mainly restricted to payment for services and the community was not allowed to participate in planning and management. For instance, reforestation activities began quite extensively from 1986 to 2000 when the United Nations' World Food Program implemented a series of projects (e.g. Project 2780 (1986-1989), Project 4126/Q (1990-1991), and the Project 5322 (1997 - 2000)). Through this program, capital and other material incentives were given to villagers to enable them to establish forest plantations. The more trees people grew, the more incentives they got. So, to gain more from the program, villagers grew forest trees in gently sloping areas that should have instead been used for crop production (see Figure 3). As a result, within areas delineated for watershed protection, poverty problems arose due to insufficient land being allocated for agriculture and food production. At the same time, access to extract timber and other forest products became uncertain for the high percentage of people that are still depending on forest products for their living. Overall, the forest cover changed spatially (see Figure 2). In terms of forest quality, however, the medium natural forest has been decreasing, while the poor natural forest along with the regenerating and plantation forest have been increasing in the last twenty years (see Figure 4).

Figure 4: Forest cover in Huu Trach watershed



3.2 Relationship between land cover change and the flood disaster in Thua Thien Hue

Activities

- Setting up GIS and remote sensing database of Huong river basin (Landsat 1989, Landsat 2003, SPOT 2005, and ASTER 2008 downloaded and geo-referenced);
- Gathering hydrometeorology data of Thua Thien Hue province;
- Analyzing the hydrometeorology data to identify the flood trend and its causes;
- Analyzing the remote sensing images to classify the land cover and detect the

land cover change over the period of 1989 – 2008;

- Identifying the relationship between forest and flood.

Methodology

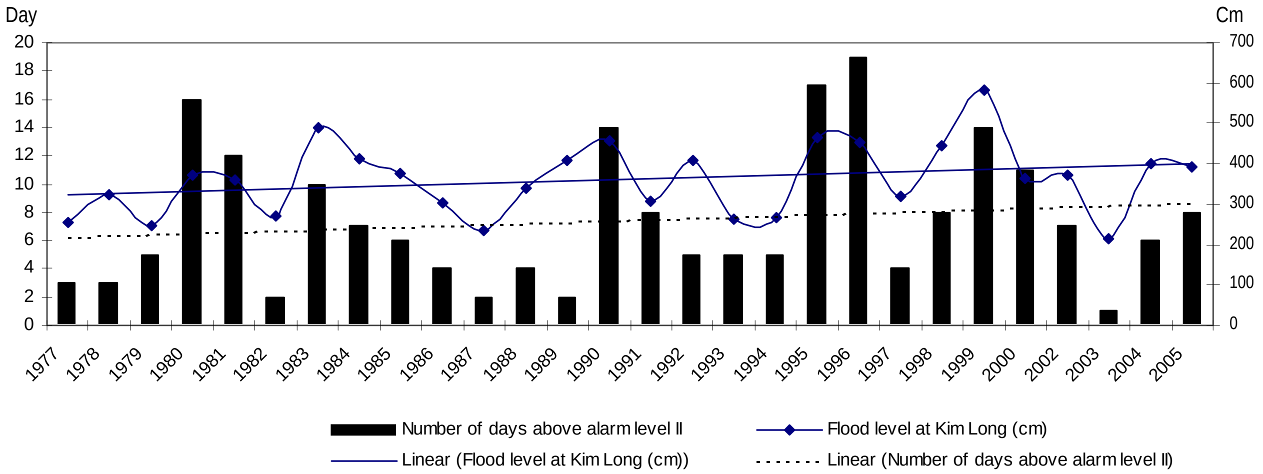
- Identifying flood causes: the available hydro-meteorological data of the last thirty years were analyzed to highlight the causes of catastrophic floods (see Appendix 2 for more details).
- Classifying land cover and detecting land cover change: this was done with satellite imagery and GIS analysis (see Appendix 3 for more details).

Achievements

The analysis of flood level trends based on the time series data for the last 30 years in the Huong River basin highlighted the following findings:

- A significant increasing trend of the yearly highest flood peak (flood level) in the lowlands (very high probabilities of 95% at Kim Long station on the Huong River).
- The number of days with floodwaters above alarm level II (200 cm) has also increased (however, this trend is not statistically significant at 95% level of confidence, see Figure 5.
- The upward trend over time for annually maximum rainfall was observed at the three weather stations, however, this trend is not statistically significant at 95% level of confidence.
- A strong linear correlation was found between the highest flood level in lowlands and the rainfall in the uplands on the days of flood peak. The linear regression model between highest flood level and rainfall showed that more than 71% variance of these flood levels at Kim Long gauging station (lowland) can be accounted for by the variance of the rainfall in A Luoi station (upland). This means that catastrophic flood levels appear mainly caused by climate change/variability.

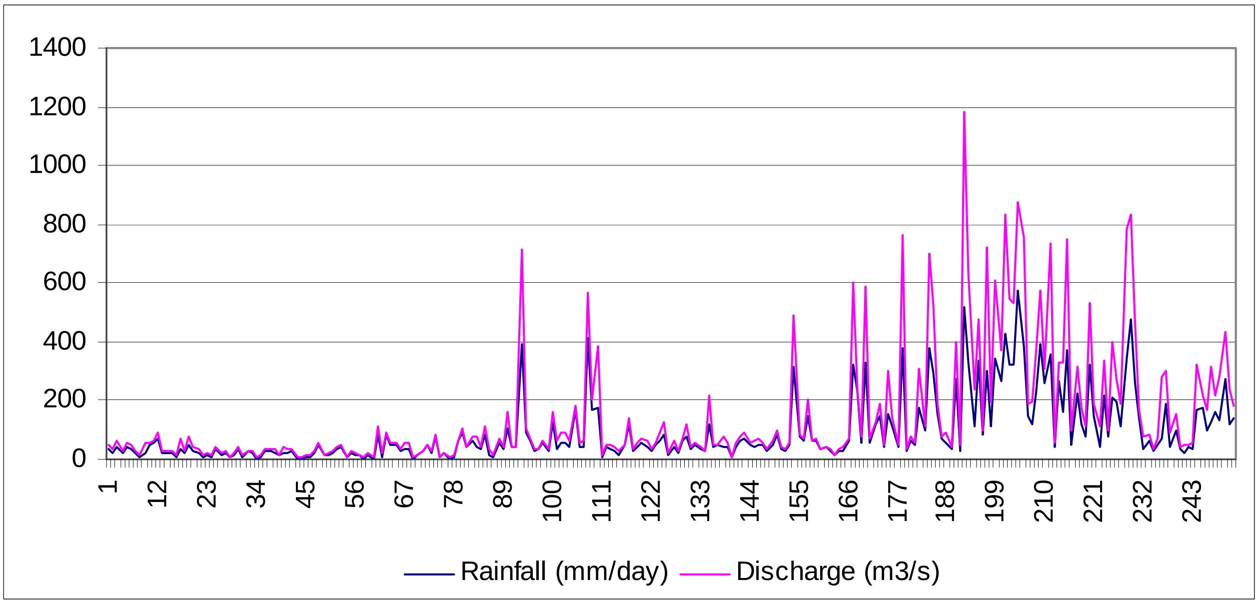
Figure 5: The increasing trend of flood peaks and duration at Kim Long station



Note: The alarm level II at Kim Long station is 200 cm.

Furthermore, the linear regression model between the maximum rainfall per day within one month at Nam Dong station and the respective discharge at Thuong Nhat gauging station showed that more than 77% variance of the discharge was accounted for by the variance of the rainfall (see Figure 6). This means that in case of extreme rainfall, the forest cover has minor role in reducing the discharge.

Figure 6: Rainfall and discharge at Thuong Nhat and Nam Dong stations



Also, the results of a multiple linear regression model for the Ta Trach tributary (in which the rainfall on the day of flood peak and the runoff coefficient of Thuong Nhat watershed were used as the predictors for the flood peak at Thuong Nhat station), showed a statistically significant correlation between rainfall and flood peak (90% level of confidence) but no correlation between flood peak and runoff coefficient. Hence, the runoff coefficient, which is often used as a proxy for land cover, has negligible impact on the catastrophic flood levels. In other words, in the Thuong Nhat watershed, the changes in the forest cover had no significant impact on catastrophic flood levels.

Table 1: Results of multi-linear regression model

	Unstandardized Coefficients		Standardized Coefficients	T	Significance
	B	Std. Error	Beta	B	Std. Error
(Constant)	6040.156	86.517		69.815	.000
Runoff Coefficient	232.127	273.148	.187	.850	.407
Rainfall at Nam Dong station	.387	.219	.389	1.771	.095

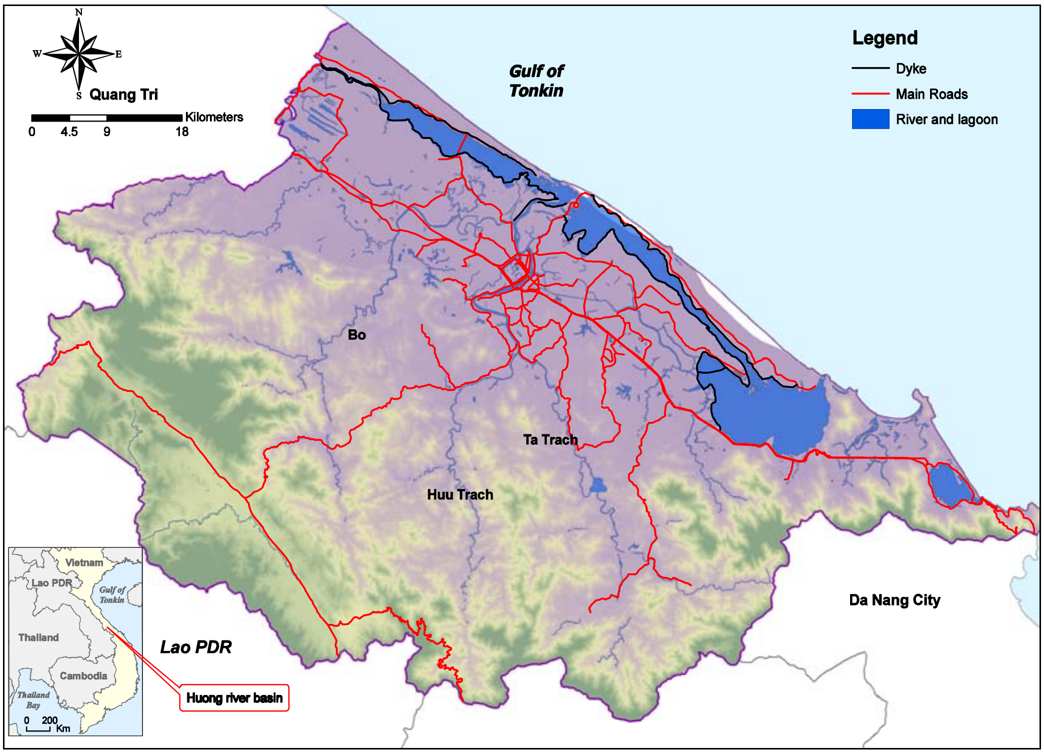
Dependent Variable: Flood level at Thuong Nhat station

Nevertheless, climate change alone may not fully explain the increasing trend of catastrophic flood impacts in the Huong river basin. Something else may be at work. It is important to note that the topography of the Thua Thien Hue province, with its steep hills that ring the coastal plain, located at a short distance to the sea, on average 50 km, and quickly rising to altitudes ranging from 200 to 1708 meters, heighten the risk of flood. This is particularly true during the monsoon season in October and November, when the heavy precipitation in the mountains quickly drains into the floodplains. Unfortunately, most flood defenses in the lowlands were built as individual local schemes with little consideration of their impacts across the wider river catchments, the aquatic and coastal environments, and their overall economic consequences. The fact that embankments and other engineering structures were most effective only for small- to medium-sized flood events was often not recognized. In addition, roads and other embankments sometimes inhibited the discharge of rainwater from waterlogged areas into the river system (particularly where the number of sluices in the embankments was insufficient) thus increasing the dimension of flooding. The available water storage of a typical reservoir is generally much less than the volume of a major flood surge. Finally, it should be considered that structural solutions often have spillover effects, shifting problems from one location to the next. For example, emergency releases of water during periods of high rainfall can dramatically and dangerously increase water levels immediately downstream of dams.

During the last thirty years the transportation systems have been significantly improved and developed, and the railway and north-south highway act as two-meter dams across the entire valley during the catastrophic floods. Furthermore, the dyke systems along the lagoon, which have been upgraded and developed during the last three decades, also block the water flow during the flood season (see Figure 7). Although there are numerous culverts, bridges and other openings, the main transportation and dyke systems are likely to restrain the flow of water towards the coast. During periods of intense rainfall and consequent peak flows, these structures probably increase the flood level and pressure at the few openings toward the lagoon area.

Although there is a significant relationship between catastrophic flood level and climate variability, the increasing trend of catastrophic flood impacts in the Huong river basin, may be also related to the human's intervention on the low drainage basin (lowland). While changes in forest covers and land use in the uplands have been shown to have negligible impacts on catastrophic flood levels, more studies are required to understand whether the development of main roads and dyke system in the lowland have significantly contributed to increase catastrophic flood impacts downstream.

Figure 7: Transportation and dyke systems in the Huong river basin



Source: Author's elaboration

3.3 Key socio-economic factors governing land cover change in the Huong River Basin, Thua Thien Hue province, Viet Nam

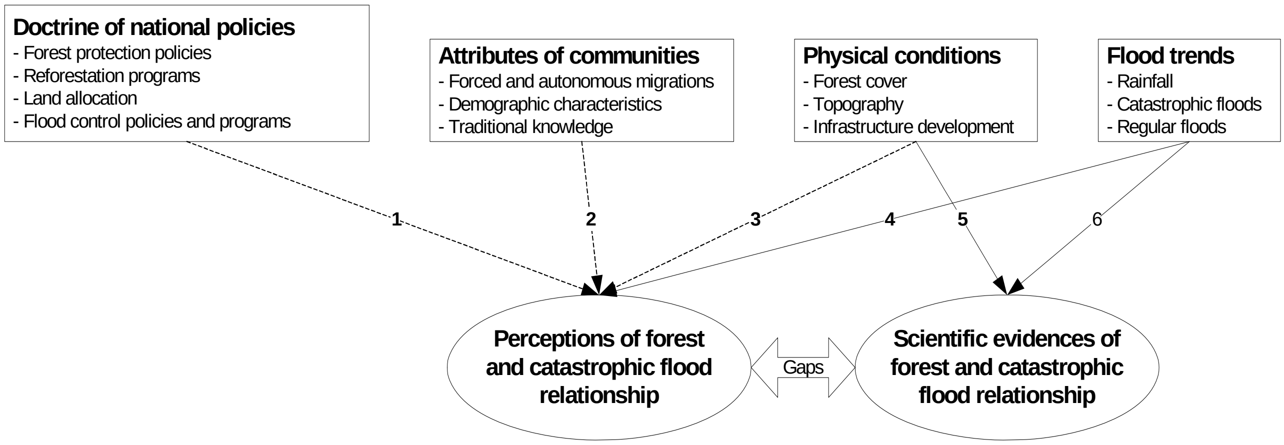
Activities

- Gathering secondary data (land use, socio-economic development, disaster management and forest management policies/programs/projects in Thua Thien Hue and research areas);
- Focus Group Discussion at Binh Thanh, Binh Dien, Hong Ha and Huong Nguyen commune;
- Household survey, semi-structured interview with commune and village leaders at Binh Thanh communes (82 households), Binh Dien communes (119 households), Huong Nguyen communes (97 household), and household survey at Hong Ha communes (94 households);
- Analyzing the disparity between the common perceptions and facts of the forest and flood relationship

Methology

Within the scope of this research, the analyzed factors actors governing land cover change in the Huong River Basin, Thua Thien Hue Province, Viet Nam included: the experiences of forest cover change and flood disasters, the social norms and traditional knowledge, and the perception amongst upland people. This was done through questionnaires and focus group discussions surveys carried out in the mountainous areas and relevant policy analysis. The overall methodology to achieve this output is depicted in Figure 8.

Figure 8: Research framework



Achievements

Experience of forest cover change and flood disasters

One of the important factors governing the land cover change in the uplands of the Huong river basin is the experience of forest cover change and flood disasters. As analyzed in output 1 and 2, because the forest degradation occurred at the same time with the increasing of flood frequency and intensity, upland and lowland people experienced that deforestation linked with the flood disaster. This experience consolidated the perception not only among local communities, but also among Vietnamese policy-makers that forest cover change and catastrophic flood are linked. At a result many forest management policies and land use regulations, which changed from exploitation to protection of the river upper watersheds. The rationale for these forest management policies relied to a large extent on the perception that forests can reduce catastrophic flooding. Hence, to protect the lowlands from excessive floods anything that interferes with the forest integrity was forbidden.

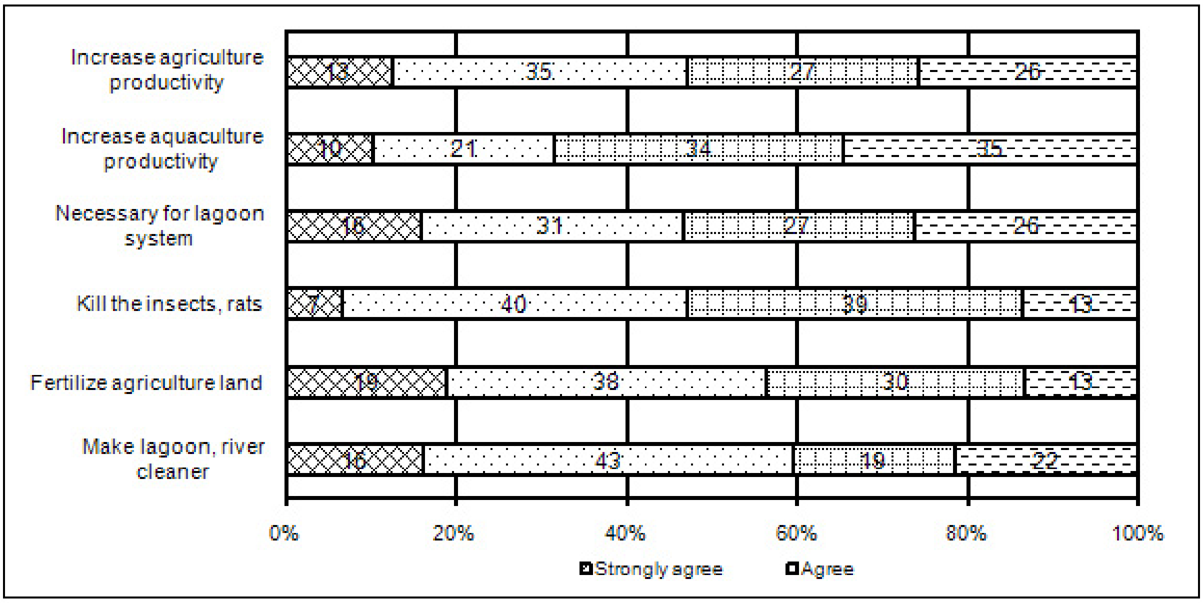
Social norms and traditional knowledge

Forest and flood relationship perception has been influenced by social norms. These norms can be viewed as statements that regulate behavior and act as informal social controls (peer pressure). They are usually based in some degree of consensus and are enforced through social sanctions. For example, the "sacred forests" in the head watersheds have been protected by traditional upland minority social norms. However, starting in 1975, with a large number of lowland people and city dwellers migrating to the upland, these norms started to be ignored. The lowland and city people brought their norms, namely intense lowland farming approach, to the new locations. These norms have gradually influenced the perception of upland people on the forest and flood relationship.

It is important to note that annual flooding in lowland communes has been a perennial phenomenon since ancient time. The Huong river and lagoon system play an important role in local people's livelihoods, such as providing food, water, and transport. The flood-borne sediment provides the nutrients that maintain lowland agriculture and aquaculture, and also serves as a natural irrigation system for the region. For centuries, farmers, fishermen, and others have made the river, delta and its vast lagoon their home. Therefore, the lowland farmers and fishermen living along the lagoon often welcome the annual flood to bring down sediments rich in nutrients and water of sufficient volume to clean the lagoon environment for the next aquaculture crop. A survey in the coastal areas revealed that a high percentage of respondents think that floods help to clean the environment (e.g. rinse lagoon and rivers) (Tran el al. 2008). Floods also bring alluvium to agricultural land and kill insects and rats. Respondents even claimed that every three years, a big flood is needed to refresh the lagoon environment. Many respondents agreed that the production of aquaculture, and agriculture increase after a large flood (Figure 9). However, lowland farmers claimed that they could do little or nothing to avoid destruction from catastrophic floods (Tran el al, 2008). As a result, the common flood coping strategy was to "live together with the flood". Houses were often constructed on elevated areas or high foundations to avoid normal floods, production activities were adjusted to avoid the adverse impacts of the flood as much as possible, and livestock (and other properties) were moved to higher places before the flood season.

In the city, where most of the people are no longer relying on floodplain waters for their livelihoods, normal flood cycles are seen as a danger. For city dwellers flooding is no longer a very important natural phenomenon that keeps the river ecosystem in balance, but rather a negative event provoked by human activities. Thus, flood control measures to protect the city from floodwaters have always been top priorities of the flood risk management. Most of these measures are structural measures, which include the constructions of levees, reservoirs, redistributions of flood flows to other areas, and outlets widening (PCFSC 2000). Forest degradation in the head watersheds is also considered the causes of the catastrophic floods. Thus, the reaction of the government after flooding was to call for an intensification of tree planting. For example, the Vietnamese newspaper Lao Dong reported from a meeting for flood recovery on November 15, 1999 where the prime minister of Viet Nam announced the implementation of the 'five million hectare forest program' in the central provinces as being a priority (Beckman 2006). The Thua Thien Hue provincial committee for flood and storm control also put forest protection in the uplands as one of the priorities to reduce the flood risks for the Hue city (PCFSC 2000).

Figure 9: Positive impacts of annual flood on environment in lowlands

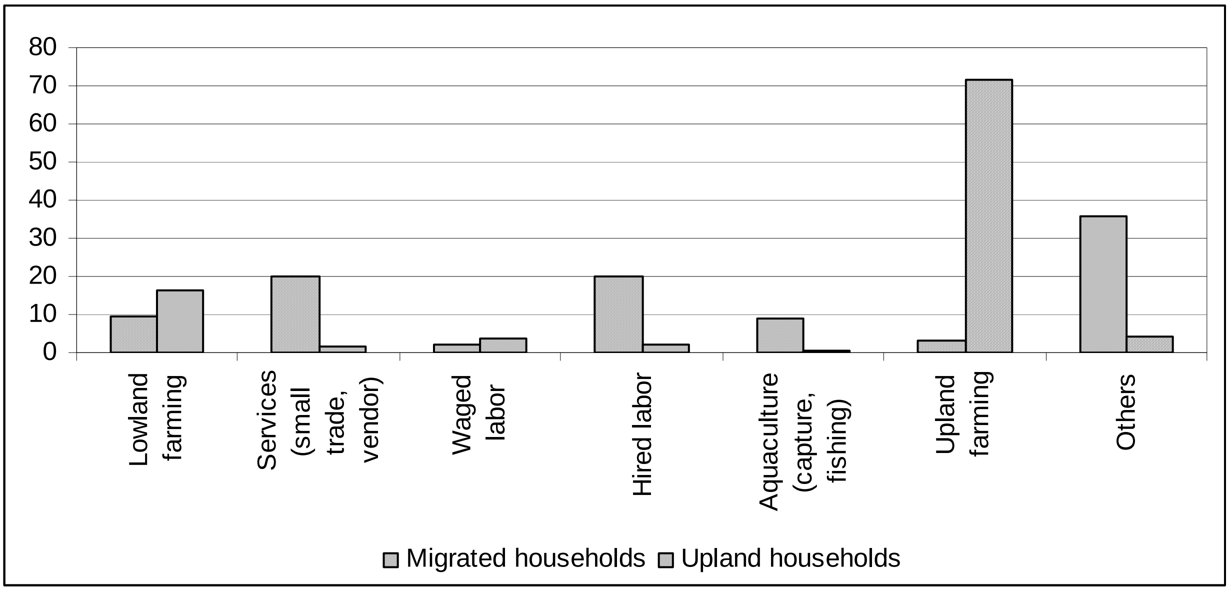


Source: Tran et al 2008

Empirical results of the perception amongst upland people

Before analyzing the perception amongst upland people, it is important to know the human geography of upland population. The survey shows that in the studied area only a slightly majority (54%) of households originated as upland farmers. The remaining households came from Hue city (29%), lowlands (14%), and boat people (3%). In terms of general education, the residents of the surveyed communes received limited schooling. Amongst 404 respondents, only 5% of them had high school education, 23% of them had secondary education, and 72% of respondents had no primary education. In addition, most of the new migrants from outside the uplands had no skills in upland agriculture (see Figure 10) and only 7% of them received upland farming training before moving to the mountains.

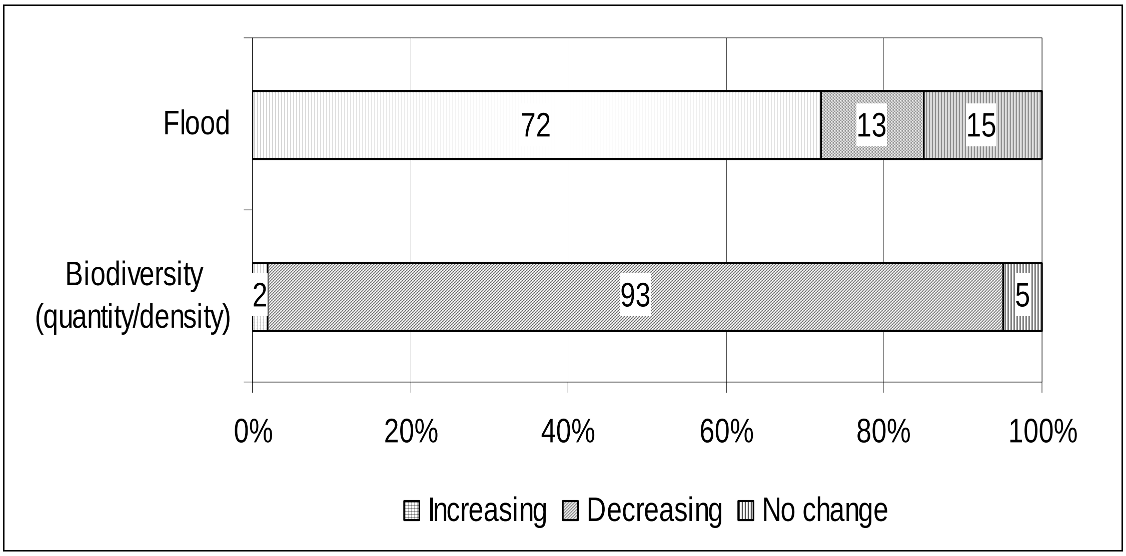
Figure 10: Percentage of main occupation before settling in the uplands



The survey also highlighted that differently from the lowlands and Hue city dwellers, the upland people did not perceived flooding as a serious problem for themselves. 26% of the respondents claimed that flood disasters significantly impacted their families, and only 7% of them stated that flood disasters had seriously impacted their livelihoods.

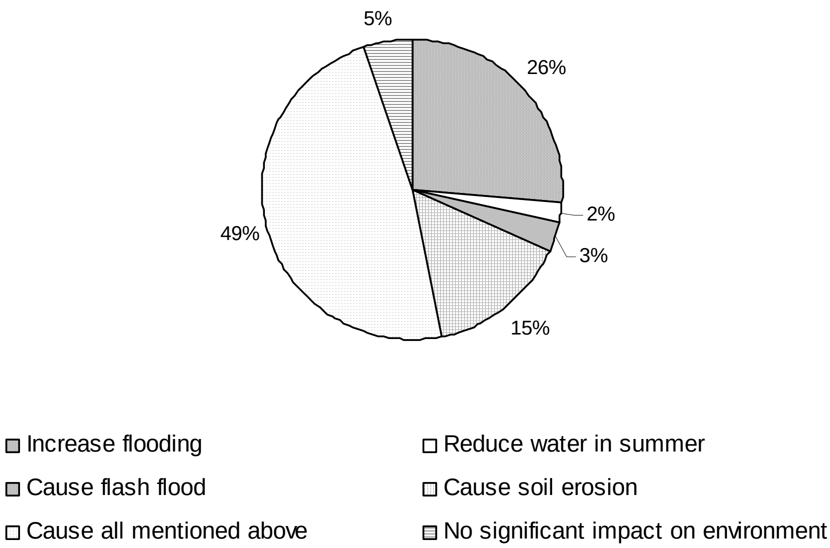
This study highlights that upland people's common perception of the relationship between forest-cover change and flooding appeared to have been shaped in two distinct phases. Before the 1980s, upland people recognized the forest's role in the watershed discharge through their observations and experiences. However, after the 1990s this perspective was gradually shaped by government forestry policies/programs, and mass media persuasion, which started paying increasing attention on the relationship between forest cover-change and catastrophic flooding. Thus, forest management practices of upland communities become perceived as one of the main causes of catastrophic floods in lowlands. For example, as it can be seen from Figure 11, the survey found that 93% of respondents believed that the biodiversity of fauna and flora, in terms of density and quality, have decreased. Most importantly, these changes were seen as concurrently with the increasing of catastrophic flooding.

Figure 11: Observation of upland people on the changing biodiversity and flood



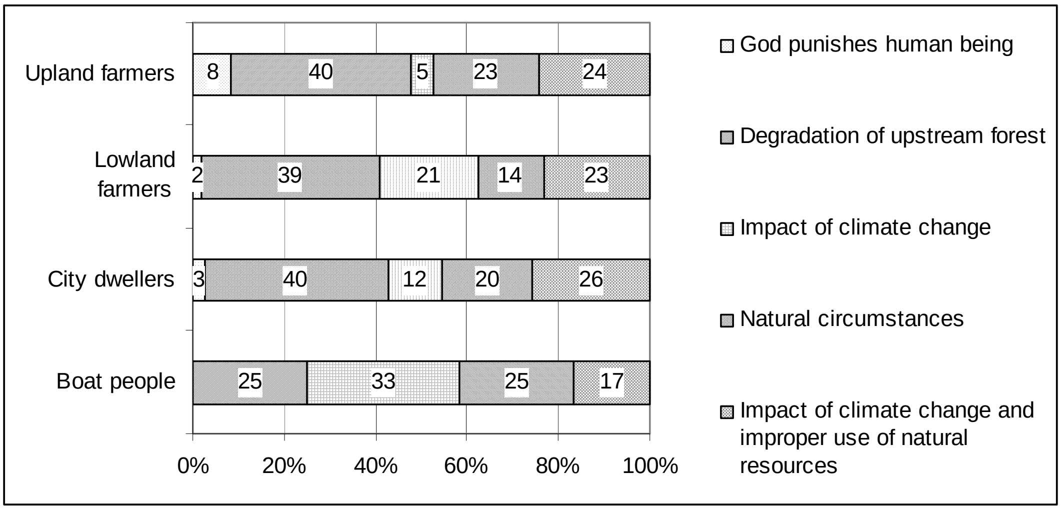
Thus, when asked about the impacts of forest degradation, upland people believed that deforestation impacted negatively the environment, and like the city people, they also believe that degradation of upstream forest causes the catastrophic flooding. Figure 12 shows that almost half of the respondents from the upland communes believed that deforestation significantly intensifies all kind of meteorological related disasters (e.g. flood, flash flood, soil erosion and reduced stream flow during the summer).

Figure 12: Perception of upland people on the impacts of deforestation



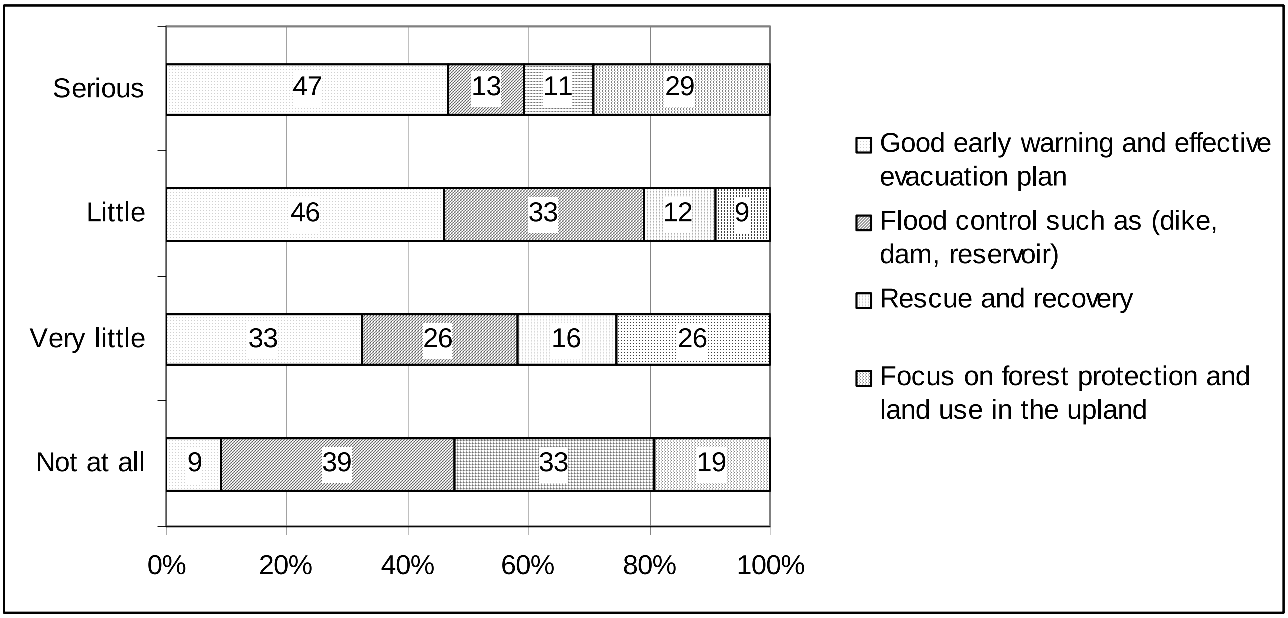
The second most indicated cause of catastrophic floods was the degradation of upstream forest (40% of the total respondents). Remarkably, it can be concluded that upland people now consider themselves responsible of the catastrophic flood downstream. Figure 13 shows that 40% of people who originated from uplands now believe that degradation of upstream forest causes catastrophic flooding downstream.

Figure 13: Perception of upland people on the causes of catastrophic floods



It is difficult to assess to what extent upland farmers believe in the environmental benefits of reforestation (which was mainly pushed by government and international projects) or still rely on their own observations. In fact, in terms of perceive solutions to catastrophic flooding, the majority of respondents thought that flood protections should be based on forecast and mitigation, and only 22% of them thought that forest protection is important. This proposed measure seems to contradict the previous finding that upland people believe that catastrophic floods are due to forest cover changes. Yet, this inconsistency could be explained with the fact that upland people rationally choose the flood mitigation measures that minimally impact their livelihoods. As discussed above, the majority of upland people did not report direct damages from a catastrophic flood, but almost half of the respondents stated that forest protection programs (i.e. State Forest Enterprise and Watershed Management Board) have decreased the family income. It is clear that these policies are affecting the livelihood of upland people making them poorer. Thus, it is likely that only those respondents whose livelihoods were seriously affected by floods, suggested forest protection and better land use management in the upland as the most important measure to mitigate catastrophic floods.

Figure 14: Relationship between the level of flood impact and suggested flood reduction measures



3.4 Develop an integrated approach of environment, development and flood risk management in the context of the Huong River Basin

Activities

- Revisiting the field to check the forest classification and carrying out in-depth interviews with key informants at villages and provincial levels.
- Reviewing the policies on the Huong river basin management and developing a mechanism to integrate disaster risk reduction, environment and development in the Huong river basin.

Achievements

Evidence from this study showed that forest plays negligible role in decreasing catastrophic large-scale flood. In the Huong River basin, most catastrophic floods were caused by climate variability, and by the development of main roads and dyke infrastructures in the lowlands rather than by land-use changes in the uplands. In addition, floods in the Huong River basin, although causing losses and damages that often inhibit economic development, are also essential elements for the agricultural subsistence of the lowland populations. Flooding in coastal areas is a vital element of the culture and economy of the people whose livelihoods are based on local natural resources. Over time these lowland communities developed coping mechanisms to reduce the negative impacts of floods, and take advantage of their positive effects. At present, these coping mechanisms are under pressures due to the increasing water level of catastrophic floods induced mostly by climate change/variability and improper development of the build environment.

It is important to note that at certain level of rainfall or for certain rainfall patterns, forest may play a significant role, but above that level or in other patterns forest role becomes minor as in the case of heavy rainfall which caused catastrophic flood in the Huong river basin. Furthermore, although forest cannot stop catastrophic flood, native forests do reduce the frequency and severity of normal floods in developing nations (Bradshaw et al. 2007, Calder et al. 2007, Laurance 2007). Moreover, large expanses of native forest can have major benefits not only for reducing floods, but also for limiting wild fires, conserving biodiversity, and slowing regional and global climate change (Clark 1987). Tropical forests, in particular, are crucial for combating global warming, because of their high capacity to store carbon and their ability to promote sunlight-reflecting clouds via large-scale evapotranspiration (Bala et al. 2007). Hence, an integrated river basin management approach that considers various measures in the uplands with those in the lowlands and look beyond the simplistic forest-flood relationship at the whole basin scale is greatly needed.

Based on the findings of this research, there are five specific recommendations for catastrophic flood management in the Huong River basin:

- Strengthen the early warning system and flood evacuation plan, as the most catastrophic floods have been caused by climate variability that is unpredictable due to the emerging impacts of climate change.

- Develop a zoning plan and policy for the entire basin to mitigate the impacts of flood disasters. The identification of clearly defined high-risk areas and the formulation of a strong provincial policy with respect to developments in these high-risk areas, perhaps creating exclusion zones, can help avoid more lives and valuables being lost in the next flood disaster.

- Raise the awareness among local communities and flood risk management stakeholders that forests may play a significant role in reduce flood risk, but when the rainfall exceeds a certain level, forests have only a minor role in reducing flood risk. This is very important when developing forest management and land use policies and programs.

- Enhance the adaptive capacity of people, particularly the upland people, to cope with natural disasters. The capacity of people living in vulnerable areas should be enhanced to adapt to the effects of climate-induced flood disasters. The safety issues need to be weighted more carefully against the socio-economic and environmental interests, as the human safety issues are vital for the sustainable socio-economic development of the province.

- Include a requirement for flood risk assessment in environmental impact assessments (EIA) of all civil, economic project/works in the Huong River basin. Improper infrastructure development has intensified flood disasters, as the study revealed that catastrophic floods were intensified by the development of main roads and dyke infrastructures in the lowlands.

Within the setting of such a policy, it is important to develop a wide range of integrated disaster management measures, whereby a balance should be found between structural and non-structural measures. Furthermore, a clear distinction should be made between measures that can best be developed at a local level through a community based approach, and measures that need a more over-arching intervention from higher level authorities and other actors. Such a management policy should comprise all the activities required to organize sustainable use of the land and the other resources available within the Huong basin, while at the same time maintaining and supporting the livelihoods of the inhabitants. This approach should integrate land-use management in the uplands with land-use planning, engineering measures, flood preparedness and emergency management in the lowlands. It should also consider the social and economic needs of communities living in both the uplands and lowlands. Integrated management has to be based on the best available scientific knowledge of the causes of floods and their environmental, social and economic impacts. Essentially, this approach should prepare people to live with and adapt to floods.

A rational river basin integrated approach should consider social vulnerabilities as a core risk component of flood disasters, and thus should demand more local and community stakeholder involvement. Local communities should not be passive recipients or victims, but active partners with a real voice, and some power. Management plans should be formulated for the entire basin in close consultation with all stakeholders. An integrated approach should promote the activities that have been already implemented and that have been known to make good sense from all perspectives (poverty alleviation, economic development, natural hazard risk, sustainable natural resources management, biodiversity conservation, urban-rural development etc.). Trade-offs of different decisions must be evaluated; for example, foregoing short-term benefits for long-term sustainability. All aspects, including information based on the scientific facts, must be taken into account when such decisions are being made, and ensure that all those involved are able to contribute to, and benefit from, the changes.

Incentives should be offered to encourage desired land uses and land-management practices, and to align private interests with the public good. Compensation should also be provided to land users negatively affected by the plans. To ensure that the objectives are being achieved and that costs and benefits are equitably shared, the results of the implementation of certain strategies should be monitored and the impacts of various policies assessed. Furthermore, because management objectives change over time as priorities and land-use practices evolve, the entire process should be evaluated on a regular basis and, if necessary, objectives or activities could be adjusted to meet new requirements or expectations. This is a dynamic process that ensures, through the various feedback mechanisms, that objectives remain realistic and reachable without causing unacceptable and unmanageable environmental and socio-economic consequences. In the Huong River basin agriculture and fishing remain very important sectors and the loss of beneficial effects from the normal flooding could potentially lead to unacceptable economic and social disruption. Unfortunately, what is beneficial to agriculture and aquaculture may inflict heavy economic costs upon other economic sectors and vice versa. Hence, the challenge is to balance costs and benefits within the entire river basin.

Finally, past experiences with floods have shown that the most cost-effective means of reducing the impact of flood disasters is the nonstructural approach of providing people with sufficient advance warning to escape. Hence, because the catastrophic floods in the Huong River basin appear to be caused by climate variability, priority should be given to the development of early warning system and dissemination networks within the entire basin.

4. DISSEMINATION AND ANTICIPATED IMPACTS

4.1 Dissemination

A paper titled "Catastrophic flood and forest cover change in the Huong river basin, Central Viet Nam: A gap between common perceptions and facts" based on the results of this study has been submitted to the international journal *Global Environmental Change: Human and Policy Dimensions*.

4.2 Anticipated impacts

In the case of the Huong River basin, the misperceptions about the causes of flooding that have incorrectly influenced decision-makers, planners and managers alike, need to be replaced by a rational understanding based on facts. It should be clear that in large-scale reforestation programs, the adoption of soil and water conservation technologies in agriculture, logging bans and the resettlement of upland people to lowland areas will not significantly reduce the incidence or severity of catastrophic floods. Importantly, the unfounded habit of blaming upland dwellers for catastrophic floods must be abandoned. Instead, practical solutions are needed to redress watershed degradation caused by inappropriate infrastructure development. Moreover, policy-makers and development agencies have a moral and ethical responsibility to ensure that new regulations and strategies are based on the best available scientific knowledge and avoid placing unnecessary vulnerabilities on upland communities.

While the ability of forests to prevent catastrophic floods appears to be limited, watershed management should definitely not be abandoned. Forests provide a variety of environmental services, which need to be protected and nurtured for the benefit of today's and tomorrow's upland and lowland populations. Watershed management must consider the needs and interests of local populations, but should also account for the needs of the wider society.

The most effective approaches to reducing damage caused by catastrophic floods in the Huong River basin require a strong focus on downstream zones and floodplains. People in these areas need to 'learn to live with flood'. At the same time, policymakers need to abandon their belief in quick fixes for flood-related problems. While the high costs of floods in the lowlands are evident, it is important that the beneficial aspects of floods are also acknowledged. It is only by promoting and supporting comprehensive integrated watershed and floodplain management that the needs and aspirations of all residents can be adequately addressed.

5. CONCLUSION ON PROJECT ACHIEVEMENTS

The impacts of major land use policies/programs on the land cover in the mountainous areas of Thua Thien Hue from 1989 to 2008 was analyzed and revealed that in the study area there was a significant change in land cover during the period of 1989 to 2008 due to the significant impacts of land use policies and programs in the uplands. The experiences of forest cover change and flood disasters, the social norms and traditional knowledge, and the perception amongst upland people were analyzed and considered as important factors actors governing land cover change in the Huong River Basin, Thua Thien Hue Province, Viet Nam. The relationship between land cover change and the flood disaster in Thua Thien Hue was carefully examined and the research revealed that the forest cover change appears not to have carried significant role on the catastrophic flood levels. In case of catastrophic floods, 71% of the variance of flood level in the downstream areas was accounted for by the variance in rainfall. Evidences from the project showed that the significant increasing trend of catastrophic flood impacts in the Huong River basin was mainly due to climate change/variability and to the development of main roads and dyke infrastructures in the lowlands. There is also a gap in the common beliefs and the actual relationship between forest cover change and catastrophic flood. Hence, forest management policies and programs shaped on the common assumption that forest degradation is the main cause of catastrophic flood in the downstream areas, should be reassessed to avoid unnecessary vulnerabilities on upland people. The integrated approach of environment, development and flood risk management for the context of Huong River basin, Thua Thien Hue province with five specific recommendations has been proposed based on the evidences and analyses of the project.

6. APPENDICES

6.1 Literature review

Introduction

Floods in Viet Nam are well known phenomena and occur in all regions of the country, especially in the Central Coast region, Mekong delta, and Red River delta (Socialist Republic of Viet Nam 2007). People had to learn to live with floods, particularly those whose livelihood depends on the productive functions of annual flooding. Floods are well known and embedded in the Vietnamese culture, as ancestors of the Vietnamese nations regarded flooding as one of the four biggest dangers to people, along with fires, robbers, and invaders (Tran et al. 2008).

In Central Viet Nam, according to Tran and Shaw (2007), there are strong evidences that unsustainable agricultural practices and inappropriate development programs have contributed to substantial increase of flood risks. Floods cause damage to natural resources and environmental quality and indirectly contribute to increasing poverty, which in turn further add to the vulnerability of both natural and human systems. The environment and flood linkage has been recognized, and many environmental programs such as reforestation, forest protection, upland fixed cultivation and resettlement, have been implemented to reduce flooding since 1990s. These flood management measures have achieved significant results in reducing the negative effects of low magnitude flooding. However, they are now under pressure because they are also used as main measures to reduce the risks of catastrophic floods, which are unfortunately increasing both at the local and global level.

Thua Thien Hue province is one of the most disaster-prone areas of Viet Nam. With a mixed geomorphology of mountains and coastal plains, the province is subject to severe extreme events such as typhoons, and floods. These hazards appear to have worsened in recent years, causing devastation to the entire province, particularly to vulnerable populations in mountainous areas and along the coastal zones. See for example, the flood of November 1999 in Central Viet Nam killed 780 people, affected around one million residents, and sunk and damaged more than 2,100 boats. The economic damage was worth US$364 million (CCFSC, 2006). Various other catastrophic floods, with water levels were above the alarm level II (see Table 2), also caused severe losses of human lives, assets and infrastructures.

Table 2: Flood Alarm Levels Used in Viet Nam

Warning level	Description
Alarm Level I	Possible flood condition - River water level is high; threat to low height embankments; flooding of very low lying areas; infrastructure safe.
Alarm Level II	Dangerous flood condition - Flood plane inundation expected; towns and cities still generally protected by flood defenses; high velocity river flows pose danger of bank and dyke erosion; bridge foundations at risk from scour; infrastructure generally safe.
Alarm Level III	Very dangerous flood condition - All low lying areas submerged, including low lying areas in cities and towns; safety of river protection dykes in jeopardy; damage to infrastructure begins.
Alarm Level III +	Emergency flood condition - General and wide spread uncontrollable flooding; dyke failure a certainty and probably uncontrollable; damage to infrastructure severe.

Source: Central Committee for Flood and Storm Control (CCFSC) available at http://www.ccfsc.org.vn

Global climate change impacts have been widely recognized as the causes of intensification of the global water cycle with a consequent increase in flood risk (Milly et al 2002). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) states that warming of the Earth's climate is now unequivocal. At the continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include the frequency of heavy precipitation events that have increased over most land areas. As a result, more intense floods have been observed over wider areas since the 1970s, particularly in the tropics and subtropics (IPCC 2007).

Yet, despite these findings, after each catastrophic flood, deforestation and rapid land use changes in the uplands are still blamed as one of the main causes. The underlying argument is that these floods were mostly induced or aggravated by human interference with the hydrological system. Consequently, many national and international government programs on natural resource management and economic development have hard-pressed for forest protection and reforestation, and improvement of land use practices in the uplands, as important remedies to reduce the catastrophic floods in the lowlands. See for example the United Nations World Food Program (WFP – often identified by the acronym PAM in Viet Nam), the 'fixed cultivation and settlement' program, the Viet Nam government program 327 and the Five Million Hectares Reforestation Program (5MHRP).

Thus, unlike the regular flood-risk-management procedures, which have been developed in Viet Nam for centuries, the more demanding measures necessary to effectively deal with catastrophic floods are more difficult to implement because misperceived among local people and decision makers (especially those at higher levels). There are two main misperceptions that challenge the development of effective measure to reduce catastrophic floods. First, because of the low frequencies of such events, people often believe that a catastrophic flood will not hit them, and that their lives and property will not be destroyed. Therefore, they prepare for floods at a level commensurate with the worst disaster they experienced, and not for the greater floods that are likely to strike in the future. Second, conventional wisdom about the flood-prevention role of forests, has clouded the perspectives of decision makers, leading to an over-emphasis on reforestation and forest protection at the expense of more holistic watershed and river-basin management. These misperceptions coupled with the lack of resources for disaster preparedness or risk assessment leave many communities unprepared for catastrophic flood.

It becomes evident that it is necessary to understand the mechanisms governing individuals and communities' perception of catastrophic flood risks and how they invest and act to prepare for those events. Hence, this study analyzed the disparity between the scientific evidences relating the causes of catastrophic floods and the common perceptions on the relationship between forest and flood. Investigations also comprised the impacts of the perception-based mitigation measures of catastrophic floods in the Huong River basin of Thua Thien Hue Province. The report begins with the literature review of the common perception and the scientific knowledge of the relation between forest and flood.

Common perception and science on the relationship between forest-cover change and flooding

In many cultures there is a strong belief that forests can prevent or reduce floods (FAO & CIFOR 2005). A review of Hamilton (1992) on the linkage between tropical forest and flood reveals that many newspapers and journal articles have blamed devastating floods on logging or firewood cutting in upper watersheds. For instance, both Openshaw (1974) in the case of India and Corvera (1981) in the case of the Philippines supported this contention. Sharp and Sharp (1982) also stated that: "over logging is now officially recognized as the cause of the July 1981 severe flooding of the Yangtze" in China. Reporting on the Bangladesh floods of August 1988, which killed 1,600 people and left 30 million homeless, an article from the Knight-Ridder news service (Kaufman 1988) was entitled "Bangladesh flood disaster blamed on deforestation", and it went on to say: "By almost all accounts, the main environmental problem is the widespread and growing deforestation of the Indian and Nepalese mountains to the north of Bangladesh."

The rationale behind this belief is that all forests tend to have higher evaporation rates than other types of vegetation, and natural forests exhibit higher infiltration rates, due to porous soils and the existence of under storey and humus layers. The combination of these two factors generally contributes to lower runoff. Some types of plantation forests may also increase infiltration rates by providing preferential flow pathways down both live and dead root channels (FSIV & IIED 2002). Therefore, it is often argued that forest covers, compared to most alternative vegetation cover types, will always diminish the risks of downstream flooding (FAO & CIFOR 2005). Land use activities in uplands are also commonly believed to have significant impacts on storm runoff volume, peak magnitude and timing of the peak. Thus, the immediate frequently drawn conclusion is that floods occur because forests have been cleared or degraded.

However, many scientific observations reported that direct links between deforestation and floods are far from certain, and hydrological systems are so complex that it is extremely difficult to disentangle the impacts of land use from those of other natural processes and phenomena (Hamilton and Pearce 1988, Chomitz and Kumari 1998, Walker 2002, Bruijnzeel 2004, Andreassian, 2004, Kaimowitz 2004, Enters et al. 2004, FAO&CIFOR 2005, Calder et al. 2004, Hayward 2005, Calder and Aylward 2006). In the case of upland/lowland as well as forest and flood relationships, existing knowledge is frequently based more on perceived wisdom, or myths, than on science (FAO&CIFOR 2005). In the rush to identify the causes and responsibilities of the most recent flood disaster, assumptions are made about processes in one region based on observations from other regions, which often have quite different environmental characteristics, or by extrapolating from small to large scales.

Considerable scientific doubts remain about most of these linkages, since many of them are highly complex and dependent on site-specific conditions. Scientific assessments have shown the following claims. First, it is often the management activities associated with forestry, cultivation, drainage, road construction, which are more likely to influence the size and frequency of floods than the presence or absence of forests themselves (Anderson et al. 1976, Jones & Grant 1996, Bradshaw et al 2007). Furthermore, while clearing and other forestry management operations can cause short-term increases in runoff, the relative magnitude of these events is inversely proportional to the magnitude, intensity or duration of the storms (FSIV & IIED 2002). Hence, little of the impact of floods from large storms can be attributed to changes in land use (FSIV & IIED 2002). For the largest, most damaging flood events there is little scientific evidence to support anecdotal reports of deforestation being the cause. Instead, flood events are more likely to result simply from climatic events. Evidence from Viet Nam, for example, shows that about 78% of discharge from the Da River happens from June to October each year, and that regardless of changing land use, large floods occur approximately every 8-9 years and very large floods approximately every 23 years (FSIV & IIED 2002).

Second, many research confirm that during heavy storms in small watersheds, storm-flow volumes are higher from bare land or logged slopes than from areas where natural forests remain intact. However, evaluation of the basin-scale effects has been problematic (Tu et al. 2005). Scale consideration is also of fundamental importance when assessing impact of land use and its change (FAO & CIFOR 2005). Increases in peak discharges from any headwater catchment can have little effect on downstream peaks because of the routing and de-synchronization that normally occur. However, when storm flow volumes from upland catchments are increased and not damped along the river channel, they can result in a cumulative effect on downstream volumes and peak discharges (Brooks et al., 1997). Some scientists also argued that the evidence for a strong connection between deforestation and increased flooding is uncertain, and that hydrological data do not demonstrate that good vegetative cover in large river basins is necessarily a factor in preventing rapid runoff of storm water (Ross 1984). Others suggest that there is no convincing evidence of an increase in runoff, despite the supposed increased incidence of flood disasters (Ives and Messerli 1989).

Based on the above arguments, it may not be appropriate to state on the direct effect of deforestation to flooding. Nevertheless, it is important to note that deforestation brings detrimental impacts to the adjacent environment increasing the vulnerability of local communities (Tran and Shaw 2007). Unlike the problem of deforestation in relation to landslides where there may be a much more immediate connection between cause and effects (Wisner et al. 2004), deforestation and flooding causation is complex and often widely taken for granted, but not substantial (Wisner et al. 2004). Deforestation and 'de-vegetation' have many causes, and the effects of various patterns of land use can be significantly different from place to place. The relationship between land use and hydrology is complex and thus difficult to be generalized from each case.

6.2 Methodology to identify forest and flood relationship

There are three main weather stations in the Huong River basin: Hue, A Luoi and Nam Dong stations. The Hue station, which is located in the downstream of the Huong River near Tam Giang Cau Hai lagoon, provided data to characterize the floodplain and the coastal area. The A Luoi station, located at an elevation of 600m and within the watershed forest, provided data to characterize the mountainous upstream area. The Nam Dong station, which is located in the transition areas between coastal lowland and mountainous areas at the south of the Huong basin in the toe of Bach Ma mountain, provided data to characterize the transitional inland zone. Amongst the various parameters of these three weather stations, this study focused on the rainfall data of the least 30 years to find out the changed trend. Monthly as well as daily records were available to analyze precipitation patterns. The records available from the Hue station covered a period of time from 1928 to 2004, whereas the records from the Nam Dong and the A Luoi stations were from 1974 to 2004. The hydrological data such as the peak discharge, floodwater level, and time to peak, were obtained from two selected gauging stations in the Thuong Nhat for the Ta Trach tributary, and the Kim Long for the Huong River. The Thuong Nhat gauging station had records of daily discharge from 1981 to 2001 and the maximum floodwater level record of each year from 1979 to 2000. The Kim Long station had records of the maximum floodwater level from 1977 to 2005.

These hydro-meteorological data were obtained from Institute of Meteorology and Hydrology (IMH 2006).

Statistical analysis were applied to test if there is any upward and downward trend of rainfall, maximum flood level, and number of catastrophic flood of each year for the last thirty years. The linear regression model was used to evaluate the correlation and variance between the flood level/number of catastrophic flood and the rainfall in the upstream areas. The study also used the rational method in hydrology to detect the runoff coefficient in a small watershed located in the Nam Dong areas. The peak discharge at Thuong Nhat station of each month, and the day occurring rainfall peak discharge were also used in this analysis. The rainfall data for calculating runoff coefficient was obtained from Nam Dong weather station. Mathematically, the rational method relates the peak discharge (q, m^3/sec) to the drainage area (A, ha), the rainfall intensity (i, mm/h), and the runoff coefficient (C) with the following equation:

$$C = \frac{q}{A \times i}$$

Following are the assumptions used in this rational method: (i) rainfall intensity and duration is uniform over the area of study; and (ii) storm duration must be equal to or greater than the time of concentration of the watershed. Since the time of concentration is the time required for water to flow from the most remote point of the area to the outlet once the soil has become saturated and minor depressions filled, it was assumed that when the duration of the storm equals the time of concentration, all parts of the watershed are contributing simultaneously to the discharge at the outlet. Finally, considering that the studied watershed is relatively small, about 212km^2, it was treated as belonging to the same microclimate zone (See Figure 1). Thus, because during the flood season in Thua Thien Hue the rainfall duration is normally very long, from three to four days, the above assumptions (i) and (ii) were easily satisfied in the studied watershed.

6.3 Classifying land cover and detecting land cover change

The spatial and temporal data to detect land cover changes over the past two decades are not available for the entire basin. Therefore, this study focused only on one of three main sub-watershed of the Huong River basin, the Huu Trach watershed. Changes in land cover were measured using time series of satellite data. Remote sensing images for the research area were interpreted for the years 1989 (thematic mapper, TM), 2005 (SPOT), and 2008 (Advanced Spaceborne Thermal Emission and Reflection - ASTER) (see Table). All images were taken in the spring season between the 16th of February and the 17th of March of all three years. Hence, these images stem from the same cropping season and from comparable climatic conditions. A Digital Elevation Model

(DEM) with the resolution 15x15m from ASTER, was also obtained to delineate the watershed boundary. In addition, other available ancillary maps such as QuickBird image, topography, hydrology and road system, commune boundaries were geo-referenced, and merged to obtain a consistent set of base information. These maps allowed the verification of land cover delineation using additional point information and linear features such as, roads, and rivers. In addition, statistics and descriptions of the past land use and available from other sources, including official statistical yearbooks, regional statistical database, scientific publications and project reports etc., were also used in combination with results from the analysis of remote sensing images. The data gathered allowed to present an overall picture of land-use changes in Huu Trach watershed.

Table 3: Remote sensing images

Satellite Image	Resolution	Imaging date
Landsat TM	28.5x28.5 m	Feb 17, 1989
SPOT	10x10m	Feb 16, 2005
ASTER	15x15m	Mar 17, 2008
QickBird	1x1m	April 6, 2006

Unsupervised classification methods ISODATA, which are mostly based on spectral information, were used to extract the main land cover types. Because some land cover classes had similar spectral properties, it was difficult to differentiate such cover classes only using this automatic classification algorithm. Thus, interpretation procedure that utilized other supporting information such as ground truth data from GPS survey, finer-resolution data from QickBird image, and other land use thematic maps to develop the land cover, were used.

Table 3 represents the procedure of land cover classification and change developed for this study. Four major phases can be identified. First, the 1989 Landsat, 2005 SPOT-5, and 2008 Advanced Spaceborne Thermal Emission and Reflection (ASTER) images, were projected to UTM 48N, WGS84, to match the existing ancillary data. A nearest neighbor re-sampling method was applied during geo-referenced process with a pixel spacing the same as the original images in order to maintain the integrity of the pixel values. The geo-referenced images were clipped to the Huong River basin boundary. Although the images do not cover the entire the Huong River basin, they do cover the entire Huu Trach watershed. Second, the Normalized Difference Vegetation Index (NDVI) images were created. NDVI is the most widely used of all vegetation indices because it only requires data from the red and near infrared portion of the electromagnetic spectrum, and it can be applied to virtually all multi-spectral data types. NDVI has demonstrated to be well suited for monitoring broadleaf forest condition, and for many other applications (Lunetta & Elvidge, 1999), and is least affected by topographic features (Lyon et al., 1998). The equation used was: NDVI = (NIR – Red)/(NIR + Red). Third, ISODATA unsupervised classification was applied to extract objectively 24 classes of each NDVI image. These 24 classes were interpreted using field data, local knowledge, and evidence from finer-resolution image of QuickBird taken in 2006, and allocated into five major land cover types (see Table 4).

Table 4: Classification system used for land cover mapping

No	Classification	Description
1	Rich Natural Forest	The forest has a stable structure, multi-story, diverse diameter sizes, but sometimes lacking lower story. The stable structure of the forest has not changed; biomass is high with a high percentage of large trees.
2	Medium Natural Forest	Heavily exploited forest, but significant time for regeneration. The forest has at least two stories; the upper story coverage is not continuous, being mostly established by the trees from the lower story before; there are maybe a few large trees.
3	Poor Natural Forest	Most heavily exploited forest. The upper story may have some large trees, but generally the forest is of low quality with numerous of vines, bushes, and bamboos.
4	Regenerating Forest and Plantation	Regenerating forest with pioneer species that have smaller diameter. These forest, regenerating after agricultural activities are characterized by pioneer species that are fast growing and prefer light. Trees are of similar age and there is only one story.
5	Non forest	Includes water, grasses, bushes, wild bananas, scattered wooden trees and bamboos, and other human land uses such as agriculture, villages.

A majority filter was applied to the land cover to remove some ‘speckle’ effects that can occur when classifying images on a pixel basis in areas of very mixed land cover. The majority filter was based on a window size of 5x5 pixels. If pixels within the 5x5 area were of a minority class, these were reallocated to the neighboring majority class. The outputs of these steps were the land cover maps for the years 1989, 2005 and 2008. Forth, and finally, the comparison of these land cover maps, using with ArcInfo and ERDAS software, allowed detecting the land cover changes, both spatially and quantitatively.