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Catastrophic flood and forest cover change in the Huong river basin, central Viet Nam: A gap between common perceptions and facts

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ABSTRACT

Recent catastrophic floods in Viet Nam have been increasingly linked to land use and forest cover change in the uplands. Despite the doubts that many scientists have expressed on such nexus, this common view prompted both positive forest protection/reforestation programs and often-unwarranted blame on upland communities for their forest management practices. This study discusses the disparity between public perceptions and scientific evidences relating the causes of catastrophic floods. The former was drawn on the results of a questionnaire and focus groups discussions with key informants of different mountainous communities, whereas the latter was based on GIS and remote sensing analysis of land cover change, including a statistical analysis of hydro-meteorological data of the Huong river basin in Viet Nam. Results indicate that there is a gap between the common beliefs and the actual relationship between the forest cover change and catastrophic floods. Undeniably, the studied areas showed significant changes in land cover over the period 1989–2008, yet, 71% of the variance of catastrophic flood level in the downstream areas appeared related to variance in rainfall. Evidences from this study showed that the overall increasing trends of catastrophic flooding in the Huong river basin was mainly due to climate variability and to the development of main roads and dyke infrastructures in the lowlands. Forest management policies and programs, shaped on the common assumption that forest degradation in the upland is the main cause of catastrophic flood in the downstream areas, should be reassessed to avoid unnecessary strain on upland people.

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1. Introduction

Floods in Viet Nam are well known phenomena and occur in all regions of the country, especially in the central coastal region, Mekong delta, and Red River delta (Socialist Republic of Vietnam, 2007). People have had to learn to live with floods, particularly those whose livelihood depends on the productive functions of annual flooding. 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 a substantial increase in flood risks. Floods cause damage to natural resources and environmental quality and indirectly contribute to increasing poverty, which in turn add to the

vulnerability of both natural and human systems. To reduce flooding, many environmental programs such as reforestation, forest protection, upland fixed cultivation and resettlement have been implemented to reduce flooding since 1990s. These measures have achieved significant results in reducing the negative effects of low magnitude flooding (The Socialist Republic of Vietnam, 2007). However, these measures may not be adequate to reduce the risks of catastrophic floods which are unfortunately increasing both at the local and global level.

Thua Thien Hue province is one the most disaster prone areas of Viet Nam, subjected to both 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. For example, the flood that hit the province in November 1999, which killed 780 people, affected around one million residents, and sunk or damaged more than 2100 boats. The economic damage was worth US\$364 million (CCFSC, 2006). Various other catastrophic floods, with water levels above alarm level II (see Table 1), also caused severe losses of human lives, assets and infrastructures.

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The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007, p. 5) 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, including the frequency of heavy precipitations that have increased over most land areas. Therefore, more intense floods have been observed over wider areas since the 1970s, particularly in the tropics and subtropics (IPCC, 2007, p. 7–8). In Viet Nam, in particular, the IPCC observed that there are more typhoons and floods with higher intensity. The typhoons with abnormal movement often occur simultaneously with floods (MONRE, 2008). 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. For example, the Vietnamese Prime Minister announced the implementation of the “five million hectare forest program” to reduce flood risks (Decision 100/2007/QĐ-TTg, 2007). This has become a priority in the central provinces where deforestation was identified as a major cause of the deadly flood. Similarly, the Thua Thien Hue provincial committee for flood and storm control also listed forest protection in the uplands as one of the priorities to reduce the flood risks for the Hue city (PCFSC, 2000). The underlying argument is that these floods were mostly induced or aggravated by human interference in the hydrological system. Consequently, many national and international government programs on natural resource management and economic development have been hard-pressed for forest protection and reforestation and for improving land use practices in the uplands, as important remedies to reduce the catastrophic floods in the lowlands. Evidence can be seen in 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 they are misperceived among local people and decision makers. There are two main problems that challenge the development of effective measures to reduce catastrophic floods. Firstly, the low frequency of such events reduces people's awareness of a flood risk. Secondly, 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.

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 paper studies the disparity between the scientific evidences relating the causes of catastrophic floods and the common perception on the relationship between forest and flood in the Huong river basin of Thua Thien Hue province.

2. 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 and CIFOR, 2005). A review of Hamilton (1992) on the link between tropical forests and floods 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 a flood case in India, and Corvera (1981) in a flood case in the Philippines have 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 1600 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 understorey and humus layers. The combination of these two factors generally contributes to lower runoff (FSIV and IIED, 2002). Therefore, it is often argued that forest covers, compared to most alternative vegetation cover types, will diminish the risks of downstream flooding (FAO and CIFOR, 2005). Not surprisingly, agricultural activities in uplands are also commonly believed to have significant impacts on storm runoff volume, peak magnitude and timing of the peak.

Contrarily to the above described common beliefs, scientists contend 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 and CIFOR, 2005; Calder et al., 2004; Hayward, 2005; Calder and Aylward, 2006). Moreover, from a hydrological perspective, the impact of (i) natural forests, (ii) forest clearing, and (iii) reforestation on water flowing, is different (van Dijk et al., 2009).

Scientific assessments have shown that it is often the management activities associated with forestry, cultivation, drainage or road construction, rather than the presence or absence of forests themselves, to influence the size and frequency of floods (Anderson et al., 1976; Jones and Grant, 1996; van Dijk et al., 2009). Certainly, forest clearing, and other forestry management operations can cause short-term increases in runoff as they are often associated with a reduction in soil infiltration rates and increase in superficial drainage. The literature confirms that heavy storms over small

Table 1
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>

watersheds create higher flow volumes on 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 and CIFOR, 2005).

In a joint publication of the Forest Science Institute of Vietnam and of the International Institute for Environment and Development (2002), it is argued that little impact of floods from large storms can be attributed to changes in land use. Even reforestation projects did not always reduce flooding. Other factors, such as soil properties, river bed morphology, or pre-existing level of soil moisture play an important role in affecting water flow.

For the largest and most damaging flood events, there is even less scientific evidence to support anecdotal reports of deforestation being the cause. Instead, flood events are more likely to simply result from climatic events. Evidence from Viet Nam shows that about 78% of the discharge from the Da River occurs 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 and IIED, 2002).

Based on the above arguments, it may not be appropriate to state on the direct cause–effect of deforestation and flooding. That said, it should not be forgotten that deforestation causes detrimental impacts on the adjacent environment increasing the vulnerability of local communities (Tran and Shaw, 2007). For example, deforestation is not only linked to decreasing rates of evaporation, but also responsible for reduced moisture flow and water retaining capacity. Impacts of deforestation are more severe in the highlands, propagating to the lowlands such as river silt up (affecting the crops depending on these waters). 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, although not substantiated (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. Yet, in the aftermath of a flood disaster and in the rush to identify the causes and responsibilities, assumptions are made about processes in one region which are based on observations from other regions. These in turn often have quite different environmental characteristics (see for example the comment of van Dijk et al., 2009, about the article of Bradshaw et al., 2007, both published on *Global Change Biology*).

3. Research in uplands of the Huong river basin

3.1. Characteristics of the study area

The Huong river basin is the largest basin of ThuaThien Hue Province (Fig. 1) with an area of 2830 km², elevation ranging from 200 m to 1708 m and the average slope varying from 15 to 35°. The basin, located on the East of Truong Son mountains and on the North of Bach Ma range, covers the majority of the province territory. The main segment of the Huong river originates from the high mountain area of Bach Ma range at an altitude of 1318 m and runs from South to North for about 104 km. The river has three main tributaries and relatively sub-drainage basins: the Ta Trach (51 km long with a drainage basin of 729 km²), the Huu Trach (70 km long with a drainage basin of 691 km²), and the Bo river (94 km long with a drainage basin of 938 km²).

The Huong river basin has the highest rainfall in Viet Nam, and the rainy season prolongs from August to December. On average, 3500 mm of rain falls in the A Luoi area, 3200 mm in the Nam Dong

area, and up to 2850 mm in Hue city (Fig. 1). Two main climatic zones, consisting of seven microclimate zones, characterize the Huong river basin (ThuaThien Hue Hydrometeorology Center, 2008). 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.

3.2. Methodology

The study was divided into four major phases: (1) identification of public perception about the relationship between forest cover change and catastrophic flooding, (2) analysis of flood trends, (3) classification and detection of land cover changes, (4) comparison and interpretation of findings. The main factors considered in the perception analysis included: the experiences of forest cover change and flood disasters, the social norms and traditional knowledge, and the policies and programs on forest management and flood management. This was done through questionnaires and focus group discussion surveys carried out in the mountainous areas and later through a relevant policy analysis. The questionnaires used a multiple-choice format and were compiled into four sections: the general information of respondent's household, flood disaster risk perception, flood impact, and coping mechanism. The results of the perception and policy analysis are presented in Section 4.1 and 4.2. Conversely, the study of the changes in flood trends was based on the available hydro-meteorological data of the last thirty years, while land cover analysis was done with satellite imagery and GIS methods. Finally, all findings were compared and interpreted to establish correlations, if any, between forest-cover change and catastrophic floods in the Huong river basin (see Fig. 2).

3.2.1. Identifying the common perception of the relationships between forest and flood

Common perception of the relationship between forest and flood was based on field surveys carried out in Binh Thanh, Binh Dien, Huong Nguyen, and Hong Ha (Fig. 1), four selected communes that best represented the socio-economic and physical conditions of the uplands of the Huong river basin. Prior to the selection of the sample communes the investigators conducted a reconnaissance visit to the upland areas to find out their economic status, main livelihood activities, and ethnic composition. In each surveyed commune, a participatory Rural Appraisal (PRA) methodology was used to identify the residents' perception of forest and flood linkages and understand the local context. For example, transect walks, participatory mapping exercises, wealth ranking, historical and problem tree with focus groups, household surveys and interviews with 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 households). The samples of households contacted were randomly selected from these lists. The final number of questionnaires gathered was 404 (average of 100 per commune). The questionnaire, using multiple-choice format, comprises four sections: general information of households, flood-forest perceptions, traditional agriculture practices and forest management (see Appendix 1 for the full questionnaire). 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.

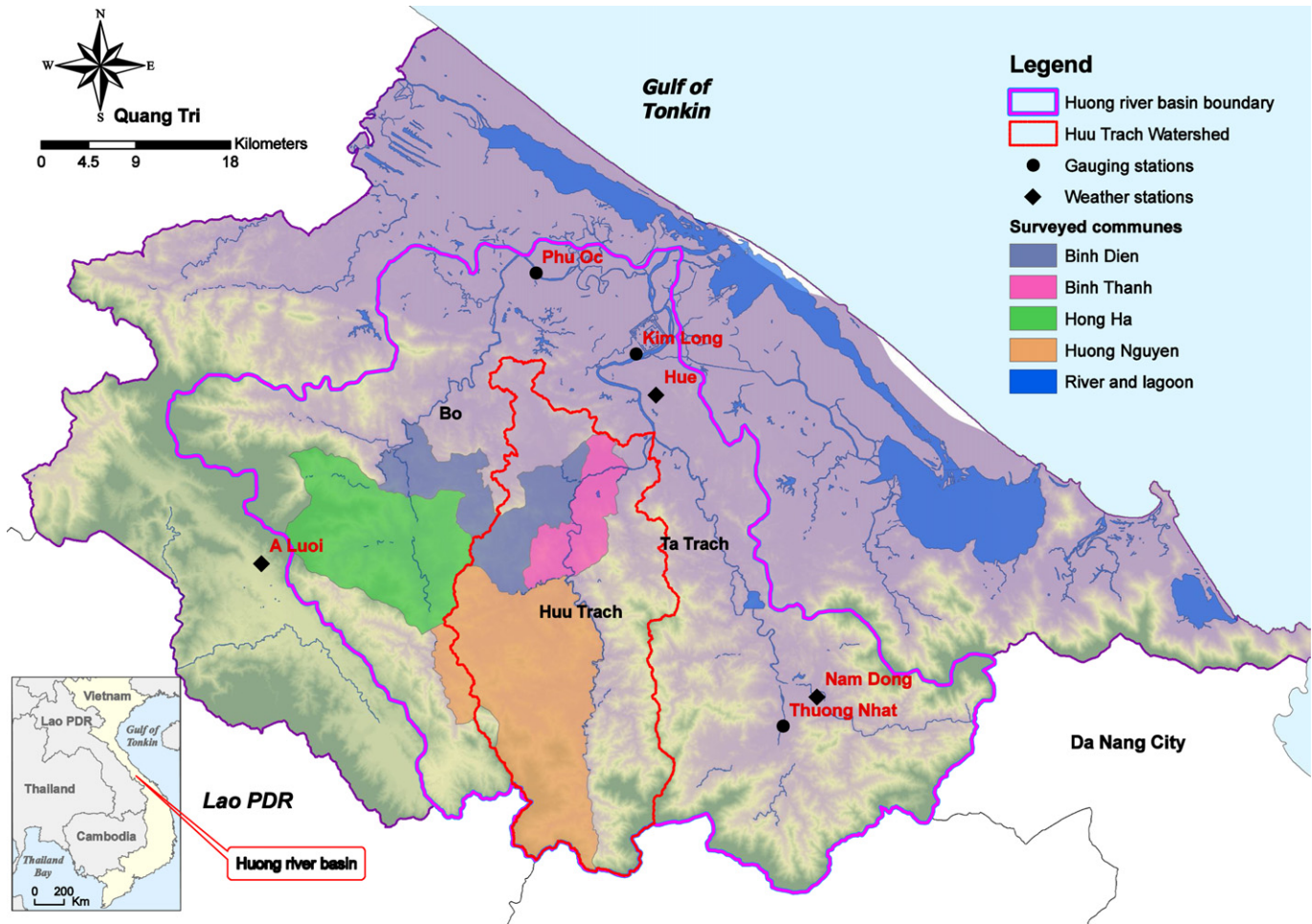


Fig. 1. Research location and selected weather stations. Source: Authors' elaboration.

3.2.2. Identifying flood trends changes

The hydro-meteorological data used for this study were obtained from the [Institute of Meteorology and Hydrology \(2006\)](#). There are three main weather stations in the Huong river basin: Hue, A Luoi and Nam Dong. The Hue station, 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 600 m and within the watershed forest, provided data to characterize the upstream area. The Nam Dong station, located in the transition areas between coastal lowland and mountainous areas at 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 daily and monthly rainfall data of the last 30 years to find out the changed trend. Conversely, the hydrological data such as the peak discharge, floodwater level, and time to peak, were collected from Thuong Nhat (in the Ta Trach tributary) and Kim Long (in 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.

A statistical analysis was applied to test whether there is any upward and downward trend of rainfall, maximum flood level, and number of catastrophic floods each year for the last thirty years. The linear regression model was used to evaluate the correlation and

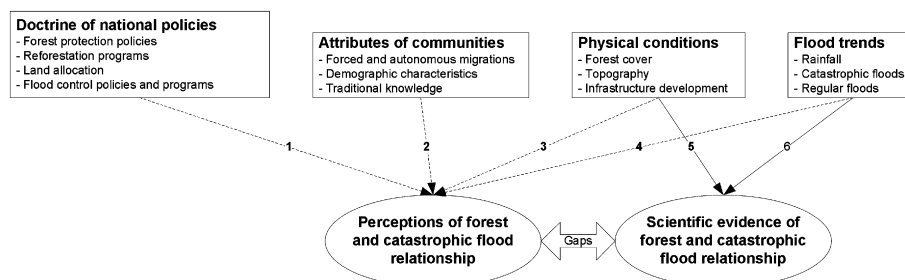


Fig. 2. Research framework.

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 (Chow et al., 1988) to detect the runoff coefficient in a sub-watershed of the Huong River Basin located in the Nam Dong areas (hereafter Nam Dong watershed). The peak discharge at Thuong Nhat station for 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 the Nam Dong weather station. Mathematically, the rational method relates the peak discharge (q , m³/sec) to the drainage area (A , ha), the rainfall intensity (i , mm/h), and the runoff coefficient (C) with the following equation:

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

We must point out that our method is a 'reasonable first approach', not necessarily applicable to any situation. For example, this model does not account for storage limitation in the landscape and buffering of flows, but seeks a direct attribution of riverflow to rainfall on the same day. Following are the assumptions used in this method: (1) rainfall intensity and duration is uniform over the area of study; and (2) 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 contribute simultaneously to the discharge at the outlet. Finally, considering that the studied sub-watershed (Nam Dong) is relatively small, about 212 km², it was treated as belonging to the same microclimate zone (See Fig. 1). Thus, due to the fact that during the flood season in Thua Thien Hue the rainfall duration is normally very long, i.e., from three to four days, the above assumptions (1) and (2) were easily satisfied in the studied sub-watershed.

3.2.3. 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 Huong river basin, but fairly complete for the Huu Trach sub-watershed (see Fig. 1). Changes in land cover in this sub-watershed were measured using time series of satellite data. Remote sensing images for the research area were interpreted for the years 1989 (thematic mapper, Landsat TM), 2005 (SPOT), and 2008 (Advanced Spaceborne Thermal Emission and Reflection – ASTER) (see Table 2). All images were taken in the spring season between February 16th and March 17th of all three selected years. Hence, these images stem from the same cropping season and from the comparable climatic conditions. A Digital Elevation Model (DEM) with the resolution 15 × 15 m from ASTER was also obtained to delineate the watershed boundary. In addition, other available ancillary maps such as QuickBird image, topography, hydrology, road system and 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 past land use 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. All the gathered data allowed us to present an overall picture of land-use changes in the Huu Trach watershed. 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 QuickBird image, and other land use thematic maps to develop the land cover, were used.

Fig. 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 the 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 the geo-referenced process with same pixel spacing 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 Huong river basin, they do cover the entire Huu Trach watershed. In the second phase, 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 conditions, and for many other applications (Lunetta and Elvidge, 1999), and is least affected by topographic features (Lyon et al., 1998).

NDVI images using SPOT-5, Landsat TM and ASTER data were calculated using the equations presented in Table 3. Due to the small differences in the range of red and NIR bands in three sensors, the comparison among the three NDVI images may be a source of some inaccuracy. However, applying NDVI segments in the classification process proved to be effective to classify land cover from imagery in mountainous areas, dramatically reducing the effect of terrain on image values (Hatfield, 2006). The ISODATA classification was performed within the segments of the NDVI image (high-, low-, and non-vegetation) on the original 4 bands of image data. Some classes, such as regenerating forest (often containing a mixture of land cover classes) were found to occur in more than one segment. Therefore, the definitive 'edge' of the NDVI segment is not as critical as separating the general groups of vegetation and non-vegetation communities using ISODATA. Also, the intended purpose of creating the NDVI segments is to increase the number of clusters that are generated using ISODATA. This procedure generally improves the separation between forest/land cover classes. The ISODATA algorithm is iterative and uses minimum spectral distance as a measure in order to assign each candidate pixel to a cluster. The process begins with a specified number of arbitrary cluster mean values. It then processes repetitively to improve the clusters.

During the third step, ISODATA unsupervised classification was applied to objectively extract 24 classes of each NDVI image. These 24 classes were allocated into five major land cover types. Labeling, or class allocation, was based on the analyst's assessment of the clusters with the aid of field survey data, local knowledge and evidence from finer-resolution images by QuickBird taken in 2006. Each cluster produced by ISODATA was evaluated individually and, where appropriate, clusters were grouped. This is the most time-

Table 2
Remote sensing images.

Satellite image	Resolution	Imaging date
Landsat TM	28.5 × 28.5 m	Feb 17, 1989
SPOT	10 × 10 m	Feb 16, 2005
QuickBird	1 × 1 m	April 6, 2006
ASTER	15 × 15 m	Mar 17, 2008

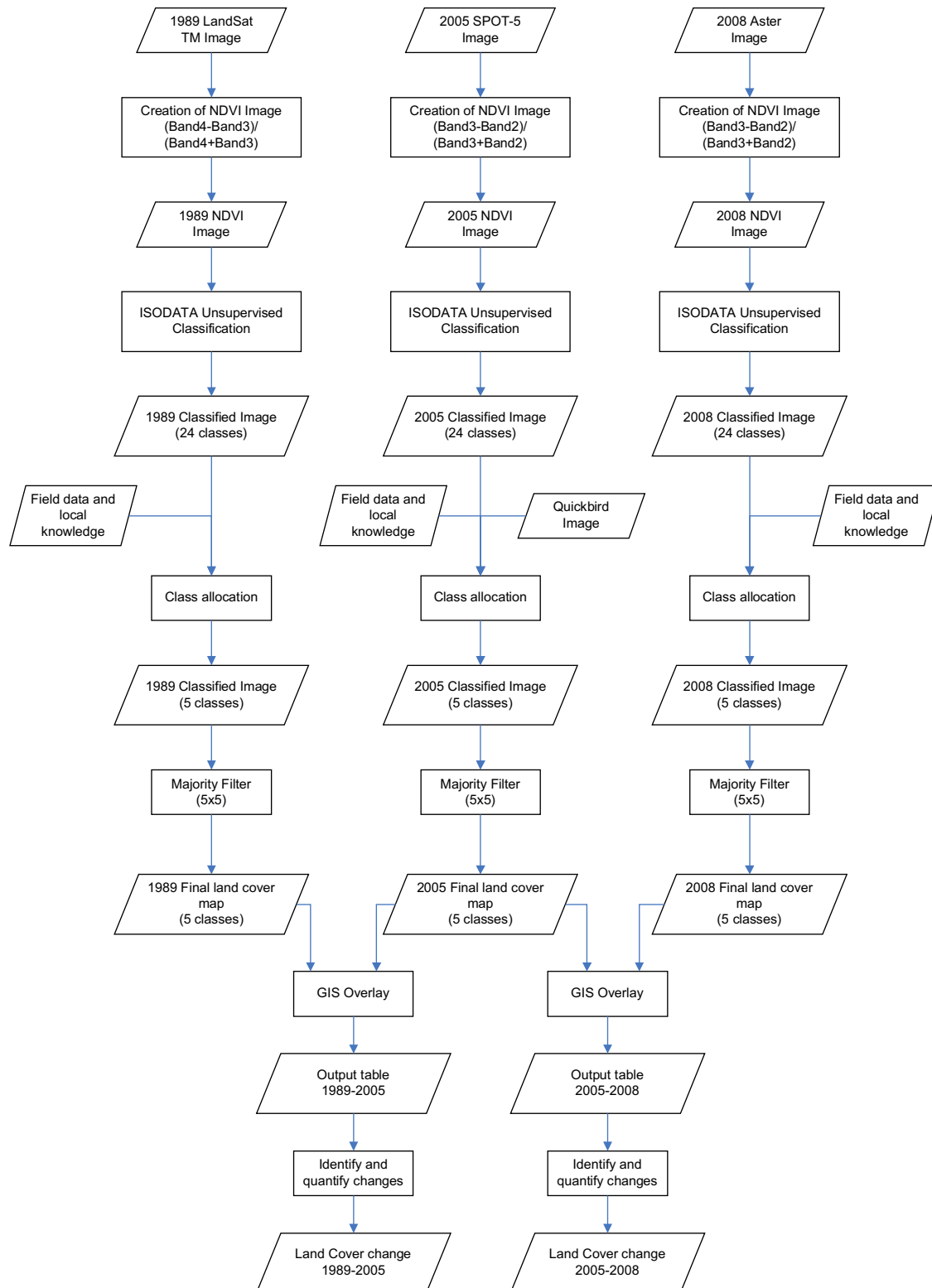


Fig. 3. Flowchart of land cover classification and land cover change detection.

consuming and user-intensive step, requiring the analyst to have prior knowledge of the area and forest/land cover (see Table 4). 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 5×5 pixels. If pixels within the 5×5

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. Fourth, and finally, the comparison of these land cover maps, used along with ArcInfo and ERDAS software, allowed us to detect the land cover changes, both spatially and quantitatively.

Table 3
NDVI equation for each image.

Image	NDVI = (NIR – Red)/(NIR + Red)	NIR (μm)	Red (μm)
Landsat TM	(Band 4 – Band 3)/(Band 4 + Band 3)	.78–.90	.63–.69
SPOT5	(Band 3 – Band 2)/(Band 3 + Band 2)	.78–.89	.61–.68
ASTER	(Band 3 – Band 2)/(Band 3 + Band 2)	.76–.86	.63–.69

4. Results

4.1. Driving forces of the perception on forest-flood relationship among upland people

4.1.1. Social-economic and natural conditions in the period before 1989

Before 1954 natural forests occupied most of the upland areas of the Huong river basin, and upland communities mainly lived on shifting cultivation, hunting and collecting products from forests (College of Agriculture and Forestry of Hue University, 1997). However, because of large forested areas, low population density and long fallow period, the impact of shifting cultivation on forestry resource was almost insignificant. The wars of 1967–1968 and 1972–1973 brought about a lot of damage which seriously destroyed the upland forests. Subsequently, from 1975 through the late 1980s, the Vietnamese government provided land and financial support to upland people to help them to build 'fixed houses', while allowing them to maintain shifting cultivation practices. In 1975, the government also implemented the New Economic Zone (NEZ) program, encouraging lowland people from Hue city and surrounding villages and the boat people (who lived on the boat along the river and lagoon) to settle in the upstream areas of the Huong river. Regrettably, the potential economic and social benefit from a more rational distribution of the population over the available territory was squandered by the lure of short-term benefits. Without proper training for sustainable long-term use of the abundant land (for example sloping for upland farming), these new settlers 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 either 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, and upland access was not restricted to any individuals or groups of people. In the meantime, logging activities and over harvesting of forest products heavily contributed to degrade the forest ecological integrity, contributing to soil erosion and landslides (College of Agriculture and Forestry of Hue University, 1997). Most likely, the negative impact of clearing forests for shifting agriculture, shaped the upland people's perception that forests, besides having a positive impact on the environment, also helped reducing flood risks.

Table 4
Classification system used for land cover mapping.

No	Classification	Description
1	Productive 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	Unproductive 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 a griculture, villages.

4.1.2. Social-economic and natural conditions in the period after 1989

During this period, the important factors influencing the perception of the forest-flood relationship were forest management policies and land use regulations which changed from exploitation to protection of the river upper watersheds. Indeed, 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. Forest management in the studied upland areas 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 Mangium* Wild. Agricultural production has been gradually transferred from the hill slopes to the river valleys. As a consequence, the forest cover types have been significantly redistributed during this period. Moreover, between 2005 and 2008, the Vietnamese National government and Thua Thien Hue province strictly enforced the forest protection law, and implemented forest reclassification and zoning, particularly in the upstream protected areas. This produced a significant land cover change over such period (see Fig. 4).

4.1.3. Social norms

Forest management has also been influenced by "social norms", namely a system of informal social controls (based on peer pressure), regulating individual and group behavior. For example, the "sacred forests" in the head watersheds have been protected by traditional upland communities' social norms. However, starting in 1975, with a large number of lowland people and city dwellers migrating to the uplands, these norms started to be ignored. The lowland and city people brought their norms, namely intense lowland farming approach, to the new locations.

4.1.3.1. Lowland farmer norms. It is important to note that annual flooding in lowland communes has been a recurrent phenomenon since ancient time. The Huong river and lagoon system play an important role in lowland 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. 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 et 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 (Fig. 5).

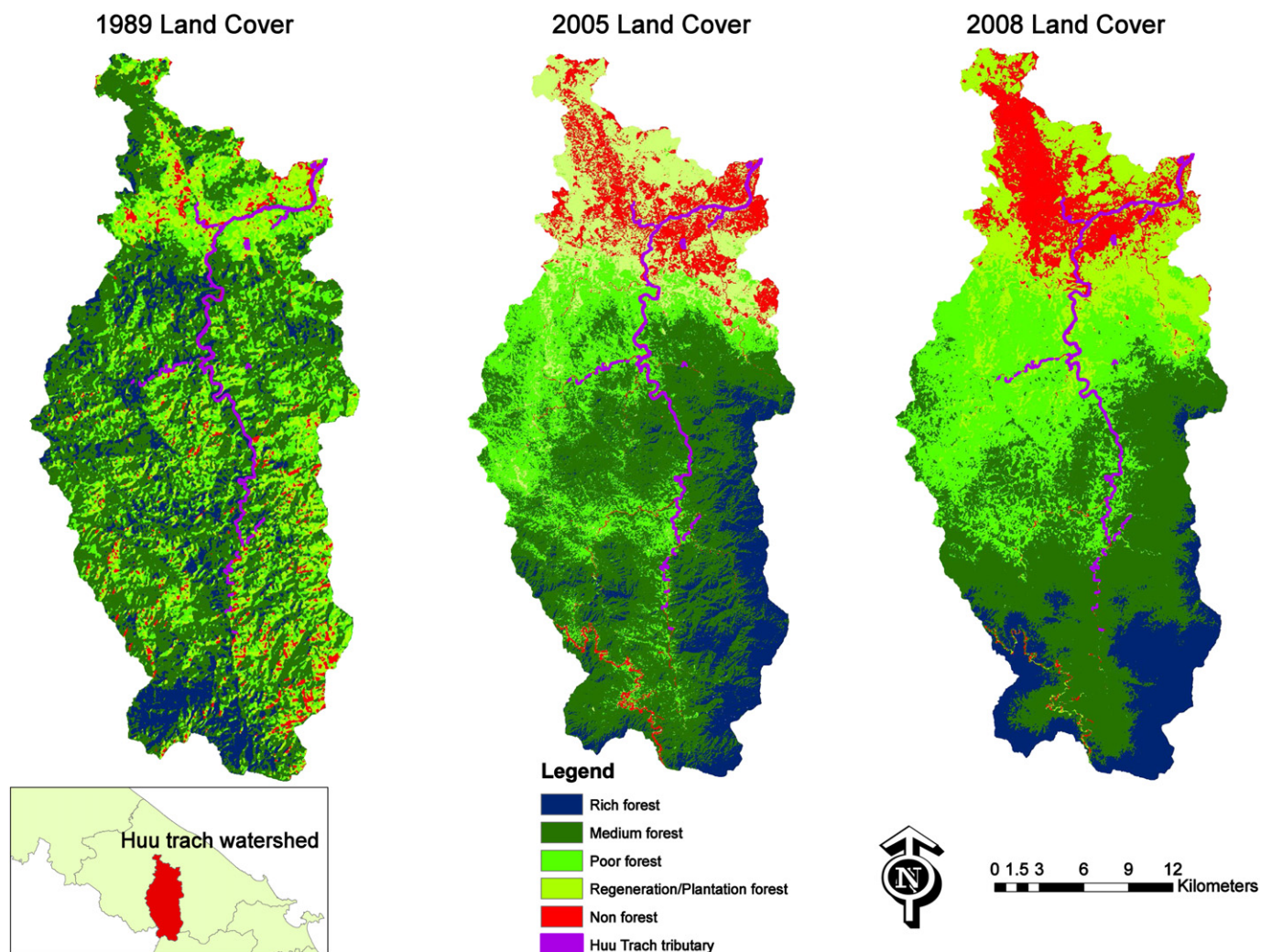


Fig. 4. Land cover in Huu Trach watershed in 1989, 2005 and 2008. Source: Authors' calculation from satellite images.

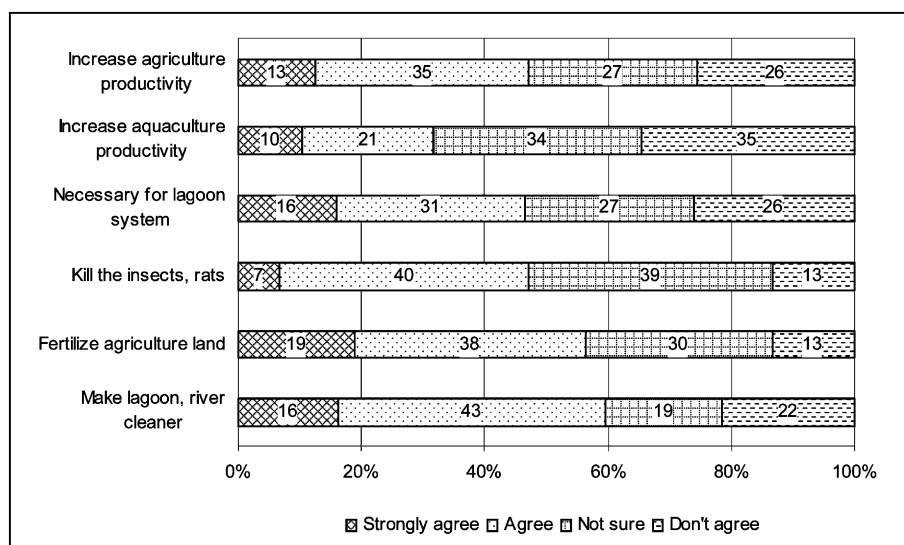


Fig. 5. Positive impacts of annual flood on environment in lowlands. Source: Tran et al., 2008.

Moreover, lowland farmers claimed that they could do little or nothing to avoid destruction from catastrophic floods (Tran et al., 2008). As a result, the common flood coping strategy was to coexist with floods. Houses were often constructed in elevated areas or high foundations to withstand annual inundations. Production activities were adjusted to avoid the adverse impacts of flooding as much as possible, and livestock (and other properties) were moved to higher places before the flood season.

4.1.3.2. City dweller norms. In the city, where most of the people are no longer relying on floodplain waters for their livelihood, annual inundation cycles are seen as detrimental and dangerous. For city dwellers, floods are no longer an 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 a top priority of the flood-risk-management programs. 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 are 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.

4.2. Empirical results of the perception amongst upland people

Before analyzing the perception amongst upland people, it is important to know the human geography of the 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%). This is due the efforts of the government through many resettlement programs since 1980. 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, and only 7% of them received upland farming training before moving to the mountains. The survey also highlighted that differently from the lowlands and Hue city dwellers, the upland people did not perceive flood 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 livelihood.

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, the upland people had 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 started to be perceived as one of the main causes of catastrophic floods in lowlands. For example, as Fig. 6 shows, the survey found that 93% of the respondents believed that the biodiversity of fauna and flora, in terms of density and quality, has decreased. Most importantly, these changes were seen as concurrent with the increase in catastrophic flooding. Thus, as visible in Fig. 7, when asked about the impacts of forest degradation, almost half of the respondents from the upland communes believed that deforestation significantly intensify all kinds of meteorologically related disasters (e.g. flood,

flash flood, soil erosion and reduced stream flow during the summer).

In addition, some 40% of the people who came from the uplands now believe that degradation of up stream forest causes catastrophic flooding downstream (Fig. 8). Remarkably, it can be concluded that the upland people now consider themselves responsible for catastrophic floods in the downstream area. It is difficult to assess as 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 perceived solutions to catastrophic flooding, the majority of upland respondents thought that protection from floods should be based on forecast and mitigation, and only 22% of them thought that forest protection is important. Certainly, this proposed measures seem 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. Although the majority of upland people did not report direct damages from a catastrophic flood, almost half of the respondents stated that forest protection programs (i.e. State Forest Enterprise and Watershed Management Board) have decreased their family income. Apparently, these policies are affecting the livelihood of upland people making them poorer. Thus, only those upland 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 (Fig. 9).

4.3. Facts from hydro-meteorological data and land cover change analysis

The analysis of flood level trends based on the time series data for the last 30 years in the Huong river basin highlight the following findings: (1) significantly increasing trend of the highest yearly flood peak in the lowlands (95% probability at Kim Long station on the Huong river, see Fig. 1), (2) 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 Fig. 10), (3) an upward trend over time for maximum annual rainfall was observed at the three weather stations (however, this trend is not statistically significant at 95% level of confidence), and finally (4) a strong linear correlation between the highest flood level in the lowlands and the rainfall in the uplands on flood peak days (see Table 5). The linear regression model between the highest flood level and rainfall showed that more than 71% variance of these flood levels at the Kim Long gauging station (lowland) can be accounted for by the variance of the rainfall in the A Luoi station (upland). This means that catastrophic flood levels appear to be mainly caused by climate change/variability.

Furthermore, the linear regression model between the maximum rainfall per day within one month at Nam Dong station

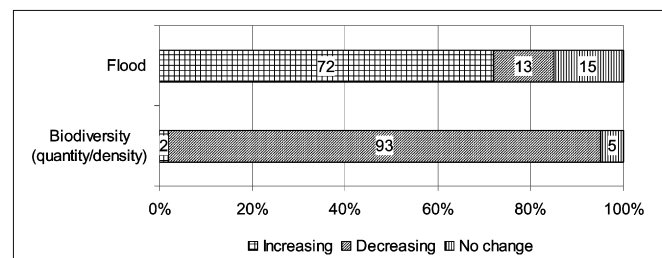


Fig. 6. Observation of upland people on the changing biodiversity and flood.

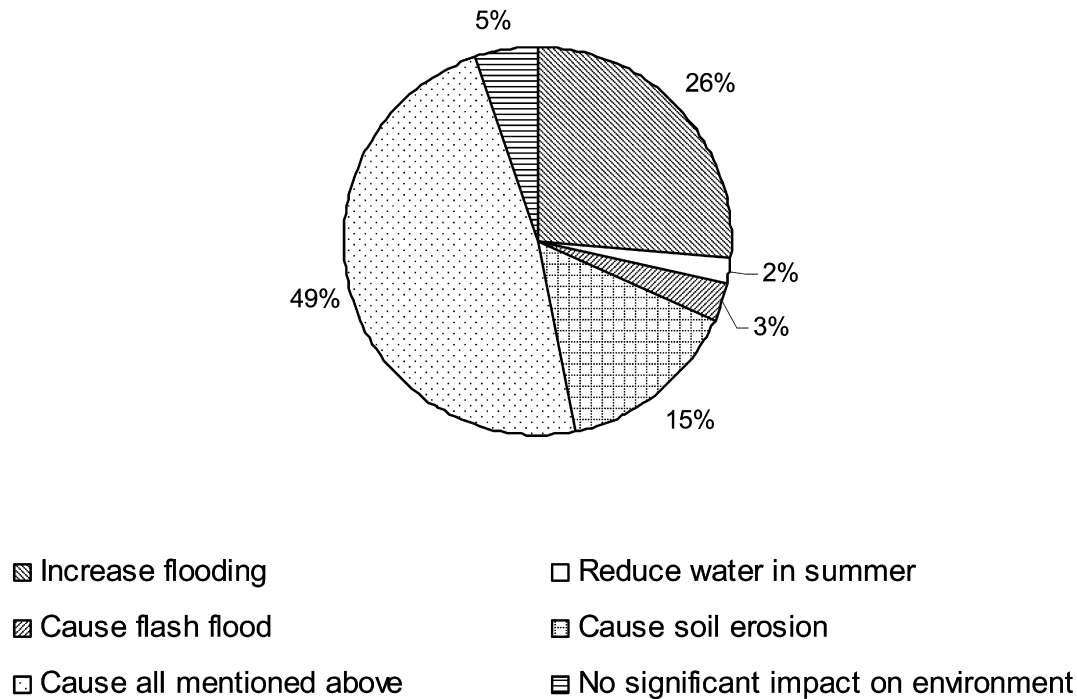


Fig. 7. Perception of upland people on the impacts of deforestation.

(upland) and the respective discharge at Thuong Nhat gauging station (also in the upland) showed that more than 77% variance of the discharge was accounted for by the variance of the rainfall (Fig. 11 and Table 6). This means that in case of extreme rainfall, the forest cover has a very minor role in reducing the discharge.

Also, the results of a multiple linear regression model for the Ta Trach tributary (in which the rainfall on the flood peak day and the runoff coefficient of Thuong Nhat sub-watershed were used as the predictors for the flood peak at Thuong Nhat station) showed a significant correlation between rainfall and flood peak, but no correlation between the flood peak and runoff coefficient (see Table 7). Hence, the runoff coefficient, which is often used as a proxy for land cover (and changes in the forest cover), has negligible impact on the catastrophic flood levels.

Nevertheless, climate change alone may not fully explain the increasing trend of catastrophic flood impacts in the whole Huong river basin. As mentioned earlier, the topography of the Thua Thien Hue province, whose steep hills located at a short distance from the sea (on average 50 km) and which quickly rises to altitudes from 200 to 1708 m, heightens the risk of floods. 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

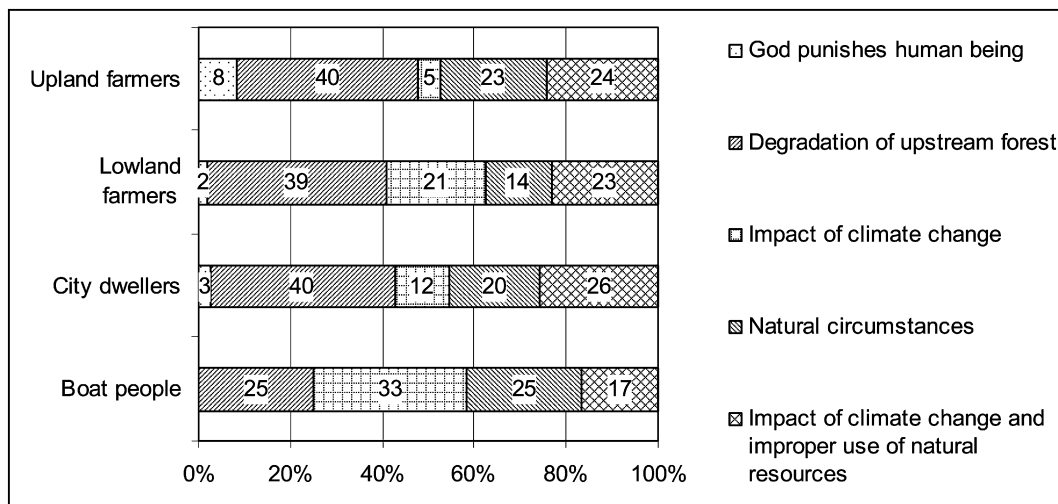


Fig. 8. Perception of people in the uplands on the causes of catastrophic floods.

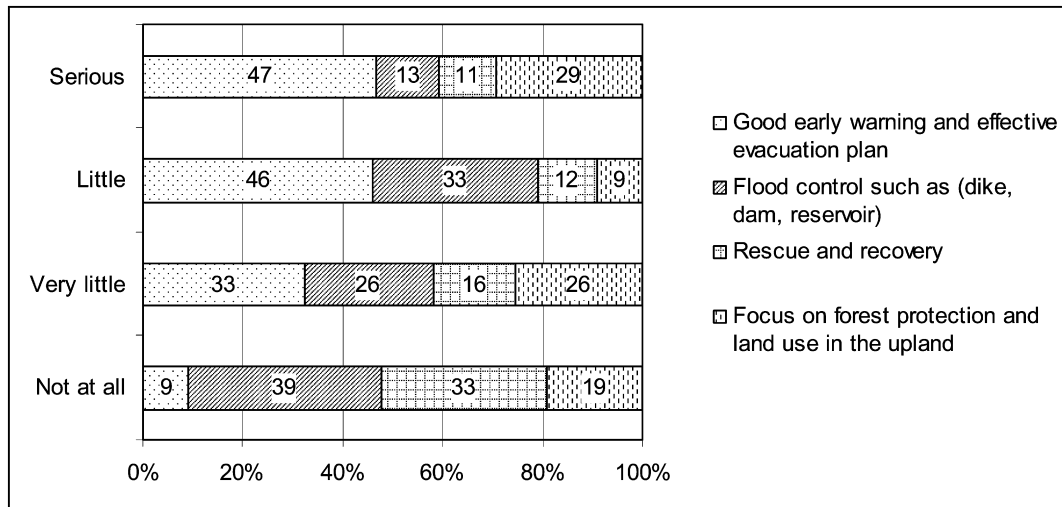


Fig. 9. Relationship between the level of flood impact and suggested flood reduction measures.

often unrecognized. 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), not to mention the spillover effect of these structural solutions, 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.

Indeed, during the last thirty years the transportation systems in the Thua Thien Hue province have been significantly improved and developed, and the railway and north-south highway hamper the valley's natural runoff. 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 Fig. 12). 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. Hence, during periods of intense rainfall and consequent peak flows, the railway and north-south highway act as 2-m dams across the entire valley increasing the flood level and pressure at the few openings toward the lagoon area.

In conclusion, 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 also be related to human infrastructures built in the basin's lowland. While changes in forest covers and land use in the

uplands have proved 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 lowlands have significantly contributed to increase catastrophic flood impacts downstream.

4.4. Impacts of land use policies and programs on upland people

As stated earlier in the paper, the rationale for many Vietnamese forest management policies relies 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 forest integrity was forbidden. For example, shifting cultivation, practiced by ethnic minority groups, was pointed out as the major cause of flood risks, and consequently banned. Leaving 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 upland farmers. The only land that could be used for agriculture cultivation was the upper river valley floodplains (obviously exposed to flashfloods). Ironically, these forestry programs and policies, in their attempt to reduce flood risks, have in fact intensified the vulnerabilities of the upland people to flood disasters.

Furthermore, by ignoring the value of indigenous practices, these modern policies have considerably disrupted existing local hazard management systems. For example, the forestland

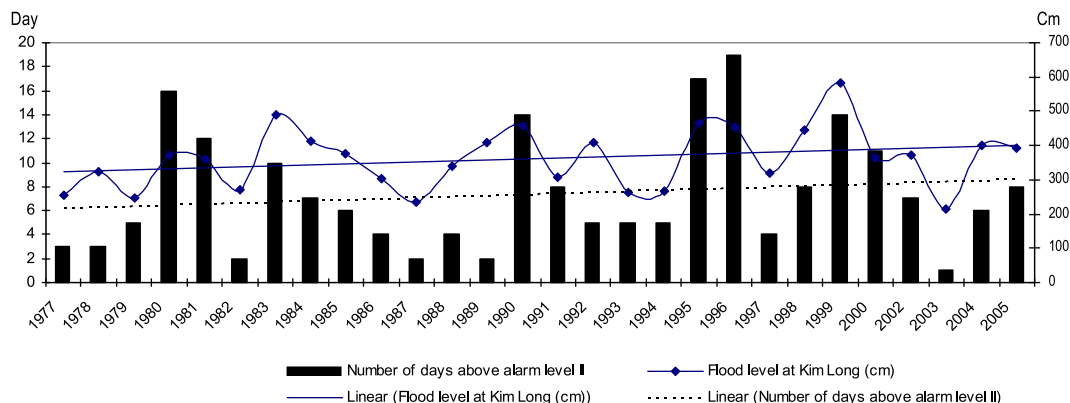


Fig. 10. The increasing trend of flood peak and duration at Kim Long station Note: The alarm level II at Kim Long station is 200 cm.

Table 5

Relationship between maximum flood level at Kim Long Station and rainfall at A Luoi station.

	Unstandardized coefficients		Standardized coefficients	t-statistics	p-values
	B	Std. Error	Beta		
(Constant)	199.433	24.576		8.115	.000
Rainfall (mm/day)	.537	.073	.844	7.366	.000

Dependent Variable: Maximum flood level at Kim Long Station (cm).

R square: .71.

B: the values for the regression equation for predicting the dependent variable from the independent variable.

allocation policy in Decision 327 (Council of Ministers, Socialist Republic of Vietnam, 1992) has instituted a land use system where all land is either state- or private-owned with no consideration for traditional common land use practices. A serious visible consequence of this policy in the uplands was riverbank erosion (Beckman, 2006). 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 other indigenous forest species to protect agricultural and residential areas. However, when the forestlands came under the control of state forest enterprise or were retailed to households, the incentives for community forestry decreased. Today, the riverbanks are left without protective bamboo planting.

This trend continued quite extensively even during the reforestation activities from 1986 to 2000 when the United Nations' World Food Program implemented a series of such projects (2780, 4126/Q, and 5322). Through these programs, 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 obtained. Thus, in order to gain more from the program, upland farmers grew forest trees in gently sloping areas that should have been used for crop production instead (The, 2001). As a result, within areas that were meant for watershed protection, poverty problems arose due to insufficient land being allocated for agriculture and food production. Overall, the forest cover has changed both spatially (Fig. 4) and qualitatively. The medium

Table 6

Relationship between rainfall and discharge.

	Unstandardized Coefficients		Standardized Coefficients	t-statistics	p-values
	B	Std. Error	Beta		
(Constant)	−18.128	3.835		−4.727	.000
Maximum rainfall per day	.790	.027	.881	29.402	.000

Dependent Variable: Average discharge of the date occurring maximum rainfall.

R square: .77.

B: the values for the regression equation for predicting the dependent variable from the independent variable.

natural forest has been decreasing, while the unproductive natural forest along with the regenerating and plantation forest have been increasing in the last twenty years (Fig. 13).

5. Toward a river basin integrated approach

Evidences from this research show that in the studied areas with steep hills that encircle the coastal plain, plantation and natural forest play a marginal role in decreasing catastrophic large-scale flash and river floods. In the Huong river basin, most catastrophic floods were caused by both climate variability and the development of road and dyke infrastructures in the lowland areas. In addition, floods in the Huong river basin although cause 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 have developed coping mechanisms to reduce the negative impacts of floods and have taken advantage of their positive effects. At present, these coping mechanisms are under pressure due to the increasing water level of catastrophic floods.

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. Certainly, it is important

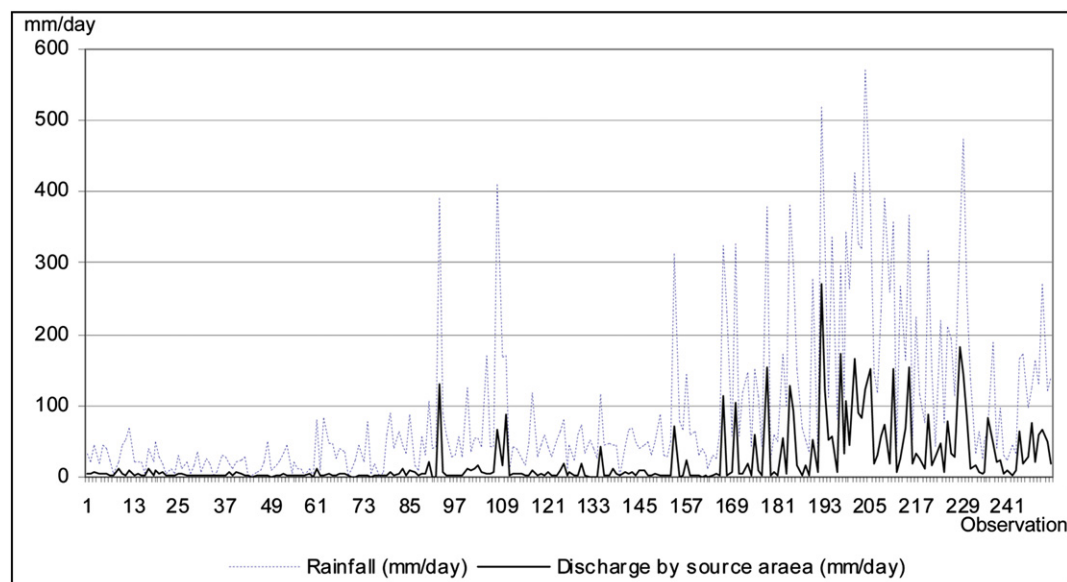


Fig. 11. Rainfall and discharge at Thuong Nhat and Nam Dong stations.

Table 7
Results of multi linear regression model.

	Unstandardized Coefficients		Standardized Coefficients	t-statistics	p-values
	B	Std. Error	Beta		
(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	.015

Dependent Variable: Flood level at Thuong Nhat station.

B: the values for the regression equation for predicting the dependent variable from the independent variable.

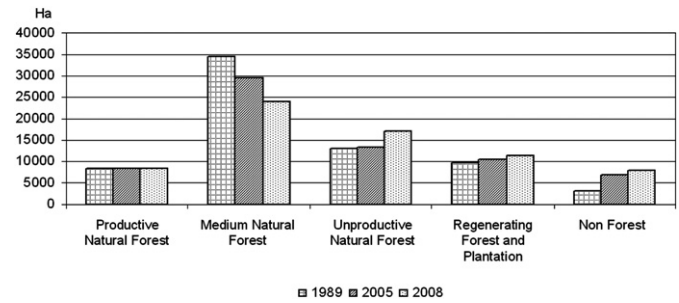


Fig. 13. Forest cover in Huu Trach watershed (Ha).

to underline that although forests cannot stop catastrophic flood, native forests do reduce the frequency and severity of annual inundations (Bradshaw et al., 2007; Calder et al., 2007). Moreover, large expanses of native forests can have major benefits 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).

Based on the results of this research, there are three specific recommendations for catastrophic flood management in the Huong river basin: (1) Development of a zoning plan and policy for the

entire basin to mitigate the impacts of flood disasters. The identification of the high-risk areas and the formulation of a strong provincial policy with respect to developments in these areas (even creating exclusion zones), can help avoid further losses in the next flood disaster; (2) Enhancing the adaptive capacity of people to cope with natural disasters in an integrated way. The capacity of people living in vulnerable areas should be enhanced so that they can adapt themselves to the effects of the climatic induced flood disasters. The safety issues should be weighed 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; and (3) Inclusion of a flood risk

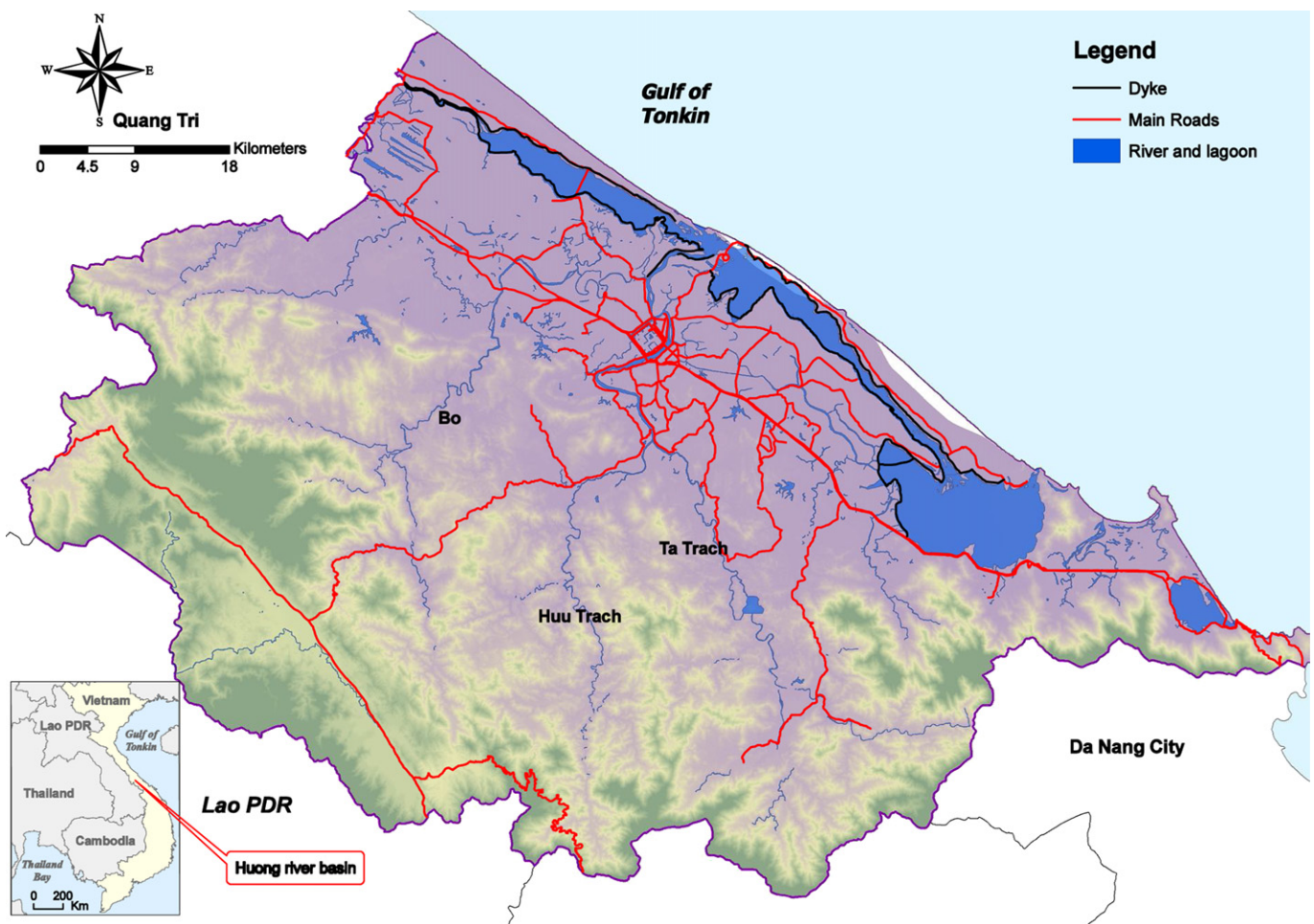


Fig. 12. Transportation and dyke systems in the Huong river basin. Source: Authors' elaboration.

assessment plan in environment impact assessment (EIA) for all infrastructural project in the Huong river basin.

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 be best 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. This kind of management policy should comprise all the activities required to organize sustainable use of the land and other resources available within the Huong river basin.

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 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, such as 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 must 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 uncontrollable environmental and socio-economic consequences. In the Huong river basin, agriculture and fishing remain very important sectors, and the loss of beneficial effects from annual inundations 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.

6. Conclusion

The causes of catastrophic flood are very complex and case specific. Integrated river basin approaches can take the complexity of flood disasters into proper consideration and lead to adaptive and effective flood management. A river basin approach integrates land management in the uplands with engineering solutions, flood preparedness and emergency management in the lowlands. This requires a good understanding of both physical and socio-cultural processes involved, as well as the economic impacts of floods and the corresponding costs of interventions.

In the case of the Huong river basin, the misperceptions about the causes of flooding that have misguided decision makers,

planners and managers alike, need to be replaced by scientific knowledge based on facts. 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. Indeed, while the ability of forests to prevent catastrophic floods appears to be limited, watershed management should 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 reduce 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 how to live with floods. At the same time, policymakers need to abandon their belief in quick fixes for flood-related problems. 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.

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Appendix. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi: [10.1016/j.jenvman.2010.05.020](https://doi.org/10.1016/j.jenvman.2010.05.020).

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