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GIS and local knowledge in disaster management: a case study of flood risk mapping in Viet Nam

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Linking community knowledge with modern techniques to record and analyse risk related data is one way of engaging and mobilising community capacity. This paper discusses the use of the Geographic Information System (GIS) at the local level and the need for integrating modern technology and indigenous knowledge into disaster management. It suggests a way to mobilise available human and technical resources in order to strengthen a good partnership between local communities and local and national institutions. The paper also analyses the current vulnerability of two communes by correlating hazard risk and loss/damage caused by disasters and the contribution that domestic risk maps in the community can make to reduce this risk. The disadvantages, advantages and lessons learned from the GIS flood risk mapping project are presented through the case study of the Quang Tho Commune in Thua Thien Hue province, central Viet Nam.

Keywords: community capacity, community participation, flood mapping, Geographic Information System (GIS), local knowledge, vulnerability assessment

Introduction

Natural disasters have their greatest impact at local level, especially on the lives of ordinary people. Current disasters are becoming more complex and climate change poses a greater potential for adverse impacts (Aalst and Burton, 2002). The damage caused by natural disasters at the community level in Viet Nam has increased exponentially in the past 20 years, despite the great efforts that the Vietnamese government, international organisations, NGOs and local communities have put into many disaster prevention programmes (CCFSC, 2006). Government and other organisations have insufficient human and financial resources to implement comprehensive disaster prevention programmes at the family level in disaster prone areas. Even if they did, mobilising local capacities and partnership with communities should be considered an essential component of any disaster management plan (Norton and Chantry, 2002). Communities have shown themselves to be a source of strength, contributing innovative ideas and local knowledge which, when mobilised and used appropriately, can lead to solutions that can make a fundamental contribution to mitigating the negative impacts of natural disasters.

Many case studies and research projects have shown that there are no general technical solutions for reducing specific local disaster risks. New insights also reveal that disaster risk programmes have failed to induce people to participate because these

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interventions have lacked both the will and the instruments to allow people to use their own knowledge. It is our conviction that greater efforts should be made to strengthen the capacity of local people for developing their own knowledge base, and to develop methodologies that promote activities for reducing risks in a sustainable way. Linking community knowledge with modern techniques to record and analyse risk related data is one way of engaging and mobilising community capacity. Realising the important roles of the local community in hazard identification and assessment, the NGO Development Workshop France carried out a participatory Geographic Information System (GIS) hazard mapping project in Thua Thien Hue province, central Viet Nam, in 2005. The purpose was to prepare detailed flood hazard maps for commune planners, villagers and other stakeholders, to identify the magnitude and extent of past flood disasters, and to make recommendations based on local knowledge and needs to local authorities and decision makers regarding flood risk reduction activities.

In this paper, the authors discuss the need to combine GIS and local knowledge into disaster management at the local level, and they suggest a way to mobilise available human and technical resources to strengthen a good partnership between local communities and local and national institutions. The paper also analyses the current vulnerability of two communes, analyses the correlation between hazard risk and loss/damage caused by natural disasters, and assesses the uses of household level risk mapping in planning to alleviate such risk. The disadvantages, advantages and lessons learned from the GIS flood risk mapping project are presented through the case study of Quang Tho Commune in Thua Thien Hue province.

Why map? Local knowledge and GIS in disaster management

It is crucial to integrate local knowledge, GIS and maps into the process of disaster risk management. There are three main reasons for this integration: (i) a hazard map plays a key role in disaster risk identification, and it is an effective tool in making local knowledge visible; (ii) local knowledge is essential for disaster risk management; and (iii) GIS maps have advantages over conventional maps. First, hazard maps are fundamental to the development of a community-based methodology for collecting and displaying the disaster vulnerabilities and risks that comprise the core content of local knowledge (Hatfield, 2006). Hazard mapping is one of the first steps of producing a community vulnerability inventory (Noson, 2002; Wisner et al., 2004). Maps can provide clear, attractive pictures of the geographic distribution of potential hazards that can be appreciated by local people with no specialist knowledge. These maps frequently provide motivation for risk management actions that would be difficult to obtain without a compelling visual (Pradan, 2004). The hazard mapping and data analysis also contribute to proper planning and resource allocation for disaster preparedness (Morrow, 1999).

Second, the information that comprises the knowledge of local people or other groups with long-term ties to the land and its biophysical resources are usually part of the oral tradition and therefore it is seldom formally recorded (Hatfield, 2006). This means that local knowledge is essentially invisible to anyone but the 'knowledge holders' themselves. Consequently, the essential goal of the participatory methodology for data collection is to make the invisible visible. The most successful way to do this is to engage in a process that enables local knowledge to be transferred from the mind to the map. The reason underlying the value of maps is that local knowledge information is fundamentally spatial and maps are all about the language of space. Since maps are seldom bound to written language, they have proven time and again to bridge the gap between language and culture in terms of communicating ideas and information (Hatfield, 2006).

In fact, community knowledge of the social and physical environment is essential for natural disaster management. People know a great deal about their surroundings and are able to indicate which areas are prone to floods and exposed to typhoon damage, where uncollected debris blocks culverts, where standing water breeds disease, where currents flow faster when floods occur, which houses are built on platforms high off the ground whilst others are built with no plinth at all, which families are poor and vulnerable to flooding. It is this local knowledge that will allow planners to survey rapidly the needs and opportunities for mitigation (Twigg, 2004). A cross section of inhabitants in the community—including the elders and village leaders, a variety of professionals, women and children—together contribute different view points and concerns that help to map local hazardous conditions, for example, where further settlement expansion should be limited because of risk.

Moreover, mapping hitherto required a very cumbersome and time-consuming process for transforming field maps into a wide range of finished cartographic products. Once these maps products were produced, they were difficult to correct or expand. For example, flood risk information was presented on flood maps based on the existing conditions of the flood plain and watershed data and the level of previous floods. These maps were generally the work of national and international organisations. Budgetary constraints and 'remoteness' from community level realities often prevented action to update these flood maps with sufficient frequency to reflect the changing flood hazards caused by natural disaster, and by man-made changes such as newly constructed roads and urbanisation, and by geological changes such as land subsidence or erosion (Noson, 2002). This meant that once published, flood risk information could quickly become obsolete.

Another shortcoming of earlier hazard maps was that most of them did not include other essential micro community-level data dealing with housing and house quality, local capacity and demography factors, or the existence of safe multi-storey buildings or raised roadways, all of which are examples of the data necessary to determine local vulnerability to a flood hazard. The situation began to change rapidly in the mid 1980s when early versions of GIS came into use. Since then its importance as a tool to link non-geographic attributes or geographically referenced data with graphic map features and to assist with the management, storage, display and query of socio-economic data has become well established (Chen et al., 2003; Dash, 1997; Kaiser et al., 2003). The database of the GIS maps provides villagers, related agencies and organisations with a better view of the real situation in rural communes. It serves as a guide map for stakeholders working in the study areas to implement disaster risk reduction projects and programmes. Furthermore, by distinguishing between areas that are safe and those that are vulnerable to natural disasters, it is easier to ensure that emergency plans for evacuation or preparedness are developed properly.

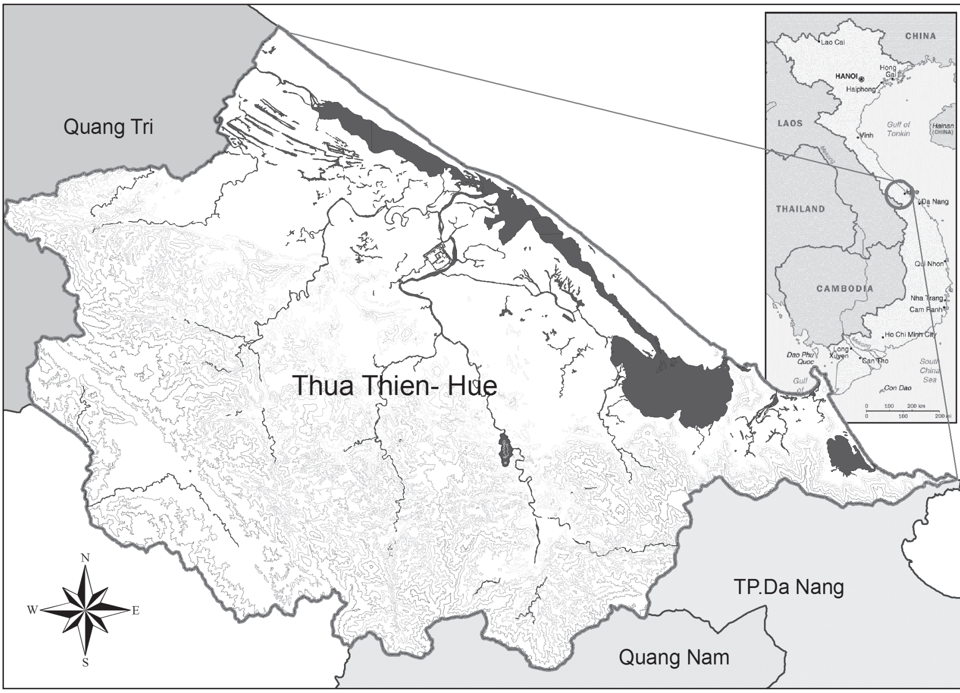
More recently, advances in computer and GIS technology have increased the accessibility and mobility of GIS tools, such that communities can use GIS to manage their local knowledge and community data collections using mobile GIS and Global Positioning System (GPS) technologies. As a consequence, GIS has now become a fundamental component of community-based methodologies (Hatfield, 2006). In addition, integration of remotely sensed data with traditional maps, mapping and GIS is beginning to emerge as the next important stage in the development of local knowledge methodologies and applications. At present, the methodologies most frequently associated with local knowledge are primarily focused on the village or cultural context within which local knowledge studies are to be carried out. They deal with the nature of the data collection process in response to the earlier disaster risk issues and not with the potential of local knowledge data now required to help monitor and manage new disaster problems. As the range of potential applications for local knowledge expands, it becomes necessary to broaden the methodology required for shaping the collection and processing of local knowledge data. This will provide insights and information needed to deal with the major environmental and disaster issues facing both small and large scale societies throughout the world. Thus, integrating GIS and local knowledge in the disaster identification stage in order to map and assess the hazard prone areas is an excellent tool for disaster risk management.

Characteristics of the study area and its problems

Thua Thien Hue province is located in central Viet Nam, bordered on the east by the South China Sea and on the west by the Lao People's Democratic Republic. The province has an area of 5,053 sq km and is divided into nine administrative districts. The population is more than one million, of which 300,000 people reside in or around the capital city, Hue. Much of the province's infrastructure and industry lies in the coastal plain and most of the population lives within 25 km of the coast (see Figure 1).

Like many other provinces in Viet Nam, Thua Thien Hue is no exception to disaster vulnerability. In fact, it is considered among the most disaster prone areas of Viet Nam. The province has a varied geography—including forested mountains and hills, rivers, streams, paddy fields, coastal lagoons and marine areas—and is located in the tropical monsoon climate zone. The main river basins are the areas

Figure 1 Project sites



Source: Tran and Shaw, 2007.

where agriculture has been the main economic activity since ancient times, and these areas are extremely vulnerable to natural disasters due to both geographical and meteorological conditions (TTHPPC, 2002). During the rainy season, crops, infrastructure and the inhabitants of these river basins suffer huge losses due to disastrous annual floods and storms. Loss and damage to property coupled with insecurity to human lives keep many households trapped in a cycle of poverty. Moreover, in the dry season low rainfall and saline water intrusion around the river estuary also badly affect agriculture, as well as lagoon and aquatic resources. Together this cycle of natural disasters inhibits the social and economic stabilisation and growth of Thua Thien Hue province (TTHPPC, 2005).

In November 1999 a severe flood occurred in Thua Thien Hue inundating 90 per cent of the lowlands. The province became isolated. The flood, which lasted for one week, broke five new floodgates and created a new river mouth near the lagoon. The heavy rainfall in the uplands caused numerous landslides. Strong winds produced fierce waves, which made mobility even more difficult. The flood caused 352 deaths and USD 120 million in damage (PCFSC, 2000). The experience of the 1999 flood was very traumatic for villagers, who had nowhere to go when the water level rose to their rooftops, and particularly for those who live in frail houses. These events once again highlighted that identifying risk areas, warning villagers about actions they should take—for example, in making the house safer and less exposed to flooding—and providing safe shelters for evacuation in case of disaster events are all crucial for disaster mitigation in Thua Thien Hue. Recognising that mapping the hazard prone areas could be an important tool in identifying risk areas, Development Workshop initiated a pilot project in 2004 that combined GIS tools with local knowledge to develop flood risk maps in two communes in central Viet Nam.

Scope and limitations of the study

Central Viet Nam experiences several hazards including flood, tropical typhoon, drought, saline intrusion and whirlwind, affecting both rural and urban areas. However, this study focused mainly on flood mapping in two rural communes. This was necessitated by the available resources and time frame within which the project had to be completed. Some of the spatial data was not sufficiently accurate, and better results would have been obtained by using a GPS device with accuracy greater than ± 5m. However, the study does effectively demonstrate the potential of combining GIS and community knowledge as an additional tool in regional and community-based disaster reduction planning. In addition, many lessons have been learned from the process of integrating local knowledge into maps, as the process of mobilising community participation in disaster management is as important as the resulting maps.

Data and methodologies

Data

The principle information collected for this flood risk mapping and vulnerability assessment included: hydrological information and flood records; geographical information including topography and land use; river morphology (in terms of return flood periods, duration and water levels, and levels of danger); meteorological information relating to flood seasons; information about existing infrastructure (housing conditions, public facilities); demographic and socio-economic conditions (such as poverty and education); and information on the damage and loss caused by previous flood disasters. Data also included spatially referenced variables dealing with topography, land cover and demographic information. In this study the authors used data at commune level, which was the most detailed level data of the latest Viet Nam census. Much of this data needed considerable processing and further transformation in order to generate the variables used in the spatial analysis.

To collect household and local vulnerability data, participatory rural appraisal techniques (PRA) were used to ensure community participation and to incorporate local knowledge in the whole process of map making (see Figure 2). In this study, most of the flood risk mapping took place in the village and was carried out by local people and local authorities. At village meetings the community members first shared their ideas and opinions on the purpose of developing the flood risk maps and what

Figure 2 Flood risk mapping process

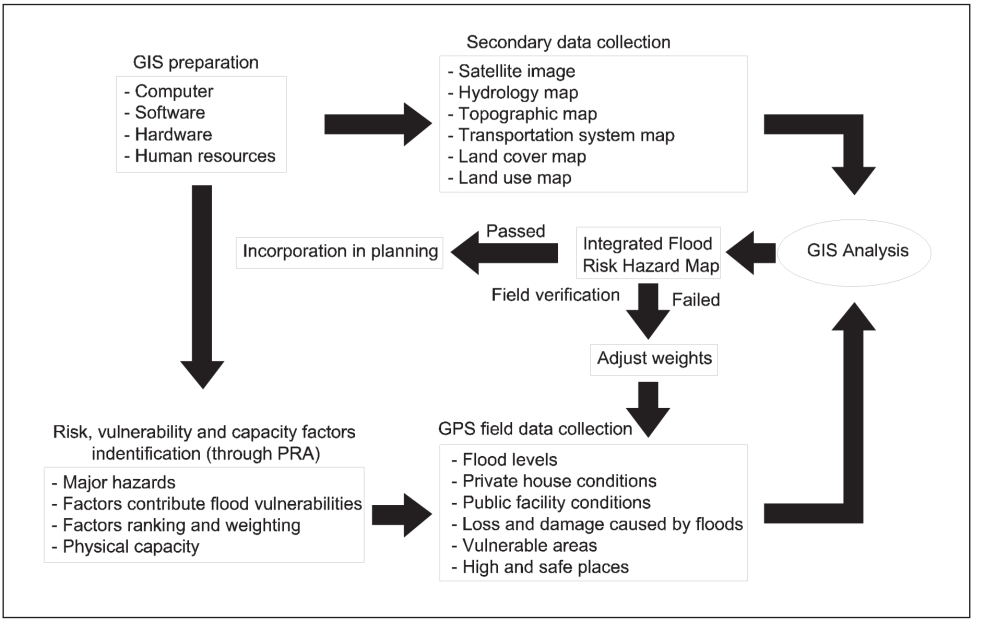


Figure 3 Temporary house located on the riverbank

Source: Phong Tran.

important factors they would like to put into the map. The next step was to draft the household flood risk maps based on the data collected from the field, and to discuss what actions should be taken to reduce such risks. This also took place through participatory appraisal, ensuring that local experiences were incorporated.

Methodologies

In Thua Thien Hue, the flooding in residential areas is one of the most frequent causes of losses to housing and lives. Thus, the main concerns of flood mapping in this study focused on identifying high-flood-risk residential areas. Focus group discussions highlighted many factors that contribute to flood vulnerability. In low-lying areas, the low level of the plinth on which a house stands, proximity to the main rivers, distance from main roads, and specific house types emerged as the most important issues. Specifically, the poorest families often settle in temporary houses in low-lying land areas far from the main roads and far from safe, two-storey houses or public facilities, and often very close to the riverbanks (see Figure 3).

Table 1 Primary data collected for flood risk mapping

	Variable	Measure
Public buildings	Safer shelter	Kindergarten, school, clinic, etc.
Private house characteristics	House type	Solid, reinforced, semi-solid, and temporary house
	Storey of house	1 storey, 2 stories,
	Level of plinth above ground	Cm (centimetres)
Livelihood loss and damage caused by 1999 flood	Level of 1999 flood	Cm
	Buffalo	Unit
	Pigs	Unit
	Ducks, chickens	Unit
	Rice	Ton
	Vegetables	Ton
	Others	VND millions
Livelihood loss and damage caused by 2004 flood	Level of 2004 flood	Cm
	Buffalo	Unit
	Pigs	Unit
	Ducks, chickens	Unit
	Rice	Ton
	Vegetables	Ton
	Others	VND millions

Source: authors' elaboration.

Based on the inputs from discussions with villagers, 30 per cent of households in each commune—equivalent to 600 households per commune—were visited to record the location of the house, to check the level of the house's plinth (floor level above the ground level), to identify the house type, and to interview the occupants about data on loss and damage caused by the historical flood in 1999 and the more recent big flood in 2004. The project also surveyed all public buildings that could potentially be used as safe shelters in case of severe floods (Table 1).

Data from GPS were imported to computers. Each household or public facility was presented as one point following the attributes in Table 1. The base map is the overlay of transportation system, river and stream network, commune boundary and land cover. The boundaries of residential areas of each village were also mapped from the field using GPS device. All data were projected into UTM 48N, WGS84. Following focus group discussions among villagers, six main physical factors were identified that contribute to household flood risk: house types; 1999 flood level; 2004 flood level; household proximity to river; household proximity to safe shelter; and household proximity to main roads. The values of the first three factors for

Table 2 Relative weightings for major factors in terms of flood risk potential

Risk severity	Very low risk	Low risk	Medium risk	High risk	Very high risk
Risk index	1	2	3	4	5
House type of household (HT)	Two-storey solid house	One-storey solid house*	Reinforced house**	Semi-solid house***	Temporary house****
1999 flood level (99FL)	<40cm	40–60cm	60–100cm	100–140cm	>140cm
2004 flood level (04FL)	<40cm	40–60cm	60–100cm	100–140cm	>140cm
Household proximity to rivers (PR)	Very long distance to rivers (>140m)	Long distance to rivers (100–140m)	Moderate distance to rivers (60–100m)	Close to rivers (20–60m)	Very close to rivers (<20m)
Household proximity to safe shelter (PSS)	Very close to safe areas (<50m)	Close to safe areas (50–100m)	Moderate distance to safe areas (100–150m)	Long distance to safe areas (150–200m)	Very long distance to safe areas (>200m)
Household proximity to main road (PMR)	Very close to main road (<30m)	Close to main road (30–60m)	Moderate distance to main road (60–90m)	Long distance to main road (90–120m)	Very long distance to main road (>120m)

Notes:

* Reinforced concrete house with thick brick or block cement walls, secure doors and windows.

** House built with reinforced concrete materials, and with insecure parts—due to improper construction techniques—that had been repaired.

*** House built with reinforced concrete materials but some parts insecure due to improper construction techniques.

**** Bamboo or mixed material frame house, roof covered by thatch or corrugated metal or tiles.

Source: authors' elaboration.

each household were obtained from the field survey (see Table 1), and the values for the remaining factors for each surveyed household were determined by using spatial analysis tools of the ArcView/Info Software Package. In order to develop the flood risk map, the severity of each flood risk factor was classified into five categories from low risk to very high risk based on the characteristics and experiences of local people from the focus group discussions (see Table 2).

The risks coming from floods arise not simply from geographical conditions and their environmental effects, but also from a host of other interrelated factors—demographic, technical, economic, social. In this research, therefore, the household flood risk was considered as the probability of expected loss (of lives, injury, property or environmental damage, livelihoods and economic activity disrupted) per household, resulting from interactions between natural hazards, exposures and vulnerable conditions. The household flood risk was calculated by the following equation:

$$\textit{Household Flood Risk Index} = \left(\sum_{i=1}^{m} a_i H_i\right) \times \left(\sum_{j=1}^{n} b_j E_j\right) \times \left(\sum_{k=1}^{l} c_k V_k\right)$$

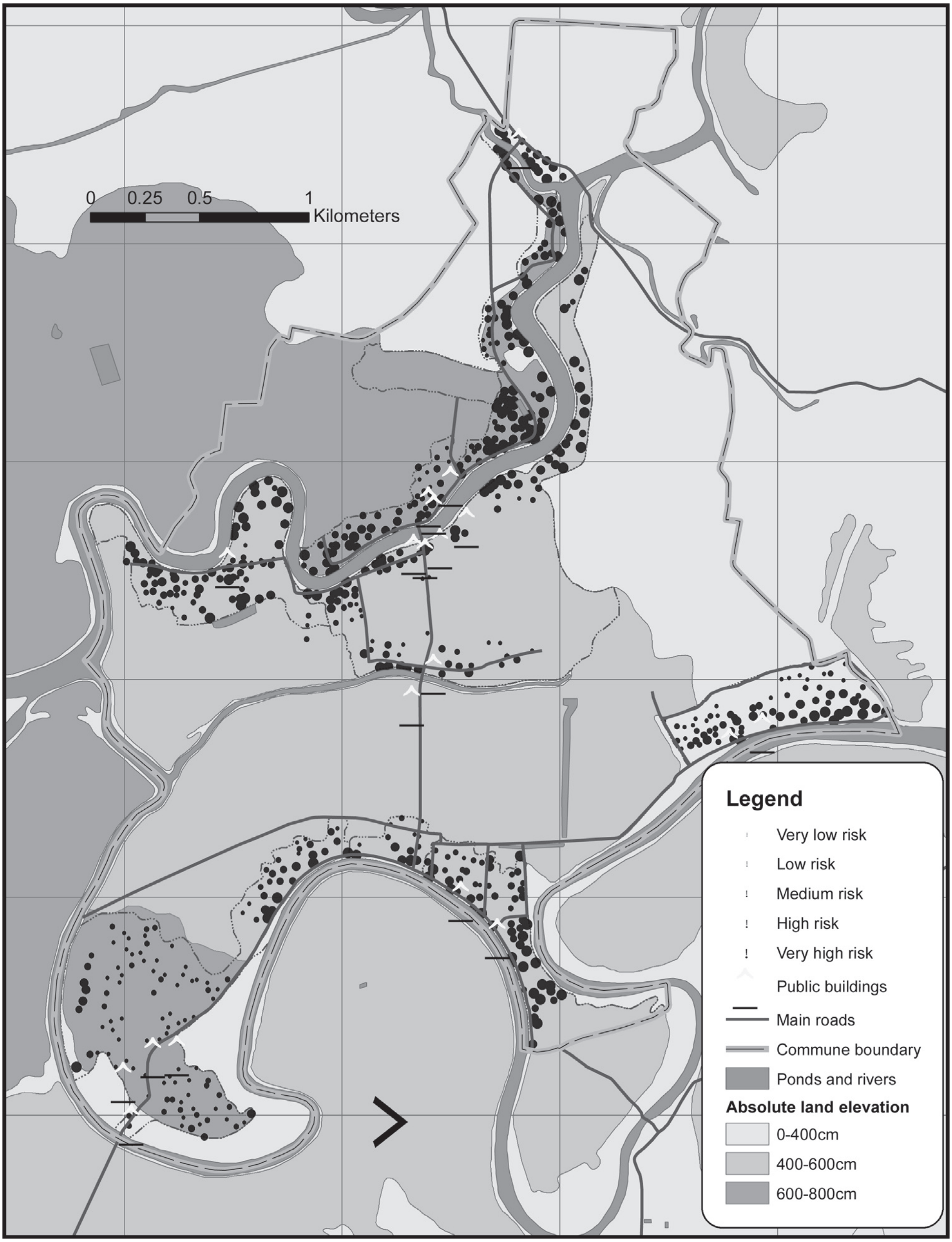
Where a_i, b_j and c_k are the weights of Hazard i (H_i), Exposure j (E_j) and Vulnerability k (V_k) respectively. And m, n and l are the total numbers of hazard, exposure and vulnerability factors respectively. First, the hazard index (H_i) can refer to the intensity of natural events, such as the water level for flood and the wind speed for typhoon. The level of the 1999 flood (99FL) and the 2004 flood (04FL) were therefore used as a proxy for hazard in this model. It is important to note that there is no linear relationship between the intensity of hazards and disaster in terms of economic and human losses. In fact, there is a difference between well-anticipated events and unanticipated events with the same intensity. For example, a flood that always occurs at the same time of year or an annually predictable flood has very different effects to a flood that occurs at different times each year or only in certain years. The former may be quite beneficial, while an unexpected flood may be disastrous. In this study, the 1999 flood was an unpredictable flood and the 2004 flood was an annual flood. Thus, the weights of the 1999 flood and the 2004 flood were assigned as two and one respectively or $a_{(1999flood)} = 2$ and $a_{(2004flood)} = 1$.

Second, the exposure to the hazard (E_j) refers to the degree, duration and/or extension of the system's contact with the hazard. The system's exposure to the disturbance is, however, an attribute of the relationship between the system and the disturbance. As such, it is not an attribute of the system. In the case of human systems, these are the households or the people that are likely to be affected by the hazard within a certain land area or geographic boundary. In this model, households living close to the river (PR) were considered as an exposure factor as they are the most likely to be affected by flood hazards. Finally, the vulnerability index (V_k) is the degree to which a system is likely to experience harm due to exposure to a hazard. Thus, house types (HT), the distance from house to safer shelters (PSS), and the distance to main roads (PMR), which are crucial in case of emergency evacuation, were considered as vulnerability factors.

Table 3 Criterion for flood risk to each household

Flood risk index	24–160	160–280	280–420	420–585	585–1,200
Risk severity	Very low risk	Low risk	Medium risk	High risk	Very high risk

Figure 4 Household flood risk index map of Quang Tho commune



Source: authors' elaboration.

The study found that for most families their house is one of their largest investments and has required enormous effort and financial savings. However, many families tell of the repeated destruction of their house by floods. A good flood resistant house can provide a family with security—for its well-being and possessions—during the flood season. Thus, among the vulnerability factors the house type factor was given more weight than PSS and PMR factors, or $c_{(HT)} = 2$.

The flood risk map is the ultimate product of the flood mapping process that integrates the effect of the six categories indicated in Table 2. The final flood risk index for each household is calculated as the following formula:

$$\textit{Household Flood Risk Index} = [2*(99FL)+(04FL)]*[(PR)]*[2*(HT)+(PSS)+(PMR)]$$

Cumulative attribute values associated with the flood map are reclassified into five different ranges using the quintile method, each range containing one fifth of the total sample (see Table 3). The results for Quang Tho commune are shown in Figure 4.

Result and discussion

What the hazard mapping process highlighted

As described above, the local experiences of coping and mitigating disaster originated in the community itself. Local people have always understood their surrounding vulnerabilities and risks, and have therefore always had disaster coping mechanisms at village level. However, this local knowledge has rarely been recorded. Some of these mechanisms are still in practice, while others have become outdated, as they could not be adapted to the present environment. This flood risk mapping successfully transferred unrecorded local knowledge into maps. The process of developing risk maps also mobilised the participation of the local population and succeeded in establishing trust, respect and an exchange of information among local communities and local authorities as well as local planners. This involvement assisted enormously in the development of a safer community plan. The research thus showed that, when mobilised, local people can become actively involved in the decision-making process and recommend solutions for risk reduction. As a result, the risk maps and recommended actions are suited to the local situation. Standard disaster management plans are no longer issued in a top-down way; instead, each village develops its own specific plans. The study provided a potential alternative for local governments to consider as they develop disaster management programmes: currently in central Viet Nam most disaster risk reduction plans are prepared by leaders without the communities' participation, and consequently may not take community needs and interests into account and may be unfeasible to implement (Tran and Shaw, 2007).

The integrated approach in this research ensures the commitment of local communities because it fits the communities' interests. Furthermore, the relationship between local communities and commune staff as well as other stakeholders has considerably improved. A dialogue in which opinions are exchanged and needs and wishes clarified in order to achieve a common understanding of the situation and the obstacles involved is essential for overcoming the communication gap between stakeholders. The village meetings at which the potential risks are discussed and mapped provide local communities with the skills they need to identify and analyse their surrounding risks and to come up with new ideas regarding disaster risk management.

Another experience from the mapping process showed that villagers have subsequently become more aware of their risks. Incorporating existing and traditional disaster coping mechanisms of the community into the disaster management plan increased the plan's acceptance among villagers and ensured an independent commitment. Once plans have been implemented, farmers feel responsible for their involvement, since they drafted the plans themselves. This reduces the costs of external monitoring and ensures the long-term sustainability of the approach. However, a good disaster risk reduction plan can only be effective if villagers are themselves motivated to keep the issue alive during village meetings and on other occasions. Such independent initiative strongly depends on community spirit and/or on the effectiveness of the commune disaster management board and other civil organisations. Only if the whole village supports the plans can a sense of ownership develop that is strong enough to guarantee their independent continuation in the long term.

Relationship between socio-physical indicators and economic loss/damage

This study noted that there was remarkable development with the road network, public buildings and private housings in the communes after 1986 when Viet Nam started its *doi moi* (renewal) policy, which moved Viet Nam from central planning to a market economy. However, there were still many households living in weak houses and semi-solid houses located far from main roads and public facilities. It is important to note that before the introduction of the Vietnamese *doi moi* policy, most people in rural areas of Thua Thien Hue lived in temporary houses built with bamboo, thatch or mixed materials. Capital investment in the house was very low and materials were obtained locally and could often be gathered. Only a very few families could afford houses with strong timber frames and tiled roofs resistant to floods and storms. When a flood or typhoon occurred houses were easily destroyed; but, conversely, they could also easily be rebuilt at very low cost with help from neighbours in just a few days. While short-term hardship might have been high, the economic consequences of losing a home were therefore low.

One effect of the *doi moi* policy is that many families have improved their financial situation. A visible effect of this is that, progressively, families have begun to put their savings into constructing stronger houses, rebuilding incrementally with more durable materials—but, literally, at a price. Whereas before construction materials were gathered, now they have to be paid for. Worse, few of these newer houses have been built in a flood- or typhoon-resistant way, and as a result, the investment in time and money that families have made is highly vulnerable to damage by such disasters (Norton and Chantry, 2002). However, despite the large amount of investment in housing, 65 per cent of housing stock in 2005 was still classified as 'semi-solid' houses, 18 per cent as temporary or weak houses, and only 17 per cent as solid houses.

The survey also showed the houses spatially by category—for example, temporary, semi-solid—and thus by a profile of income group related to other vulnerability issues. First, families living in temporary houses, who are therefore the very poor, are situated more than 200m from multi-storey or safe public buildings, and compared to families living in better quality houses they are further away from evacuation roads. As a result these families are more vulnerable in the event of floods, which highlights to local authorities where additional safe public infrastructure and transport routes could be added.

The proximity to main rivers is one of the important factors related to flood risk, since the houses close to rivers are often subject to flash floods, riverbank erosion and inundation. The survey showed that eight per cent of houses are located very close to riverbanks (houses located within a 20m river buffer zone). Families living in these houses need as much advance warning about flood events as possible and they need a plan for moving to safer places and, if possible, to protect their belongings. Thirty-three per cent of households live close to the riverbank (within a 60m river buffer zone). This defines areas where preventive measures should be implemented to reduce the impact of flooding inside the houses and improve access to safe shelter, storage and escape routes.

The experience of the 1999 flood was the most traumatic to the villagers, particularly for those who live in temporary or weak houses, as they had nowhere to escape to when the water level rose to their rooftops. In addition, the strong wind caused fierce waves, which made mobility difficult. The results show that poverty and vulnerability to floods are integrally linked and mutually reinforcing. For example, Table 4 illustrates that although most surveyed houses were built with an elevated ground floor (higher than garden level), most of the poor and medium households living in temporary or semi-solid houses had ground floors that were lower than those of better-off households. Hence, the poor are more exposed to flood water. There is a statistically significant difference between the levels reached by floodwaters during the 1999 event in better-off, poor and medium households.

Table 4 Average 1999 flood level and current level of plinth by household category

Household category	Height reached by water during the 1999 flood (cm from ground floor)	Elevation of current ground floor from garden level (cm)	Total economic loss caused by 1999 flood (VND million)
Poor	123.2	37.5	4.8
Medium	106.3	55.3	6.4
Better off	90.0	67.0	5.9

Note: statistically significant at 95% level of confidence.

Source: authors' elaboration.

In absolute terms, the flood caused more economic impact and damages to better-off and medium households (see Table 4), but overall the poor suffered the most in proportion to their income.

Another important result is that there is a statistically significant relationship between the total loss per household caused by the 1999 flood and the household flood risk index. As shown in the regression analysis: *(Total economic loss) = 4.6 + 0.004 × (Household Flood Risk Index)*. The positive sign of the coefficient on the household flood risk index implies that if policies and programmes can reduce the flood risk index, the total economic loss can be reduced. However, this model only explains a total 14 per cent of the variance in the total loss ($R^2=0.14$) due to the household flood risk index. In other words, 14 per cent of the statistical variation in total economic loss is accounted for by the flood risk index. This is because, although the physical vulnerability and exposure factors are important to determine the loss and damage caused by a disaster, other factors such as socio-economic vulnerability have greater impact on economic loss and damage. It is clear that a mix of actions are needed to reduce flood risk problems that combine structural spatial measures (access/reduced proximity to river, havens) with structural measures (building or retrofitting houses for safety) and social measures (reducing poverty in particular as a root contributor to vulnerability). Bearing in mind that relocation of families is not often a viable option for many reasons—proximity to the place of work being a prime one—the hazard mapping provides useful data indicating action that should be taken to reduce vulnerability in specific locations. Hazard mapping and planning for disaster prevention must therefore highlight how to address flood risk in a comprehensive manner with strategies dealing simultaneously with social, economic, spatial and structural issues.

Finally, the flood risk maps provide a quick illustration of areas that are flooded and the height of flooding relative to local ground level. With GIS technology, the thematic map can show selective information such as which houses are built on raised platforms, and which are built close to ground level. This gives an indication of flooding risk inside houses in different locations—some neighbourhoods have the same outside flood risk, but differ in their indoor flood risk. It also highlights what house criteria should be used and where, for example, by the Vietnamese government in its 'temporary house replacement programme', which aims to help poor families acquire decent durable shelter.

Partnership to overcome GIS operational problems

GIS mapping requires sophisticated and expensive software and hardware, as well as extensive workload to input, retrieve and analyse data. This can lead to incomplete databases if the workload is underestimated. Collecting data from the field using GPS and then entering it into the computer is time-consuming and costly. These technical problems could be solved by partnerships with local universities for data collection and technical support, since the human resources as well as the software and hardware are available in universities. Development Workshop worked with the geography department of Hue University, which significantly reduced the costs of the project. Such partnerships also create opportunities for students and faculties to enhance their practical skills and gradually increase disaster awareness in the university.

Another issue is that of access to reliable data. Since GIS is a relatively new technique in Viet Nam, the spatial data is scarce and inconsistent. Significant time is required to collect data from the field as well as to process and geo-reference the secondary data. To overcome this problem strong support is needed from national and provincial GIS projects using the same coordination system, enabling access to the GIS database for disaster risk management purposes. It is also essential to have a clear understanding of what data needs to be collected before implementing data collection since this stage takes up the most time and money. The stakeholders must, therefore, first clarify the community risk management goals and objectives and then determine what data is needed in order to accomplish them.

Finally, databases for GIS mapping need to be updated regularly. Thus, the data collection should be the responsibility of local communities. The commune staff should be trained to collect and input data. Data processing and analysis should be carried out at district level, where databases can be retrieved from communes. This should be possible as Viet Nam is working on developing an e-governance system. Soon, almost all communes in Thua Thien Hue will be connected to the internet, and the Provincial Committee for Flood and Storm Control has the human and technical resources to analyse the data. Both of the communes studied have staff with degrees in computer sciences and in cartographic management who can manage the database with basic training on GIS. Thus, applying GIS in disaster management is a realistic option in Thua Thien Hue province. The role of provincial government is to support the network that retrieves this data and delivers it to the Provincial Committee for Flood and Storm Control, so that a disaster management plan can be developed in a timely and effective manner.

Conclusion

The findings from this research confirm that the integration of local knowledge into the process of mapping provided important factual data and ideas about the social and physical environment, while identifying community vulnerabilities to disasters and developing disaster management strategies. This research proved that these contributions can be incorporated into other, often science-based, activities and methodologies associated with present-day programmes and policies for disaster risk management. As part of this integration, new technology and capacities derived from GIS and remote sensing must quickly become an essential element in community-based disaster management projects and in the application of the findings from these projects.

Using local knowledge in disaster management also enables local communities to participate actively in the decision-making process. Local knowledge is a powerful resource of rural peoples and therefore a key element in disaster risk reduction.

Integrating local knowledge into disaster risk management can improve the quality of disaster management plans by providing policy makers and practitioners with deeper insight into the many different aspects of disaster vulnerabilities and the interrelated role of local peoples and their cultures.

Finally, this study could be replicated in other areas or contexts provided that key conditions are met. The first important condition is that the local authorities accept the approach, and recognise that the map-making process is as important as the resulting maps. Second, relevant technical and human resources must be available as this model requires certain technical skills to use GIS software. With the current pace of IT and e-governance development in Viet Nam, the replication of the GIS mapping model is not far off for many local communes.

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Endnote

1 Phong Tran is a PhD Student and Rajib Shaw is Associate Professor at the Graduate School of Global Environmental Studies, Kyoto University, Japan. Guillaume Chantry is Project Coordinator and John Norton is President at Development Workshop France, Lauzerte, France.

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