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Cost-Benefit Analysis of Flood Adaptations in the An Xuan Tributary Basin, Thua Thien Hue, Vietnam

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March, 2014

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COST-BENEFIT ANALYSIS OF FLOOD ADAPTATIONS IN THE AN XUAN TRIBUTARY BASIN, THUA THIEN HUE, VIETNAM

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EXECUTIVE SUMMARY

Flooding is one of the most significant natural disasters to affect Vietnam. This is due to the high frequency of floods in the country and the severe impact they have on agriculture, transportation, water resources, infrastructure and human lives. Floods are a particularly significant problem for households living in low-lying areas such as the district of Quang Dien in Thua Thien Hue province. Projections show that the frequency and severity of floods in Thua Thien Hue will increase in the future due to climate change. Flood depths and inundation areas are also projected to increase significantly. To deal with current flood problems, local communities and government agencies design and implement various adaptation options. This study examines the economic feasibility of upgrading the flood control system in the An Xuan tributary basin in Quang Dien district, Thua Thien Hue province. This assessment is made using a cost-benefit analysis (CBA), in which the costs and benefits of the project were identified and valued using different valuation methods.

The findings show that upgrading the flood control system of the An Xuan tributary basin would help communities and households avoid the damages that floods cause to their livelihoods, houses and assets. The adaptation project would also help reduce damages to infrastructure, increase the net benefit of rice production and avoid the cost of social disruption caused by floods. The benefits of the project were valued using both a market-based method and the contingent valuation method (CVM). The change in flood risk due to the adaptation option, and the reduction in the probability of inundation that it would bring, were taken into consideration when calculating the costs and benefits of the adaptation project.

The CBA results show that the adaptation is economically feasible (although the estimated values of its benefits using the two valuation methods were not the same, with the CVM giving the bigger value). Upgrading the entire An Xuan tributary would bring great benefits to households and the government and would make good policy sense in light of the potential impact of climate change on future rainfall and sea levels. In other words, because the frequency and intensity of floods is set to increase (along with expected sea level rises), they will cause even more damage to communities than they do now if the An Xuan tributary is not upgraded. This means that it is really worthwhile for the government to invest in this project, as it will increase the sustainability of both agricultural production and socio-economic development. Besides, given the potential economic benefits that it will bring to communities, upgrading the entire An Xuan tributary will also make a significant contribution to sustainable agricultural water management and will improve sanitation conditions.

1.0 INTRODUCTION

1.1 Flooding in Thua Thien Hue Province

Located on Vietnam's north central coast, Thua Thien Hue is the center of the region's economics and culture. It has a total population of about 1.2 million people who live in eight districts and one city. Thua Thien Hue is divided into three sub-regions: an upland region that includes the Nam Dong and An Luoi districts, parts of Phu Loc and Phong Dien district; a low-lying delta region that includes Huong Thuy, Phu Vang, Quang Dien and Hue city (which is very vulnerable to floods); and a coastal region that incorporates the communes that surround Tam Giang lagoon and which are located along the coastal line. Thua Thien Hue is known as the flood basin of the north central coast.

"Living with floods" is the name of the strategy adopted by households that live in Thua Thien Hue province, particularly those located in the low-lying areas of the province such as Hue city, Quang Dien district, Phu Vang District, and Huong Thuy town. This approach manifests itself in two ways: first, through the significant efforts made by both government and households to adapt to floods; and second, by the fact that flooding is a chronic disaster in the province.

It is stated that there has been an increase in both the number and severity of floods in Thua Thien Hue province in the last 30 years. This has been linked to climate change (Do 2000). Records from the Thua Thien Hue Hydrometeorology Centre and the findings of a vulnerability analysis project[1] reveal that there has been an increase in the frequency and intensity of floods over the last few decades, particularly in recent years; from 1978 to 2008 there were 108 floods in which the water reached higher than flood warning level 2. During this period there was an average of 3.5 floods per year, while in the Huong and Bo river basins there were more than 7 floods per year during the period 1996-2007 (Table 1). In contrast, for the 19th and the early 20th century (from 1804 to 1945), only 38 floods and typhoons are historically recorded (PCFSC 2008).

Table 1. Average number of floods per year on the Huong and Bo Rivers (1996 to 2007)

River basin	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Huong river	0.0	0.0	0.0	0.2	1.4	3	2.1	0.7	7.4
Bo river	0.0	0.0	0.0	0.1	1.7	2.6	2.1	1.1	7.6

Source: IMHEN 2008a

The Thua Thien Hue Provincial Committee for Flood and Storm Control reported that the number of floods has increased significantly due to the impact of the El Niño-Southern Oscillation (ENSO) (PCFSC 2008). For example, ENSO was linked to the fact that there were seven floods in 1996 and six floods in 1998.

In the last ten years, the amount of precipitation falling in the region has increased. Moreover, daily maximum and monthly maximum precipitation levels have increased drastically. Most notably, the precipitation on 2 November 1999 was 978 mm, and the total precipitation in November 1999 was 2451.7 mm; both these levels were the highest on record. These precipitation levels contributed to historically significant floods in November 1999 in which flood water levels reached 5.3 m in height and killed 352 people. In 2007, four heavy floods occurred within one month (from 13 October to 16 November). These inundated 90 communes; some communes in Quang Dien, Phu Vang were inundated for 30 days.

There are two main river basins in Thua Thien Hue province that are particularly prone to floods and are known as flooding basins. Table 1 shows the average number of floods in these river basins per annum from 1996 to 2007. As the table shows (and as noted above) there was an average of over seven floods a year in both river basins during this time, with flooding mainly concentrated between October and November; although there was some flooding in September (i.e., early floods) and flooding also continued into December (late floods). One key problem is that the Tieu Man floods occur in May and this often causes huge amounts of damage to agricultural production as it is difficult for households to predict exactly when the floods will come and so prepare for their arrival.

[1] The vulnerability analysis project was carried out by the current study's research team as phase one of this research project.

As all of the above statistics suggest, flooding is the most frequently occurring natural disaster in Thua Thien Hue province – one that causes huge losses and damages to communities.

1.2 Floods and Damages

There is much clear evidence that floods have a wide range of negative impacts on households. As shown in Table 2, floods often affect agricultural production. In particular, paddy rice in Quang Dien, Huong Thuy, Phu Vang and Huong Tra is often inundated by floods. For example, heavy rains during 5 September 2009 inundated about 1,100 ha of rice in Thua Thien Hue province while the 1999 floods inundated about 12,495 ha of rice in the province. This means that food security is a problem for households living in Thua Thien Hue, particularly in its low-lying districts.

Table 2. Damages by floods and storms in Thua Thien Hue province

Years	Rice inundated (ha)	Inundated houses (# of house)	Dead (person)	Damage costs (bil VND)
1995	1,224	306	20	60
1996	8,628	464	31	127
1997	n/a	137	1	10.9
1998	n/a	6,203	31	168.1
1999	12,495	25,056	352	1,761.8
2000	2,30	182	5	73.6
2001	6,558	n/a	5	15.1
2002	754	231	9	15.0
2003	167	227	5	27.2
2004	345	1,626	12	248.0
2005	194	1,686	6	157.0
2006	1,500	34,015	8	2,931.0
2007	1,500	8,000	23	1,164.0
2008	258	57	5	61.0
2009	1,100	2,935	6	208.9

Source: PCFSC annual reports 2000-2011; Nguyen 2007

The annual disasters, floods and storms, in Thua Thien Hue also cause massive amounts of damage to houses. Vast numbers of houses are inundated and damaged every year, which places a massive financial burden on both households and the local government. Many households have been pushed into debt by floods and, as a result, have become trapped in a vicious cycle of poverty. In the 1999 floods, 25,056 houses in Thua Thien Hue were inundated; the floods that occurred in 2006 inundated 34,015 houses. What's more, it is estimated that from 1995 to 2009, floods and natural disasters killed 519 people and caused damage worth about VND 7,028.6 billion, which translates to about VND 468.6 billion per annum.

It is clear that, besides the direct economic damage they cause, annual floods also have many negative social and environment impacts on households, especially on those who live in communities with poor infrastructure (such as those surrounding Tam Giang lagoon) and those who live in communities near river banks and tributaries. Floods in Thua Thien Hue often inundate local roads, markets, irrigation systems, electricity stations and schools for several days. Information gleaned through focus group discussions (FGD) conducted by this study show that floods are lasting for longer than they did in the past, with the number of flood inundation days increasing from about four days in 1990 to the current length of seven days. Floods therefore lead to widespread and long-lasting social disruption. This means that affected households find it hard to recover their livelihoods and to get their living conditions back to normal.

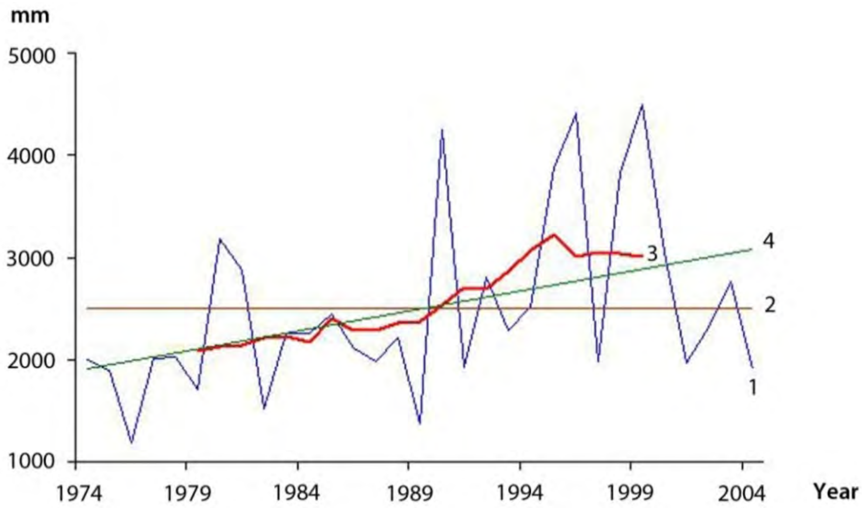
Floods also cause environmental problems to households. Households living in low-lying communes (i.e., Quang An, Quang Phuoc in Quang Dien, Phu Thanh and Phu Thuong in Phu Vang district) are often inundated with the solid waste, mud and debris that is brought down by flood water from upstream communes and Hue city. There is also a lot of concern about the use of agricultural chemicals and agricultural waste, which often appears in flood water. This study's FGD participants[2] state that floods often cause serious health problems, particularly for the elderly, women and children. Epidemic diseases such as marsh fever, malaria, dengue fever and diarrhea are amongst those that appear when floods occur. This is particularly worrying as sanitation and other health-related infrastructure is often poor in those communes that are affected by floods.

1.3 Floods in the Context of Climate Changes

Projections for the impact of climate change in Thua Thien Hue province are based on Vietnam's national climate change scenarios and on the assessments of the Intergovernmental Panel on Climate Change (IPCC), which include a review of the most recent regional climate change projections for the Southeast Asian region. The provincial climate change projections are based on the following IPCC scenarios: the A2 high emission scenarios, the B2 medium emission scenarios and the B1 low emission scenarios.

In reality, it should also be recognized that there have already been changes in the flooding season in Thua Thien Hue province. The arrival of the rainy season now occurs early (in April and May) and this causes damage to rice crops. Rainfall has decreased from June to August and increased from September to the end of November. Thus, flooding has become a regular occurrence at this period and has become more frequent and more intense.

Statistical records of rainfall collected from the Thua Thien Hue Centre for Hydrometeorology are shown Figure 1. These reveal the variation in rainfall in Thua Thien Hue from 1974-2005. Overall, there was a considerable increase in rainfall from 1974 to 2004 - from under 2000 mm/year in 1974 to nearly 3000 mm/year in 2004 (see red line 3). The rainfall from August to December has also clearly changed in the last 30 years (see green line 4). This explains the increase in the frequency and intensity of floods that have occurred in Thua Thien Hue in recent years.



Variability (1), climatologically average (2), moving average (time step – 11 years) (3), and linear trend (4) of August-December rainfall at A Luoi station.

Figure 1. Rainfall variation in Thua Thien Hue from 1974 -2005

The frequency and severity of floods in Thua Thien Hue have been projected to increase in the future. As shown in Table 3, rainfall will increase by 11% by 2100. A closer look at the table shows that there will be a difference in rainfall changes between months of the year. Rainfall will decrease by about 23.4% from the end of November to February and increase by 15% from October to the end of November. This means that there will be an increase in the frequency and severity of floods in the future.

[2] The FGD was conducted in 2012. See Section 2.3.2 for FGD description and details.

Table 3. Variations in rainfall during different seasons compared with 1961-1990 under A1F1 scenario (%)

Periods	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Year	0.5	0.9	1.5	2.5	4	5.7	7.3	8.7	10	11
Nov-Feb	-1	-2	-3.3	-5.4	-8.5	-12	-15.4	-18.5	-21.2	-23.4
Mar-May	0.4	0.8	1.3	3.1	3.4	4.8	6.1	7.4	8.4	9.3
Jun-Aug	0.7	1.1	2.2	3.6	5.6	8	10.3	12.3	14.2	15.6
Sep-Nov	1.1	2.1	3.5	5.7	8.9	12.7	16.3	19.6	22.4	24.7

Source: IMHEN 2008

In addition to rainfall projections, estimates of future flooding in Thua Thien Hue have also been conducted. These projections indicate that flood depths and inundation areas will increase sharply in the next 100 years. They show that the maximum depth of floods will increase by about 0.63 m in Thua Thien Hue in the next 100 years. The total area of flooded land will also increase by 17% (Table 4). This means that floods will have an even greater impact on households in Thua Thien Hue province in the future.

Table 4. Flood depth and inundation areas in Thua Thien Hue under A1F1 CC scenario

	1999	2030	2050	2070	2090	2100
Max flood depth (m)	5.81	5.96	6.08	6.16	6.27	6.44
Inundation area (km^2)	388.4	404.5	419.2	438.5	448.8	453.7
Percentage of inundation area (%)	7.69	8.01	8.29	8.68	8.88	8.98

Source: IMHEN 2008a

As it is located on the bank of the Tam Giang lagoon and along the coastal line, Thua Thien Hue is not only vulnerable to floods but also to sea level rises. This is because sea level rise (SLR) and sea surges reduce the discharge of flood water to the sea and therefore increase flood depths, duration and inundation areas.

Table 5 shows the correlation between the different emission scenarios and projected SLR in Thua Thien Hue (in comparison with the sea level in 1990). Sea level will rise by 22 cm in Thua Thien Hue in the High Emission scenario. This scale of SLR will affect large areas of low-lying paddy field and residential areas in Quang Dien, Phu Loc, Huong Thuy and Phu Vang. This will mean that large areas of paddy field will not be available for paddy rice cultivation. Many households living in low-lying areas, along the lagoon and the coastal line, will therefore need to be resettled to higher areas. With the Medium and the Low emission scenarios, the sea level will rise up by 15 cm and 13 cm, respectively. Even these smaller SLR will severely challenge Thua Thien Hue and require significant adaptation.

Table 5. Sea level rise* in the central region (cm) through the 21st century for different emission scenarios

Scenarios	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
High**	1,6	2,6	3,6	5,5	7,6	10,3	13,1	16,1	19,1	22,0
Medium***	1,6	2,6	3,9	5,4	7,1	8,9	10,7	12,5	14,2	15,9
Low****	1,6	2,6	3,7	5,1	6,8	8,5	10,0	11,4	12,6	13,6

* In comparison with 1990 sea level; ** high scenario = A1FT, A2; *** medium scenario = A1B, B2; **** low scenario = A1T, B1
Source: IMHEN 2008b

The above projections about the potential impacts of climate change in Thua Thien Hue were also confirmed by the information from the key informant interviews (KII) and FGDs conducted as part of this study, which highlighted the scale of SLR and variations in rainfall that cause floods in Thua Thien Hue. It is therefore important to realize that flooding in the region represents a major disaster that causes heavy losses to households. As there will be an increase in the frequency and intensity of floods even under the Medium emission scenarios, it is likely that, in the future, households will be exposed to even more dangerous floods, which will cause even heavier damages. This also means that any flood risk reduction measures will need to be significant and carefully planned if they are to prevent and mitigate the flood risks facing households.

1.4. Adaptation Measures to Floods in Thua Thien Hue

1.4.1 Government and adaptation practices

a. Adaptation to floods

It should be recognized that, until now, the provincial government has not had an official budget allocated to climate change projects. However, the provincial government has developed an institutional framework and has sought a budget to implement adaptation measures to climate change.

Thua Thien Hue has adopted the national framework and scenarios for climate change in order to design a provincial scenario for the impact of climate change for all sectors. Committees have been established for storm and flood control in all sectors at a provincial and commune level. These have been established in order to respond to disasters. The Committees for Flood and Storm Control have about 22-24 members who are drawn from different functional agencies such as the Medical Department, Agricultural Department, Financial Department, Environmental Department, Women Union, Youth Union, Police and Military.

The local government in Thua Thien Hue has made great efforts to strengthen local capacity to adapt to annual floods and disasters in recent years. It is clear that both local government agencies and local mass-participation organizations are aware of climate change and its impacts.

In order to prevent and mitigate the impact of floods, local governments may adopt a number of different adaptation strategies that incorporate both structural and soft (non-structural) measures. In Thua Thien-Hue, the local government has adopted a twin-pronged strategy of "living with flood" and "four self-reliance on-the-spot" for when disasters occur. This approach involves control measures, logistics, self-administration and human resources. For example, before the 'disaster season', the provincial government requires local governments to prepare and/or stock up on foods, water, medicines and logistics (enough to last for at least seven days, to cope with extreme disasters). This approach has proved effective at mitigating the impact of disasters and has become the adaptation measure of choice for both local authorities and local communities in flooded areas.

The provincial government in Thua Thien Hue has conducted a number of projects to improve and upgrade local infrastructure in disasters-prone areas. Such infrastructure includes dams, dikes and reservoirs constructed in order to mitigate the impacts of floods and flood flash (examples include the Thao Long dam, Tu Hien dam, and PAM dike construction). However, due to budget constraints, only a limited number of projects have been implemented. The government has also implemented resettlement programs for 540 out of 1,100 Sampan people. These are people who live on boats in Tam Giang lagoon and in houses on land along rivers in Thua Thien Hue. Thua Thien Hue province has also mobilized resources in order to consolidate and reinforce social welfare projects throughout the province, such as new schools, roads, electricity stations, local health care systems, and canal systems. These public infrastructure projects provide safer shelters wherein local communities can evacuate to when extreme disasters occur.

Early warning systems (EWS) have also been built to forewarn communities. These are wireless systems designed to work even in extreme conditions. Flooding markers have been built along river basins, lagoons and low-lying areas. Four rainfall monitoring and flood warning stations have been built in A Luoi, Nam Dong, Hue and Phu Loc of Thua Thien Hue (PCFSC 2011).

In terms of agriculture, Thua Thien-Hue province has put in place various flood adaptation measures. These include adjusting the cropping calendar for different crops and cropping patterns. Many new short-term crop varieties have been delivered to households to help shorten the cropping calendar in order to avoid the impact of early disasters on rice varieties such as Khang Dan, TH5, and TH95. Livestock farmers are asked to sell their animals before the start of the flooding season; this is particularly the case for farmers raising cattle and pigs in low-lying delta regions and along the Tam Giang lagoon. Other adaptive measures that have been put in place in the province are the re-greening of barren hills and the planting of trees along rivers and dunes along the coastline. Reforestation activities are also conducted in the upstream districts of Nam Dong, Aluoi, Phong Dien, and Phu Loc.

As mentioned previously, annual disasters do have a significant negative impact on the health of local communities, especially the poor. Moreover, local health care systems in vulnerable regions are not generally able to provide adequate treatment standards when communities have to cope with extreme disasters. The results of this study reveal that various adaptation measures should be implemented to enhance the capacity of local communities to adapt to floods. These include improving village health care systems by providing first aid training and equipment along with treatments for common illness. Sanitation, water treatment and water supplies, solid and liquid waste management, and the protection of groundwater should also be prioritized for improvement. The resilience of the ecosystems, on which communities depend for food and income, should also be strengthened.

Raising awareness of the risk of floods is vital. In collaboration with NGOs, the government has already organized many training courses related to floods, climate change and other natural hazards. These have covered many of the issues discussed above, such as changes in cropping calendars and first aid. Children have also been trained to swim and houses have been built and reinforced to withstand floods.

Overall, there have been many things done in order to increase the adaptive capacity of households living in flood-prone areas in Thua Thien Hue. However, the effectiveness of such measures has been limited and annual floods and other disasters still cause huge amounts of damage to households.

Many measures are just short-term responses to the risk of flooding, rather than long-term adaptation measures. Such short-term responses include reinforcing houses and dikes, upgrading EWS, selling cattle and pigs before the flooding seasons, implementing the “four self-reliance on-the-spot” approach, and establishing committees for storm and flood control. The effectiveness of these short-term measures is limited due to the fact that floods have increased in both frequency and intensity and that they also now occur ‘out of season’. This means that long-term adaptation measures are vital to reduce the vulnerability of households to flood risks.

b. Difficulties in adaptation to floods

It is important to note that a lack of resources (including money, materials, and knowledge) is the biggest factor constraining the work that the various levels of local government (and local communities) can do to respond to annual flood disasters and climate change. The study found that until now the provincial government has not had an official budget allocated to climate change projects. The money that has been spent on adaptation options has come from different sources in the government. This lack of money has meant that there are many vital disaster adaptation measures that haven’t been put in place.

A closer look at the Committee for Flood and Storm Control (CFSC) (from the provincial to the commune level) highlights the fact that the committee has to deal with many difficulties that are constraining its response to annual disasters. No CFSC member works full-time for the committee and the work the members do is not paid; all of them are government staff and their involvement in the committee is an extra responsibility. The CFSC has no state budget officially allocated for its operation and it suffers from a lack of operational equipment such as transportation, life vests and torches. The committee also suffers from a lack of experience, expertise and preparedness when it comes to coping with significant disaster events. This means that all CFSC members have to deal with a lack of budget, tools and institutional support.

It is important to bear in mind that local communities in many parts of Thua Thien Hue are very poor and have a low awareness of flood risks and environmental issues. For example, many households do not evacuate their families to safe shelters when they are flooded because they were not involved in putting together the relevant evacuation strategies, and feel that they must stay at home to protect their assets. It is also important to realize that it is difficult for local government agencies to put in place any necessary adaptation options due to a lack of resources.

Moreover, the recent increase in the frequency and intensity of floods has reduced the effectiveness of existing flood risk prevention measures that households have put in place. In other words, measures that have been adopted to cope with normal floods have not been able to deal with more hazardous or unseasonal floods (i.e., the early flood in May 2009 and the late flood that occurred in December 2007). These floods caused significant damage to agricultural production as they were outside local experience and were therefore not well coped with by households.

1.4.2 Households and adaptation to floods

As mentioned previously, households living in areas of Thua Thien Hue that are prone to flooding use the "living with flood" strategy to adapt to floods. As a result, various flood adaptation measures have been put in place. However, as most villagers are poor, only a few have had the capital to act, so the number of projects is relatively low. This study's FGD results revealed that structural adaptation measures are the most effective ways to mitigate the impacts of floods. Such measures include building households with high foundations, building mezzanine floors, building houses on steel frames, and reinforcing buildings.

Moving foods and house items to a safe place and buying and storing food, water and amenities are among the adaptation measures adopted at the household level under the "four self-reliance on-the-spot" approach (i.e., leadership on-the-spot; human resources on-the-spot; materials on-the-spot; and logistics on-the-spot). This is an effective strategy for both the local government and households as, when extreme floods hit, many communities are often isolated for about three to five days. In such situations, self-reliance is vital. It also means that people do not have to go out to get the things they need, which reduces their exposure to risk.

FGD results also indicated that households have made a great effort to change the crop varieties in both their garden and their paddy fields. Households recently replaced Khang Dan and HT5 rice varieties with the T92-1 and T94 varieties as their lifecycle is 10 days shorter. Despite their lower yields (5.3 ton/ha), they have still proved to be an effective way of avoiding the impact of the early floods; although some farmers are still using traditional varieties because of a shortage of the T92 variety, alongside a lack of capital and knowledge. Many farmers have also shifted from groundnut cultivation to the cultivation of short-term vegetables in order to escape the impact of early flooding. Because these vegetables can be harvested early, farmers are able to sell them before the storm and flood season. However, they do face a disadvantage when negotiating and often have to accept a low price.

Diversifying livelihood practices, preparing the means for evacuations and migrating to the city (to seek a job) are other adaptation practices used by households living in flood-prone areas of Thua Thien Hue province. These adaptation measures have helped to mitigate the impacts of floods. When asked why they adopt these measures, most respondents stated that they were acting upon their own experiences and the experiences of their communities. FGD results show that most local people realize the importance of weather forecast in disaster prevention; they therefore always watch the TV news or listen to the radio for weather reports in order to be as ready as possible in case of floods.

The above findings highlight the fact that, alongside the great efforts that have been made by government agencies, households have also adopted many measures in order to prevent and mitigate the impact of annual floods. It is, however, reasonable to conclude that many of the things that have been done are 'response' rather than 'adaptation' measures. This means that the so called "living with floods" strategy is more about response than adaptation. What's more the response measures adopted by households often mitigate the impact of normal annual floods, but do not mitigate the impact of extreme events. This explains why unseasonal floods and extreme floods often cause a huge amount of damage to households.

1.5 Flood Prone Areas and Study Site Choice

1.5.1 Flooding risk map of Thua Thien Hue

The above discussion confirms that floods are a very serious disaster, particularly for households living in low-lying areas in Thua Thien Hue province. The flood risk map of the province reveals that Quang Dien is one of its lowest delta areas and that it has a flood risk of the highest level (Figure 2). Quang Dien is a rural district of Thua Thien Hue province. It is located in the north of the province within about 20 km of Hue city. The district shares a border with Huong Tra district to the east and the south, with Phong Dien to the west and east. There are 82,813 people living in its 16,329 ha. There are 10 communes and one small town in the district (Quang An, Quang Thanh, Quang Phuoc, Quang Tho, Quang Vinh, Quang Thai, Quang Loi, Quang Ngan, Quang Cong, Quang Phu and Sia). The Bo river runs southwest through the district.

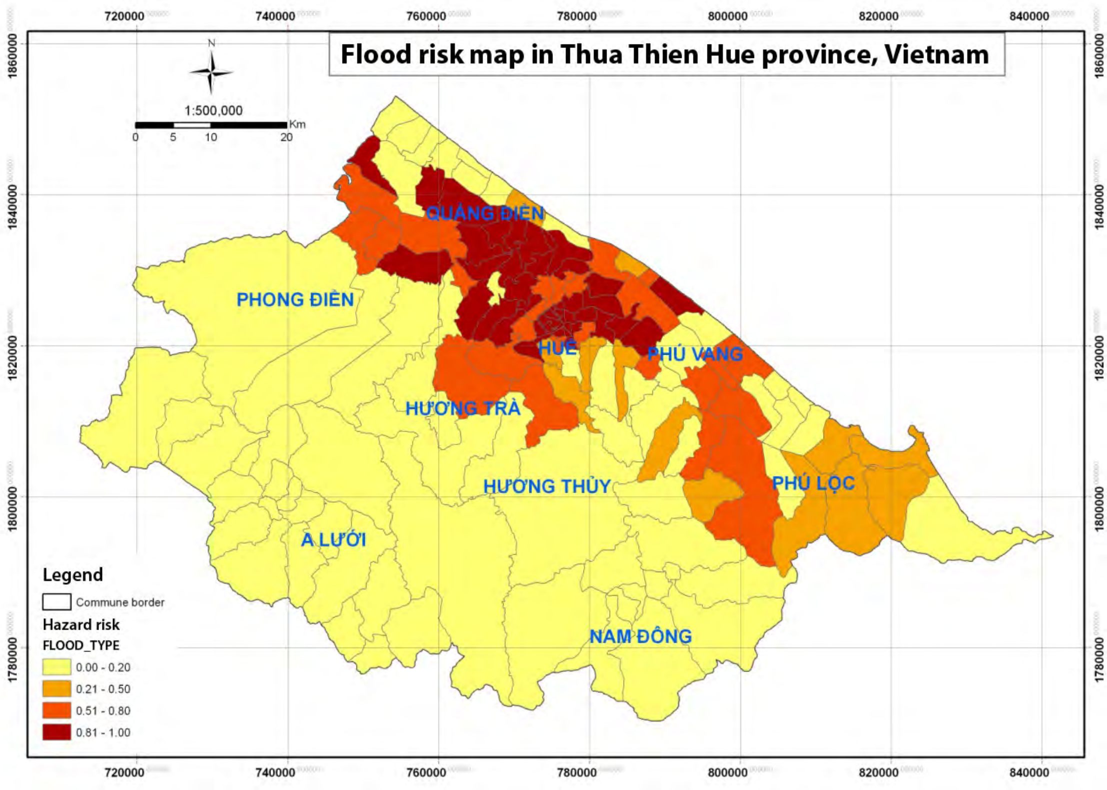


Figure 2. Flood risk map in Thua Thien Hue province

Flood risk mapping shows that almost 10 communes in Quang Dien district have a vulnerability index of 0.8 to 1. This means that they are among the communes that are most vulnerable to floods in the whole of Thua Thien Hue province (there are some communes located in Phu Vang and Hue city that are also very vulnerable to floods). These 10 communes are located near the Bo river, the Tam Giang lagoon and the coastline. Their households mainly rely on agricultural production for their livelihoods. This means that floods often have more severe impacts on the households in these communes than they do elsewhere. In turn, this means that any adaptation measures designed and implemented in Quang Dien district are more likely to prevent and mitigate the impact of floods.

1.5.2 An Xuan tributary basin

The An Xuan tributary basin is the lowest-lying land area in Quang Tho, Quang An and Quang Phuoc communes, all of which lie in Quang Dien district. The basin's total area is 1,200 ha. The Bo river runs from the southwest through the An Xuan tributary to the Tam Giang lagoon. This study's FGD results and KIIs confirmed the important role of the An Xuan tributary as the main rice production area within the Quang Dien district; it has a total of about 810 ha under rice cultivation. Hence, as highlighted in the flood risk map (Figure 2), the An Xuan tributary has one of the highest flood risks in the district. Accordingly, annual floods in the area have a severe impact on households and rice production.

There are many reasons why the An Xuan tributary is a high flood risk area. Firstly, this is because of the recent general increase in the frequency and intensity of floods, caused particularly by heavy rainfall between September and November. Secondly, the drainage capacity of the Bo river has been reduced by sedimentation. Indeed, many participants in this study confirmed that sedimentation in the An Xuan tributary and its canals has rapidly increased in recent years. It is strongly recommended that dredging and other upgrading work is vital to mitigate the impacts of floods. Thirdly, An Xuan is the part of Quang Dien district where flood waters naturally collect. Indeed, the An Xuan tributary, one of the two main tributaries of the Bo river, is considered to be that river's main downstream flood outlet; it is 4.6 km long from Nga Tu Bridge (the provincial road 4) to the An Xuan drain which is in Quang An Commune, Quang Dien District. The study also found that the irrigation systems in An Xuan (i.e., dams, canals, and roads) have been downgraded.

In the rainy season, the mouth of the An Xuan tributary has a width of more than 1km, however its cross-sectional area is not wide enough for adequate drainage (it has a bottom-width of 11m). Its drain gate only has three apertures (each of which is only 2.5 m wide) and these are not large enough to drain water adequately. This results in the inundation of residential areas and paddy fields, and subsequent damage to private property, public infrastructure (i.e., schools) and, especially, agricultural production.

The above analysis underlines the conclusion that many government flood adaptation plans (i.e., “four self-reliance on-the-spot”, reinforcing houses, and the selling of cattle and pigs before the flooding season) are actually only response measures. It also highlights the fact that a lack of budget is constraining the choice of structural adaptation options that the local government can adopt.

The study’s FGD results showed that there are four types of floods that affect households. The first type is the Tieu Man flood, which often occurs in April and May. The second type is the early flood, which often occurs in August or SeptemberThe third type is the main flood, which is divided into two sub-types: the first merits a second level flood warning; and the second type merits a higher flood warning level. The fourth type of flood is the late flood, which occurs in late December and January. The different flood types and their impacts are further described in Section 1.6.2.

It is projected that under the ‘medium’ climate change scenario, flooding will increase in both frequency and intensity (in combination with rising sea levels) in the future. This means that, if no proper action is taken, households will be exposed to greater flood risks and will suffer more damage in the future.

The main question raised in this study’s FGDs was what should be done to help the communities in the An Xuan tributary to adapt to floods, given the likely impact of climate change and the fact that resources are limited. In response, many adaptation options were touched upon, but the main focus of most recommendations was the need to upgrade the An Xuan tributary flood control system.

1.6 Identification, Preliminary Assessment and Design of Flood Adaptation Option

1.6.1 Natural, socio-economic features of the An Xuan tributary basin

The An Xuan tributary (Figure 3) is located in Quang An commune, 10 km away from Hue city (as the crow flies). It geographical coordinates are: 1633’23” to 1634’10” of the north latitude, and 10731’58” to 10733’42” of the east longitude.

LEGEND: Commune boundaries — Provincial road no. 4 — Dike system of An Xuan tributary — Border of project site

Figure 3. An Xuan tributary

The boundaries of the area that will benefit from the adaptation are as follows: its southwest border is contiguous to the provincial road 4, its northern border is Bau Kho Street, its eastern border is the cross-commune road between Quang An and Quang Thanh, and its northeast border is Tam Giang lagoon (Dike ICCO). The An Xuan tributary is one of the two main tributaries of the Bo river, and is considered to be the main flood outlet of this river's downstream section.

The study site covers a production area of about 812.5 ha, of this 495 ha belongs to the Quang An commune and 317 ha to the Quang Phuoc commune. The area's topography gradually lowers to the northwest (contiguous to lagoons). The area of agricultural land stretches through the two communes and has a width ranging from 2.7 km to 4.8 km. The field surface height varies from -0.6 m to -0.3 m (i.e., it is below sea level).

There are about 19,000 inhabitants living in 4,197 households in Quang An and Quang Phuoc communes (about 10,700 in Quang An commune and about 8,300 person in Quang Phuoc). Over 50% of the population of the An Xuan tributary is of working age (about 10,200 laborers). This is an important resource for the households living in this poor community where people mainly rely on agricultural production for their livelihoods.

It is important to note that Quang An and Quang Phuoc are two of the poorest communes in Quang Dien district. In Quang An, 21.79% of the population lives in poverty while in Quang Phuoc the poverty rate is 18.77% (Table 6). The average poverty rate in Thua Thien Hue province, which includes six other districts and one town, is about 14%. The per capita income in 2011 was about VND 8 million in Quang An and about VND 9.5 million in Quang Phuoc (equivalent to USD 500). Both these income levels are lower than the per capita income of the whole province, which is USD 1,100. The high rates of poverty in the two communes explain why the two commune governments cannot afford to upgrade the An Xuan tributary, although there is a high demand for this to be done.

Table 6. Socio-economic conditions in the An Xuan tributary

Commune	No. of households	No. of inhabitants	No. of laborers	No. of poor households	Ratio of poor households	Capita income 2011
Quang An	2.226	10.724	4.954	485	21.79%	8.000.000
Quang Phuoc	1.971	8.302	5.269	370	18.77%	9.500.000
Total	**4.197**	**19.026**	**10.223**	**855**	**20.37**	**8.750.000**

Source: Quang An and Quang Phuoc People Committee, Annual Report on Disaster Damages and Mitigation and Prevention Strategy 2011

It is important to note that land is an important resource for most of the households living in the An Xuan tributary as a large proportion of households are involved in agricultural production. The two communes have a total area of natural land of 2,455 ha; of this about 1,400 ha is agricultural land. This is made up of 988.7 ha of paddy rice, 21.5 ha of cereal, and 408 ha of aquaculture ponds (Table 7). Gardening land is also an important resource for households that often cultivate vegetables and fruits in order to improve their income. It is, however, important to note that almost all the available land in the An Xuan tributary has been used, so there is little opportunity for expanding agriculture or horticulture.

Table 7. Land resources in Quang An and Quang Phuoc commune

Commune	Natural land (ha)	Agricultural land			Residential land		Non-use land (land)
		Rice (ha)	Cereal (ha)	Fisheries (ha)	Building land	Gardening land	
Quang An	1.187	528	12.1	188.1	96.2	355.9	6.7
Quang Phuoc	1.268	460.7	9.4	219.9	69.3	494.4	14.3
Total	**2.455**	**988.7**	**21.5**	**408.0**	**165.5**	**850.3**	**21.0**

Source: Quang An and Quang Phuoc People Committee, Annual Report on Disaster Damages and Mitigation and Prevention Strategy 2011

A closer look at land use patterns in the An Xuan tributary reveals that rice is the main crop grown in this area. It has a total area under rice cultivation of 812.5 ha (Table 8), which accounts for about 82.1% of the total rice production area of Quang An and Quang Phuoc communes. The area of fishing ponds in the An

Xuan tributary (206 ha) accounts for about 50% of the total area of fishing ponds in the two communes (408 ha). This means that the An Xuan tributary plays an important role in agricultural production in this region, even though it is very vulnerable to floods.

Table 8. Rice and aquaculture area in An Xuan tributary

Commune	Cooperatives	Rice (ha)	Aquaculture (ha)
Quang An	Dong Phu	242.0	
	An Xuan	253.0	141.0
Quang Phuoc	Dong Phuoc	264.0	
	Mai Duong	53.5	65.0
	Total	**812.5**	**206.0**

Source: Quang An and Quang Phuoc People Committee, Annual Report on Disaster Damages and Mitigation and Prevention Strategy 2011

A review of the socio-economic development strategy for Thua Thien Hue province shows that the province is aiming to capitalize on its regional potential and advantages to both speed up its economic development and reduce poverty. For Quang Dien district, the Thua Thien Hue People's Committee has planned to maximize the use of agricultural land for rice and other crops and to maximize the use of the lagoon for aquaculture. It is recognized that rice production and aquaculture should be improved by upgrading irrigation systems to deal with the impact of natural disasters, and so increase crop productivity. With these improvements, it is hoped that the An Xuan tributary will be an even more important area for rice production and aquaculture in Quang Dien district. These goals will become more feasible if the An Xuan tributary is upgraded. Given the advantage the area enjoys in terms of its large area of agricultural land, the local authorities have designed a plan for the development of agricultural production that will introduce intensive farming into the whole lowland area. The aim is to boost rice productivity, so that there are two crops per year and yields of between 65-70 quintal/ha.

Households in the An Xuan tributary have diversified their livelihoods as a way of adapting to floods. This strategy is highlighted in Table 9, which shows that there are over ten main sources of income. Of these, agricultural production is the most important, with 32% of income coming from cropping, 15% from livestock and 6.5% from aquaculture. This means that over half of household income is from the agricultural sector, which is very vulnerable to floods. Daily work and small local market businesses are also important sources of household income (they account for about a quarter of the total). The average income of households is about VND 30.7 million, which is about VND 8.5 million/person.

Table 9. Source of income of surveyed households in the An Xuan tributary (in 1,000 VND)

Source of income	Mean	Share (%)
Cropping	9,743	31.7
Salary/daily work income	4,744	15.4
Livestock	4,618	15.0
Small business	3,132	10.2
Aquaculture	2,000	6.5
Handicraft	1,782	5.8
Other source of production	1,650	5.4
Pension	982	3.2
Remittance	975	3.2
Other sources	950	3.1
Forestry	206	0.7
Total income	**30,782**	**100**

Note: Survey conducted in 2012; see Section 2.3.2 for survey details

1.6.2 Flood risk in the An Xuan tributary basin and existing adaptation options

a. Flooding situation

As highlighted in the flood risk map (Figure 2), Quang Dien is the district that is most vulnerable to floods in the whole of Thua Thien Hue province. In Quang Dien, the An Xuan tributary is one of the most flood-prone areas, thanks to its location near the Tam Giang lagoon and the Bo river. As a result, annual floods have a severe impact on households and rice production in this area.

There are many factors that explain why the An Xuan tributary is a high flood-risk area. As previously mentioned (Section 1.5.2), one of the main reasons is because the An Xuan tributary is a low-lying area that collects flood water not only for Quang An and Quang Phuoc communes but also for many other communes in Quang Dien district. This means that during any flood (from the least to the most extreme) the An Xuan tributary is the first area, at both a commune and district level, to be inundated. This study's FGD participants confirmed that households living in the An Xuan tributary suffer greater damage to their crops and other assets than households living in other communes.

The result of the household survey[3] conducted by this study shows that there are four main types of floods that often occur in the An Xuan tributary. These are the:

1. ***Tieu Man floods*** - often occur in March to May, which is during the pre-harvest season of rice and cereal. This flood therefore causes massive damage to rice crops. For example, in 2009, the Tieu Man flood occurred on the 11th May, which caused tremendous damage to about 1,800 ha of rice in Thua Thien Hue province.
2. ***Early floods*** - often occur in August or September, which is about the time of the harvest of summer-autumn crops. Thus, if the early floods occurs before the harvest has been gathered, it will cause significant damage to crops.
3. ***Main floods*** - often occur from November to early December. It is important to note that by this time rice and other crops have been harvested, thus main floods have less impact on crops than the other types of floods. However, they do cause serious damage to houses, animals, and other assets.
4. ***Late floods*** - often occur in late December and January, which is the time when new crops are being prepared. Thus, late floods result in the delay of new crop preparations and increase the probability of Tieu Man floods having an impact on spring-autumn crops.

In the last five years, households in the An Xuan tributary have had to suffer 3.68 Tieu Man floods, 7 early floods and about 22 seasonal floods. On average, about 2.6 floods occur annually in the An Xuan tributary (Table 10).

Table 10. Number of floods affecting interviewed households in the last five years in An Xuan tributary

Type of floods	Mean	Std. deviation
1. Tieu Man flood	2.1	1.551
2. Early floods	1.3	4.745
3. Main flood	5.8	3.645
4. Late floods	3.8	1.542
Total	**13.0**	

Note: Survey conducted in 2012; see Section 2.3.2 for survey details

An assessment of the impact of floods in the An Xuan tributary (Table 11) found that floods pose various risks to households in the area. Of these, damages to houses and agricultural production are the most significant. The results of the survey showed that floods have a serious impact on agricultural production, particularly early floods and Tieu Man floods. This finding can be explained by the fact that Tieu Man floods and early floods often occur before harvests take place and therefore cause huge losses to crops (though the magnitude of these floods is less than those that merit second and third level warnings).

[3] A household survey was conducted on 2012. Details of the survey design are discussed in Section 2.3.2.

Table 11. Flood risk to households in the An Xuan tributary

Type of floods	Impacts	Yes	No
1. Tieu Man floods	Inundation on crops	76.3	23.7
	Impacts on houses	5.9	94.1
2. Main floods	Inundation on crops	45.1	55.0
	Impacts on houses	26.2	73.8
3. Late floods	Inundation on crops	48.7	51.3
	Impacts on houses	77.6	22.4
4. Early floods	Inundation on crops	52.9	47.1
	Impacts on houses	9.9	90.1

Note: Survey conducted in 2012; see Section 2.3.2 for survey details

Meanwhile, the survey found that main floods have a less significant impact on agricultural production, with less than 50% of households confirming that their crops had been affected by main floods. This finding can be explained by the fact that main floods often occur in November and October, when crops have been harvested.

The results of KIIs and FGDs reveal that the average depth of the Tieu Man floods that occur from March to May is 0.8 m. The average area that these floods cover is 760 ha, of which 640 ha is agricultural land. Floods that merit an Alert Level 2 normally affect two communes and have an average depth of 0.8 m. The average area that these floods cover is about 760 ha, of which 640 ha is agricultural land. Main floods (from September to end of November) affect three communes and have an average flood depth of 1.3 m. The average area that these floods cover is 915 ha, of which 710 ha is agricultural land.

It should be noted that floods have an impact not only on crops, but also on houses and on other household property. Floods have a slightly different impact on houses and property than they do on crops. Their impact is positively correlated with their magnitude. This means that the higher the flood, the more severe the damage it will cause to houses and property. The survey results show that less than 10% of households reported that Tieu Man and early floods had caused any damage to their houses and property.

The results of this study's FGDs conducted in the An Xuan tributary found that annual floods also have an impact on the environment and on human health. As it is the lowest-lying area in Quang Dien district, the An Xuan tributary collects flood water that is contaminated with solid waste and floating animal remains. These cause environmental pollution issues and threaten the health of households living in the region.

b. Existing adaptation measures to floods in the An Xuan tributary

Local government agencies and households have recognized the severe impact that floods have; they have also recognized the likelihood that the frequency and intensity of floods will increase in the future. Because of this, they have been making great efforts to prevent and mitigate the impact of floods. At the commune level, a commune CFSC has been established. This involves commune functional units, community organizations (such as farmer and youth associations) and village leaders. The commune has also adopted various structural and organizational adaptation measures. These include:

- Dredging irrigation systems, in order to ensure that flood waters can drain away easily. However this measure has only been implemented on a very small scale as the irrigation system in the An Xuan tributary has been downgraded due to budget and resource constraints.

- Changing the cropping calendar of paddy cultivation and adopting new, shorter-term varieties. This measure has helped to shorten cropping time by about 10 days, which has helped farmers to avoid the impact of some floods. However, this study's FGD participants stated that it is really hard to change the cropping calendar as it has been used for many years. Moreover, the unpredictability of floods and the recent increase in their frequency and intensity means that they still cause huge amounts of damage to crops in the An Xuan tributary.

- Building new houses on higher foundation and reinforcing households before the flooding seasons. This measure has helped some households; however, the number is very limited as this option is only affordable to a small proportion of the people living in the An Xuan tributary, most of whom are poor. This means that there is still a large proportion of the area's population that live in houses that are vulnerable to floods.

- The government also organizes training courses on agricultural adaptation options and on medical care for households and other vulnerable groups such as school pupils. Governmental and non-governmental organizations also work to raise local awareness of flood risks in the An Xuan tributary. However, the number of courses that can be organized is limited due to a lack of resources and budget constraints.

- During the flooding season the local government often asks local people to prepare themselves to live with flood by adopting the "four self-reliance on-the-spot" approach. The government asks both households and community groups to stock food and water, prepare the necessary human resources, implement control systems, and organize rescue teams. This approach is deemed an effective response measure rather than an adaptation option.

At the household level, various adaptation options have been implemented in order to prevent floods and mitigate their impact. These include building houses on steel frames, building houses on higher foundations, selling livestock before the flooding season, adopting new crop varieties, and adopting the "four self-reliance on-the-spot" strategy.

Households also contribute their labor and other resources to collective adaptation projects such as irrigation system dredging and community relief efforts. However, due to resource constraints, households mainly focus on cheaper adaptation or response measures. For example, many households involved in the FGDs stated that, while they recognized the effectiveness of building new houses on steel frames or reinforcing houses before the flooding season, they could not adopt such measures as they did not have enough resources.

1.6.3 Proposed adaptations to floods in the An Xuan tributary

a. Proposed adaptation options

The above analysis shows that there is a pressing need to design and implement adaptation options to help households adapt to floods and mitigate their impact. This is particularly urgent, given the challenges that will be posed by climate change in the future. The result of this study's FGDs and KIIs (conducted from the provincial-government level down to the community level) outlined many potential adaptation options. These included dike improvements to prevent salinity intrusion from brackish lagoon water, and the construction of an overflow dam. However these were rejected as they were either not linked to extreme events linked to climate change or because they were emergency response measures rather than adaptation options.

The main recommendation from both government agencies and the community was upgrading the An Xuan tributary. This approach was selected based on the support it received and because it is a priority area of work in the national climate change adaptation strategy. This means that central government funding for the project is more likely, as it is in close alignment with the national strategy.

In light of the suggestions and advice received from participants in the study, a list of adaptation project activities was drawn up. Key project elements were as follows:

- Upgrading the An Xuan tributary to prevent small floods, early floods and late floods by diverting floodwater from the An Xuan tributary to stop it from overflowing into paddy fields. The key focus of this work is to protect crops on the 812.5 ha of agricultural land in the two communes of Quang An and Quang Phuoc in Quang Dien district.

- Gaining better control over water resources for rice irrigation.

- Widening the top (crest) of the dike to create a road link to help improve communications, local daily life, and agricultural production.

- Preventing landslides in the banks of the tributary, allowing water to flow in its natural way, reducing floods in residential areas, protecting homesteads by the tributary banks, constructing roads, and boosting local culture, welfare and livelihoods so that people can live and work in safety and contentment.

- Making a significant contribution to the hunger eradication and poverty reduction plan in the region.

- Constructing dikes to help clear flood water runoff and so ensure faster drainage. These dikes must be constructed so that they are aesthetically appealing and beautify the local landscape.

Using the list of proposed adaptation projects, the researchers conducted further sharing and learning dialogues. Participants included representatives from various government agencies, technical experts and households living in the An Xuan tributary. These participants were asked to consider two adaptation options: a) upgrading critical sections of the dike in the An Xuan tributary; and b) upgrading the entire dike in the An Xuan tributary.

b. Screening the adaptation options

The participants of the sharing and learning dialogues evaluated the effectiveness, advantages and disadvantages of the two adaptation options indicated above.

The first adaptation option (i.e., upgrading critical sections of the dike in the An Xuan Tributary) was evaluated as the cheaper and easier of the two options by both communes and households. However, many participants argued that this option was more like a 'response option' rather than an 'adaptation option'. In other words, the upgrading of only the critical parts of the dike would not be a sustainable option as other parts of the dike would also be prone to degradation over time due to floods and other natural hazards. The communes were therefore concerned that they would have to upgrade the dike again and again, year by year. Other participants also shared this concern about the potential project's effectiveness. They argued that, given the unpredictable nature of floods, their increased frequency and intensity, and the likelihood of future SLR, the effectiveness of upgrading a critical section of the dike would be limited.

The second adaptation option (i.e., upgrading the entire An Xuan tributary dike) got a more positive response from participants. It was strongly recommended as an effective adaptation option that would increase the adaptive capacity of households and mitigate the impact of floods. Participants evaluated this option as being more expensive than option one. However, they thought that the government should mobilize funds so that it could be undertaken. It was felt that, if the government could save resources and divert funds from other sources, then it would be able to overcome any resource constraints.

1.6.4 Technical design of the selected adaptation option

a. Technical design

Upgrading the entire An Xuan tributary dike was chosen as the best adaptation option. The technical design for this project was provided by experts from Consultancy and Construction for Irrigation Ltd. Key project elements are as follow:

- Dredging and widening the tributary bottom at those parts that are not large enough for adequate drainage. Making the dike higher, and constructing a road along its crest. Reinforcing the whole crest (which would have a total bank length of 9.4 km).

- Designing a new An Xuan drain with a system of automatic sluice gates. These would have apertures that would be able to cope with the drainage capacity of the tributary bottom after it had been dredged and widened.

- Building eight new open drains at the beginning of the winter-spring crop cycle to prevent water from overflowing from the An Xuan tributary onto paddy fields when small floods, early floods and late floods occur.
- Building 10 ring drains, each with a diameter of 100 cm, for irrigation purposes.
- Building a bridge over the Nga Tu tributary on the right bank of the An Xuan tributary with a length of 24 m and a width of 5 m.

b. Technical specifications

Dike height

A field inspection showed that the maximum small flood level at Tu Nga bridge is +2.0 m above sea level, and that the maximum small flood level at An Xuan drain is +1.60 m. The calculated dike height for the area from Nga Tu bridge to Phu Luong B bridge (a length of 1.7 km) is +2.50 m; from Phu Luong B bridge to An Xuan drain, the dike height should be +1.60 m, with the length of 3 km and a slope where i=3.10.

Dredging and widening the tributary bottom from Con Bai bridge to An Xuan drain

The field inspection indicated that the tributary section from Con Bai bridge to An Xuan drain has an average bottom height that varies from -0.90 m to -1.10 m, and a bottom width of 11 m. The maximum small flood level at An Xuan drain is +1.60 m. This causes water to overflow the embankment by about 0.3 m. The minimum bottom width is 22 m. The width of the cross-section of this part of the tributary should therefore be expanded to 22 m, the bottom height raised to -2.0 m and the slope changed to i=1.50.

Redressing the section from Con Bai bridge

The part of the An Xuan tributary that runs for 300 m from Con Bai bridge is bent. This should be redressed, which will shorten its length to 210 m. The cross-section of this part of the dike should be remodeled to the same specifications as the section from Con Bai bridge to An Xuan drain (see above).

1.6.5 Embankment reinforcement combined with road construction

Based on the study, it is vital to reinforce a 4.7 m long length of the bank of the An Xuan tributary.

- The crest-width can be used for building a road with a width of 5.0 m. This should be reinforced by M200 concrete with a thickness of 20 cm. The dike height should vary from +2.50 m to +1.6 m, the dike slope should be i = 2%.
- The dike base height should be -0.20 m. It should be supported by 1.5 m long bamboo poles. These should be positioned with a density of five poles per meter.

a. Primary construction solutions

Construction features and conditions

The proposed work would stretch along the right and left bank of the An Xuan tributary, this means that the construction work could be conveniently organized. Construction materials should be gathered near the construction site. There is a large area of wasteland that could be used for storage. Every effort should be made to avoid road encroachment.

Earthworking should be done by hand and using machines as appropriate. Excess soil and the soil from the surface weathered layer (which is not good for the dike) should be transported by van to urban planning zones where it can be used for gradation purpose.

The main construction materials should be transported from other places as follows: a) sand and gravel bought in from An Lo; b) freestone bought in from the Truong Son mine; and c) cement, iron, steel and others bought in from Hue.

b. Construction procedure and time

Because of the two-season weather in the region, and the fact that the dry season occurs when agricultural cultivation is taking place, the project will have to allocate time and assign activities carefully, so that agricultural production is not affected.

The construction project is expected to take two years to complete. The first year's work will involve works on the dike and the construction of the section from the Con Bai bridge to the An Xuan drain; the rest of the work will be finished in the subsequent year.

2.0 METHODS TO ESTIMATE COSTS AND BENEFITS OF THE FLOOD CONTROL OPTION

2.1 Cost Identification and Measurement Methods

The identification of costs for the chosen adaptation project was relatively straightforward. The first step of this cost assessment involved group discussions with the engineers who designed the option, with Quang Dien district officials, and with representative of the local communes and households that the project would affect. The design of the adaptation option was presented to and discussed with these participants.

As mentioned in the section above, the chosen project would involve upgrading the entire An Xuan tributary. Its key steps include: a) dredging and removing the sediment from the bottom of the whole of the An Xuan tributary; b) upgrading and reconstructing the dikes along two banks of the An Xuan tributary, in combination with the construction of a 5 m-wide road along its two banks; c) upgrading the An Xuan sluice so that it would have five gates with apertures corresponding to the drainage capacity of the tributary bottom after it had been dredged and widened; d) building eight new open drains to remove water at the beginning of the winter-spring crop cycle and to prevent water from the An Xuan tributary overflowing onto paddy fields when small floods, early floods and late floods occur; e) building 10 ring drains (with a diameter of 100 cm each) for irrigation purposes; f) building a bridge over the Nga Tu tributary on the right side of the An Xuan tributary with a length of 24 m and a width of 5 m; and g) diverting a 300 m meander of the An Xuan tributary. Based on the project's technical design, a list of cost items (and the measurement methods used to estimate them) was drawn up (Table 12).

Table 12. List of cost items and measurement methods

Activities	Cost item	Measurement methods
1. Dredging and removal of sediment from the An Xuan tributary	Machinery, petrol, labor, other costs	Market-based
2. Diverting a 300 m meander of the An Xuan tributary	Machinery, petrol, labor, resettling 10 households, materials, other costs	Market-based
3. Upgrading and reconstructing the dikes of the An Xuan tributary: - Road construction along two banks - Reconstruction of the An Xuan Sluice - Building eight new open drains - Building 10 ring drains - Building a bridge over the Nga Tu tributary	Machinery, material (sand, gravel, free stone, cement, steel, etc.), labor, petrol, other cost	Market-based
4. Consultancy and management	Consultant, management	Market-based
5. Operation and maintenance	Operation, maintenance	Market-based

The total cost of this adaptation option was the sum of its five main cost items. These were: a) dredging and removal of sediment; b) diverting the 300 m meander; c) upgrading and reconstructing the dikes, sluice systems and bridge; d) consultancy and management costs; and e) operational and maintenance costs. All of these costs were estimated using market-based method. These were decided through the common consensus of experts, consultants, local government agencies and households.

2.2 Benefit Identification and Measurement Methods

An assessment was then carried out of the benefits of the chosen adaptation project for local communities. It is clear that this flood adaptation option will create various sources of benefit for communities and households alike.

At the household level, the study measured the benefits that the project would bring by reducing the impact of floods on agricultural production. As mentioned above, floods often cause large amounts of crop damage. It is assumed that much of this damage can be avoided by upgrading the entire An Xuan tributary dike system.

The study also assessed the value of the following potential project benefits:

- Changes in cropping techniques (i.e., labor costs and the volume of seed, fertilizers and pesticides used);
- Changes in the cost of water drainage from flooded paddy fields (this has been necessary during the winter-spring and summer-autumn crop cycles);
- Reduction in damages to houses and property that would occur when floods are mitigated;
- Reduction in medical costs for the treatment of injuries and disease; and
- Reduction in funeral costs.

To help assess the value of these benefits, the households involved in the study were requested to recall the value of the damage that floods had caused to their agricultural production and to their houses and property.

At a community level, floods often cause severe damage to infrastructure; this, in turn, causes social disruption. Local government agencies often have to mobilize their resources (both material and man-power) in order to repair this damage. The government must also often provide flood victims with relief. It was assumed that the proposed adaptation project would stop much of this damage from taking place and so reduce repair costs and the cost of relief work. The study therefore assessed these saved costs as part of the benefits of the adaptation project. Figures for these savings were calculated using secondary data from the commune government and contributions from FGDs and KIIs.

Two main methods were used to calculate the benefits of the proposed adaptation project: the contingent valuation method (CVM) and the market-based pricing method. The market-based pricing method was used to estimate the flood damage costs that would be avoided at a household level if the project were implemented (a). The data used came from household surveys and the results of FGDs.

CVM was used to estimate the total willingness of households to pay for the proposed adaptation project over 20 years, which is the lifetime of this project (b). This piece of assessment was possible as households living in An Xuan tributary have experienced many extreme floods. They were therefore aware of the risk of floods and the likelihood that they will get worse in the future due to the impact of climate change. In turn, they are likely to be willing to help pay for something to be done to mitigate the problem. Payment from the community is likely to be vital to the success of the proposed adaptation project as, due to resource constraints, it is beyond the capacity of the local government alone.

The market-based pricing method was then used to estimate the total value of the proposed adaptation project for communities (c). Secondary data relating to the damage caused by floods (from local government sources) was used to carry out this estimate.

Overall, this means that the total benefit of the proposed adaptation project is a sum of (c) plus either (a) or (b). In this study, the total benefit of the project was calculated as both the sum of a + c and the sum of b + c. A summary of the total benefits of practicing the chosen adaption project is shown in Table 13.

Table 13. Summary of total benefits of practicing the adaptation option

Benefits	Data source	Estimation method
Benefits at household level		
Avoided production damages (agriculture, livestock, aquaculture, etc.)	Household survey data, FGD	Market-based
Avoided damages to households and property	Household survey data, FGD, KII	Market-based
Avoided income loss due to disruption	Household survey data, FGD, KII	Changes in net benefit of cropping system and Market-based
Net income changes in rice production	Household survey data, FGD	Market-based
Avoided household medical costs	Household survey data, FGD	Market-based/transferred value
Benefits at commune level		
Reduction of irrigation costs (flood drainage and pumping water)	Secondary data, FGD, KII	Market-based
Avoided damages to infrastructure/ avoided repair costs	Secondary data, FGD, KII	Market-based
Recovering cost of flood impacts	Secondary data, FGD, KII	Market-based
Co-benefits (transportation on dike)	Expert consultations	Transferred value

2.3 Data Collection and Analysis

Mixed method was used to collect data for this study (i.e., secondary data collection, KIIs and FGDs).

2.3.1 Secondary data

Secondary data was collected from various government agencies. At the provincial level, these included the Thua Thien Hue Hydrometeorology Centre, and the provincial government's Department of Agriculture and Rural Development, and its Department of Environment and Resource Management. Information from these bodies was combined with project findings to contextualize and select the project site.

At the district level, secondary data was collected from different district agencies, such as the district Agricultural Production and Rural Office, the district Statistical Office, and other community organizations. Annual reports containing information on socio-economic developments and other related statistical data were collected to contextualize the An Xuan tributary and to help calculate the benefits of the chosen adaptation project.

2.3.2 Primary data

Based on the study objectives, a commune questionnaire was designed to capture data for commune-level cost and benefit calculations. The questionnaire was used to collect information about the area's population and labor force, its land use patterns, cropping patterns and productivity, the cost of its irrigation systems (both flood drainage and water pumping for rice production), the levels of flood damage sustained by infrastructure, repair costs, relief activities, and resource mobilization measures.

A household survey questionnaire was also used to gather information. This was based on the results of the study's secondary data collection and its commune survey (see above). The household survey questionnaire was designed to capture the demographic characteristics of households, their resources, livelihoods and living conditions, their experiences of floods, and the damages they had sustained from different types of flood. The questionnaire also asked about the households' views of the different flood adaptation options available. In addition, it contained CVM questions. In order to make sure that all questions were answerable and that the necessary information was available at the household level, the questionnaire was pre-tested on 15 households in each commune of Quang Duan district covered by the study: Quang An and Quang Phuoc. The questionnaire was finalized based on the result of this pretest.

The total population of the Quang An and Quang Phuoc communes is 19,026. These people live in 4,197 households. Of these, 2,226 households are in Quang An commune and 1,971 households are in Quang Phuoc commune. In order to ensure that a representative sample of this population was interviewed (and that results would therefore be significant), a minimum sample size was calculated using the following formula:

$$n = \frac{N}{1 + N.e^2}$$

In which:
n is the sample size (i.e., the number of households to be surveyed)
N is the number of households living in Quang An and Quang Phuoc
e is the desired margin of error

In this study, the desired margin of error that was 5% (standard value 0.05), thus the minimum sample size for the questionnaire survey was about 450 households. However, in order to avoid non-responses, incomplete responses or recording errors during data collection, the estimated sample size was increased by 30%. This meant that a sample of about 550 households was needed.

A random selection method was used to select households for the survey. Then 600 questionnaires were conducted using face-to-face interviews. In the end, 548 questionnaires were completed and checked for data entry. This survey provided an important source of primary data for the calculation of avoided damages/costs and for CVM calculations at the household level.

Qualitative information for this study was collected through KIIs and FGDs. Six FGDs were organized: one at the provincial level, one at the district level, two at the commune level, and two at the community level. Twenty-five (25) key informants, drawn from both the provincial and local community level, were interviewed. In this way, a robust dataset was collected and analyzed.

2.3.3 Data analysis

A cost-benefit analysis of the chosen adaptation project was the main task of this study. In order to analyze its costs and benefits, the study looked at avoided damages, and the difference in the net income from rice production "with" and "without" the project. It also took into account the probabilities of various flood levels and the damage they would cause, the useful lifetime of the project, and the time value of money (calculated using a discount rate). Annualized damages were calculated for each type of flood, taking into account the probability of each. Net present value (NPV) and present value were calculated. This was done using the following two formulae:

$$PV\,(X) = X_t \frac{1}{(1+r)^t}$$

where X is the present value of costs (C) or benefits (B) at time (t) at interest rate (r)

$$NPV = \sum B_t(1+r)^{-t} - \sum C_t(1+r)^{-t}$$

A non-parametric estimation of willingness-to-pay (WTP) was used to estimate the total WTP. A lower-bound method of payment ladder was used, which had the following steps (all values in thousands of VND): 0 -100, 100 - 200, 200 - 300, 300 - 400, 400 - 500, 500 - 700, 700 - 1000, 1000 - 1200, 1200 - 1500, 1500 - 2000, and >2000.

The following calculation was employed: Using the lower-bound method of payment ladder, let *N* denote the number of households in the sample and t_j the level of bid (j=0 to J, where J is the highest level of bid and t_0 is always zero). Let h_j be the number of households with WTP higher than or equal to t_j. The total number of households in the sample with WTP higher than or equal to t_j is:

$$n_j = \sum_{k=j+1}^{J} h_k$$

Then the survivor function will be:

$$S(t_j) = \frac{n_j}{N}$$

From the above analysis:

$$\alpha_1 z_j + \beta\left(y_j - t_j\right) + \varepsilon_{j1} = \alpha_0 z_j + \beta y_j + \varepsilon_{j0}$$

Therefore:

$$WTP = \frac{\alpha z_j}{\beta} + \frac{\varepsilon_j}{\beta}$$

Assume that $\frac{\varepsilon_j}{\beta}$ has mean zero and variance $\frac{\sigma}{\beta^2}$, then mean WTP is calculated using:

$$MeanWTP = \sum_{j=0}^{J} S(t_j)\left[t_{j+1} - t_j\right]$$

Based on the payment ladder responses, the mean of the values ticked can be taken as the lower-bound WTP; that is the average value that respondents were certain they would pay each year for the implementation of the chosen adaptation project.

The parametric method was used to estimate the WTP of the households for the adaption option, using logit regression, in which dependent variables is the household saying "yes" to pay for t_j and "no" payment for the t_j bid level. The list of independent variables that were subjected to a regression analysis included household income, household size, education, age, gender, and damages.

Based on the logit regression results, the mean WTP of the sample households was calculated using the following formula, where α, β are the estimated coefficients and z_j the mean values of the independent variables of the logit regression:

$$MeanWTP = E\ (WTP\ /\alpha,\beta,z_j) = \frac{\alpha z_j}{\beta}$$

3.0 COST AND BENEFIT ANALYSIS OF THE ADAPTATION OPTIONS

3.1 Demographic Characteristics of Households

There were 548 households involved in this study (about 13.6% of total population of the study site), 275 (50.2%) of which are from Quang An and 273 from Quang Phuoc. About 35.6% of respondents were female and 64.4% were male. Majority (71%) of respondents were household heads and 29% of them were the spouse of a household head or their child (Figure 4). About 85.9% of respondents were married, 5.8% were single and 8.2% were widowed or divorced.

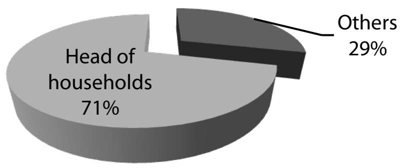


Figure 4. Distribution of respondents based on role in household

It is important to note that the educational level of respondents was relatively poor. The average number of school years that respondents had completed was about 6.2. About 14.3% of respondents were illiterate, while 64% had completed either primary school (31.2%) or secondary school (33.2%). Only 20.6% of respondents had completed high school and less than 1% of respondents had received a university education (Table 14).

Table 14. Education of respondents

Education level	Frequency	Percent	Valid percent
Illiterate	78	14.2	14.3
Primary	170	31.0	31.2
Secondary	181	33.0	33.2
High school	112	20.4	20.6
University	4	0.7	0.7
Total	**545**	**99.5**	**100.0**

Source: Surveyed in 2012

Most respondents had lived in the study site for many years with over 66% having lived in An Xuan tributary for over 30 years and only 5% having lived there for less than five years (Figure 5). This means that almost all respondents had experienced many flood events and knew first-hand about the damage floods can cause. They also all had a good understanding about the An Xuan tributary and its importance to agricultural production and their lives in general.

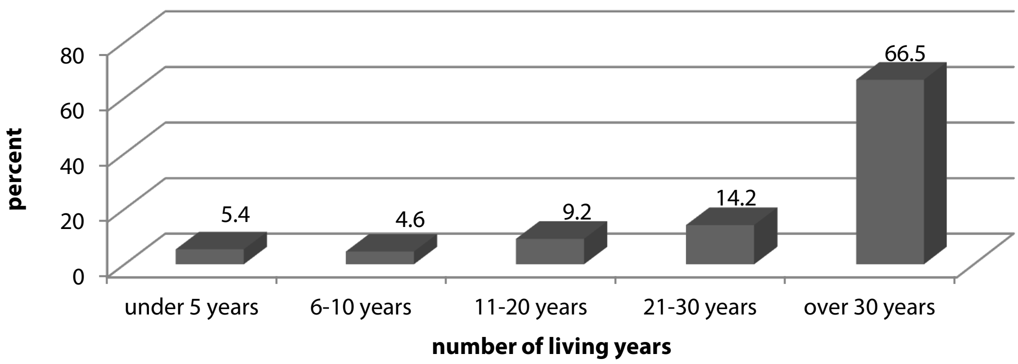


Figure 5. Distribution of respondents by number of years living in the study site

In terms of resources, it is important to note that the communities living in the An Xuan tributary are very poor. This is important as land and labor are two important resources that enable households to adapt to flood events and recover in their aftermath.

The study found that the average household size was 4.8 persons and that there was an average of 2.7 laborers per household. This meant that the average number of dependent persons in each household (2.1) was relatively high (Table 15). The study also found that, because the main form of livelihood in the study area was agricultural production, workers received a low average income and were affected by seasonal unemployment. Because of this, a large proportion of young laborers have migrated to cities to seek work. This has compounded the challenge posed by extreme floods as many households lack the manpower they need to prevent flood damage and to recover from it when it happens.

Table 15. Demographic features of interviewed households in the An Xuan tributary

Family member	Mean	Std. deviation
Total household members	4.8	1.9
16 to 60 year old members	2.7	1.8
Under 16 year old members	1.3	1.2
Over 60 year old members	0.5	0.8
Disabled members	0.04	0.2

Source: Surveyed 2012

Land is the second most important resource available to households in the An Xuan tributary. Land provides the main source of income for households; about 60% of total income is generated from agricultural production. As shown in Table 16, the average land area available to households is about 2,695 m^2. About 68.8% of this is agricultural land, much of which is suitable for two crops. However, the study found that most farmers have a paddy field irrigation system that only works well for winter-spring crops, but not for summer-autumn ones. The adoption of the adaptation option would improve agricultural irrigation and drainage. It would therefore significantly improve the net return from crop production (including rice production).

Table 16. Land resources of households

Type of land	Mean (m^2)	Share (%)
Residential land and garden	350.9	13.0
Agricultural land	1854.9	68.8
Aquaculture land	489.8	18.2
Total area	**2,695.6**	**100.0**

Source: Surveyed 2012

Aquaculture is another important source of livelihood for households in the study area. Aquaculture is practiced near the Tam Giang lagoon, and households have an average of 489 m^2 of aquaculture land. There is no forest land in the An Xuan tributary. The availability of other types of land or unused land is also limited.

In 2012, the average total annual income of households in the study area reached VND 30 million (USD 1,500/household). This means that An Xuan communities are among the poorest in Thua Thien Hue province (even when compared with upland ethnic minorities).

The study also found that household living conditions were low, with nearly 50% of total living costs being spent on food and about 18% on clothes. Expenditure on petrol, education, weddings and funerals was minor. This means that households are only able to meet their basic requirements for daily life. Moreover, a field trip visit to the An Xuan tributary found that sanitation systems and infrastructure in the area are in poor condition and are often damaged by annual floods.

3.2 Net Present Value, Internal Rate of Return and Cost-Benefit Analysis

3.2.1 Total investment cost of adaptation option

The total investment cost of upgrading the entire An Xuan tributary was calculated by the technical consultants who designed the chosen adaptation project. They were verified by FGDs and consultations between local communities, district government officers, commune government officers and researchers. The details of the adaptation project design are described in Section 1.6.3.

The undiscounted costs of the project are presented in Table 17. The total investment cost of constructing the adaptation project is VND 40,000 million in year one and VND 60,469 million in year two. The operational and management costs are zero in year one, but increase to VND 708.5 million in year two. In year three they increase to VND 1,417 million and they stay at this annual level for the lifetime of the project. Thus, the total operational and management cost of the project is VND 40,384.5 million and the total cost of the whole project over its lifetime is VND 140,853.5 million (Table 17).

Table 17. Total investment cost of upgrading the entire An Xuan tributary dike system

Year	Investment cost for upgrading entire An Xuan tributary (10^6 VND)	Operation and management cost (10^6 VND)	Total cost (10^6 VND)
1	40,000.0	0.0	40,000.0
2	60,469.0	708.5	61,177.5
3	0.00	1,417.0	1,417.0
4	0.00	1,417.0	1,417.0
5	0.00	1,417.0	1,417.0
6	0.00	1,417.0	1,417.0
7	0.00	1,417.0	1,417.0
8	0.00	1,417.0	1,417.0
9	0.00	1,417.0	1,417.0
10	0.00	1,417.0	1,417.0
11	0.00	1,417.0	1,417.0
12	0.00	1,417.0	1,417.0
13	0.00	1,417.0	1,417.0
14	0.00	1,417.0	1,417.0
15	0.00	1,417.0	1,417.0
16	0.00	1,417.0	1,417.0
17	0.00	1,417.0	1,417.0
18	0.00	1,417.0	1,417.0
19	0.00	1,417.0	1,417.0
20	0.00	1,417.0	1,417.0
21	0.00	1,417.0	1,417.0
22	0.00	1,417.0	1,417.0
23	0.00	1,417.0	1,417.0
24	0.00	1,417.0	1,417.0
25	0.00	1,417.0	1,417.0
26	0.00	1,417.0	1,417.0
27	0.00	1,417.0	1,417.0
28	0.00	1,417.0	1,417.0
29	0.00	1,417.0	1,417.0
30	0.00	1,417.0	1,417.0
Total cost	**100,469.00**	**40,384.50**	**140,853.50**

3.2.2 Total benefit of adopting the chosen adaptation project

a. Avoided damages and losses at the household level (market-based methods)

The data obtained from the household questionnaire was used to calculate the value of the damage caused by different types of floods. This assessment shows that damages to agricultural production and houses are the highest costs that households have to bear (Table 18).

An assessment was then made of the damages and losses that would be avoided if the chosen adaptation project were implemented. The value of the total damages caused by floods (without the project in place) was calculated to be about VND 2.29 million per household per year (Table 19). If the proposed adaptation project were implemented, then the probability of floods would be significantly reduced, which would, in turn, significantly reduce the amount of damage caused to households and communities. The total value of these avoided damages was calculated to be VND 1.27 million/household per year (Table 19). When this figure is multiplied by the 4,197 households living in the An Xuan tributary, it gives a value of the total damages avoided by household of VND 5,330.19 million per year.

Table 18. Damages and losses per household per flood event by types of floods (in million VND)

Damaged items		Types of flood				
		Tieu man	Early floods	Main floods	Late floods	Total
1	Household damages	0.00	0.00	0.24	0.10	0.34
2	Property/asset damages	0.00	0.10	0.12	0.10	0.32
3	Crops	0.13	0.12	0.10	0.18	0.53
4	Livestock	0.00	0.00	0.12	0.10	0.22
5	Aquaculture	0.11	0.10	0.12	0.10	0.43
6	None-farm activities/due to social disruption	0.00	0.10	0.15	0.10	0.35
7	Migration	0.00	0.00	0.12	0.00	0.12
8	Medical cost	0.00	0.10	0.10	0.00	0.20
9	Lost income due to flood disruption	0.10	0.12	0.24	0.10	0.56
	Total cost	**0.34**	**0.64**	**1.31**	**0.78**	**3.17**

Source: Household survey and FGD

Table 19. Avoided damages and losses per household per flood event by type of flood

	Damaged items	Units	Tieu man	Early floods	Main floods	Late floods	Total
A	TOTAL COST	Mill VND	0.34	0.64	1.41	0.78	3.17
	Probability of floods recurring without project	%	0.4	0.25	1	0.75	
B	Total damages without project	Mill VND	0.136	0.16	1.41	0.585	2.29
	Probability of floods recurring with project	%	0.1	0.1	0.6	0.1	
C	Total damages with project	Mill VND	0.034	0.064	0.846	0.078	1.02
D	Total avoided damage for communities	Mill VND	0.102	0.096	0.564	0.507	1.27

Source: Household survey, 2012

b. *Willingness to pay estimation*

Non-parametric method

The non-parametric method was used to estimate the total benefit of the chosen adaptation project by using WTP questions. As mentioned previously, respondents have lived in An Xuan tributary for over 30 years, and therefore have a good awareness of the current situation in the An Xuan tributary and the effect that severe floods have on their lives. As described in detail above, respondents were asked how much they would be willing to pay for the chosen adaptation project that would upgrade the whole of the An Xuan tributary dike system in order to mitigate the impacts of floods and provide irrigation for summer-autumn crops.

The lower-bound WTP value was calculated to be VND 496,100/household per quarter. This was multiplied by four to give a total WTP of VND 1,984,300/household per year. This means that the total undiscounted WTP for whole communes with 4,197 households over 20 years was VND 166.6 billion.

Table 20. Non-parametric willingness-to-pay for project

Bids (thousand VND)	Total responses	"Yes" responses	"Yes"/Total	Probability of "yes"	Lower-bound	WTP
0-100	-	-	-	0.141	0.0	0.00
100-200	64	55	0.859	0.180	100	18.00
200-300	56	38	0.679	0.153	200	30.60
300-400	57	30	0.526	0.090	300	27.00
400-500	55	24	0.436	0.061	400	24.40
500-700	56	21	0.375	0.092	500	46.00
700-1000	60	17	0.283	0.095	700	66.50
1000-1200	64	12	0.188	0.060	1000	60.00
1200-1500	47	6	0.128	0.026	1200	31.10
1500-2000	49	5	0.102	0.023	1500	34.50
>2000	38	3	0.079	0.079	2000	158.00
						496.1

Source: Survey and calculation by authors

Parametric method

The logit regression method was used to estimate households' parametric WTP for the chosen adaptation project. This showed that there are a number of variables that affect a household's WTP. These include age, household size, household income, and bid level (Table 21). Households with large families and with elderly persons tended to be less willing to pay for the project, while better-off households tended to be more willing to contribute. Gender, marital status and education level did not affect household WTP.

Table 21. Bid function of parametric willingness-to-pay estimates

Dependent Variables	Coefficient	S.E.	Sig.	Zi
1.Gender	0.1597	0.22	0.4660	1.06
2. Age*	-0.0174	0.01	0.0403	50.9
3. Education	0.0509	0.03	0.1007	6.2
4. Married	0.2830	0.29	0.3238	1.33
5. Household size*	-0.0257	0.05	0.063	4.8
6. Household income*	0.028	0.00	0.0620	30.782
7. Bid level*	-0.003	0.00	0.0000	496
Constant	0.36	0.90	0.6881	
Log likelihood	576.9397			
Pseudo R-square	0.237175		0.000	

Source: Survey and calculation by authors

Using the equation for a non-parametric WTP estimate with lower-bound method, the WTP mean was calculated to be VND 496,100/households per quarter, or about VND 1,984 million/household per year. This is deemed to be slightly high, but feasible as it is equivalent to about 6.4% of the average total annual income of households in the area.

Using the bid function of parametric WTP, the mean WTP is VND 518,300/household per quarter, which is equivalent to VND 2,073 thousand per annum (about 6.7% of the average household income). Therefore, the total undiscounted WTP of all 4,197 households in the communes over 20 years is VND 174.02 billion.

c. ***Benefit and avoided damages at the community level***

Net benefit of changes in rice production

A comparison was made between the net benefits from rice production both before and after the implementation of the chosen adaptation project. The improvements in rice production that the project would produce were found to be one of its most important net benefits. The calculations were based on secondary data and the results of FGDs, KIIs, and consultation meetings.

The study compared the difference in net income from rice production "with" and "without" the chosen adaptation project. It was clear that the project would bring about a significant change in the cost and productivity of rice production in the An Xuan tributary. In terms of productivity, in the "without" scenario, annual winter-spring rice production is 6.0 tons/ha, while annual summer-autumn rice production is 5.7 tons/ha (Table 22). The total production cost of both crops is VND 28,334,000/ha. Overall, the net benefit reached VND 7.666 million/ha and VND 5.820/ha for the winter-spring and summer-autumn crop, respectively (Table 22). The difference in the net benefit of the two crops is explained by the fact that water availability is good for the winter-spring crop, while the summer-autumn crop often has to deal with droughts. Thus, productivity is higher for the winter-spring crop.

Table 22. Net return per hectare of rice in the case without project

Items	Unit	Winter-spring crop (with irrigation)			Summer-autumn crop (with irrigation)		
		Volume	Price (VND10^3)	Total cost (VND10^3)	Volume	Price (VND10^3)	Total cost (VND10^3)
I. Production	**ton**	**6.0**	**6000.0**	**36000.0**	**5.7**	**6000.0**	**34200.0**
II. Production cost				**28334.0**			**28380.0**
A. Labor cost	*Man-day*	*140.0*	*100.0*	*14000.0*	*140.0*	*100.0*	*14000.0*
B. Material cost				*9754.0*			*9800.0*
Seed	kg	130.0	12.0	1560.0	140.0	12.0	1680.0
Manure	Ton	0.0	40.0	0.0	0.0	40.0	0.0
N	Kg	300.0	11.0	3300.0	320.0	11.0	3520.0
P	Kg	400.0	4.0	1600.0	400.0	4.0	1600.0
K	Kg	150.0	12.0	1800.0	150.0	12.0	1800.0
Lime	Kg	540.0	1.1	594.0	0.0	1.1	0.0
Pesticide	liter			900.0			1200.0
C. Other cost				*4580.0*			*4580.0*
Land preparation				2400.0			2400.0
Tools				180.0			180.0
Plucking rice off				200.0			200.0
Irrigation fee				1800.0			1800.0
III. Net return				***7666.0***			***5820.0***

Source: FGD and KIIs

There is a significant difference in the net benefit of rice production "with" the chosen adaptation project. This is because upgrading the entire An Xuan tributary dike system will help farmers to drain flood water and change to more productive crops that will command better selling prices (for both winter-spring and summer-autumn crops). Farmers will also be able to cultivate summer-autumn crops in accordance with their cropping calendars and with the support of irrigation systems. They will therefore be able to avoid the damage that is currently caused by early floods. This means that with the project in place, productivity should reach 7.0 tons/ha for the winter-spring rice crop and about 6.5 tons/ha for the summer-autumn crop (Table 23). Selling prices should also increase to about VND 6,500/kg, which in turn will lead to an overall increase in the net benefits that can be gained from rice production in the An Xuan tributary.

Table 23. Net return per hectare of rice in the case with project

Items	Unit	Winter-spring crop (with irrigation)			Summer-autumn crop (with irrigation)		
		Volume	Price ($VND10^3$)	Total cost ($VND10^3$)	Volume	Price ($VND10^3$)	Total cost ($VND10^3$)
I. Production	**ton**	**7.0**	**6500.0**	**45500.0**	**6.5**	**6500.0**	**42250.0**
II. Production cost				**28504.0**			**28504.0**
A. Labor cost	*Man-day*	*140.0*	*100.0*	*14000.0*	*140.0*	*100.0*	*14000.0*
B. Material cost		*0.0*		*8784.0*			*8784.0*
Seed	kg	130.0	12.0	1560.0	130.0	12.0	1560.0
Manure	ton	0.0	40.0	0.0	0.0	40.0	0.0
N	kg	300.0	11.0	3300.0	300.0	11.0	3300.0
P	kg	400.0	4.0	1600.0	400.0	4.0	1600.0
K	kg	150.0	12.0	1800.0	150.0	12.0	1800.0
Lime	kg	540.0	0.6	324.0	540.0	0.6	324.0
Pesticide				200.0			200.0
C. Other cost				*5720.0*			*5720.0*
Land preparation				540.0			540.0
Tools				180.0			180.0
Plucking rice off				3000.0			3000.0
Irrigation fee				2000.0			2000.0
III. Net return				**16996.0**			**13746.0**

Source: FGD and KIIs

A comparison of the difference in the net benefits of rice production "with" and "without" the chosen adaptation project is shown in Table 24. The project would lead to total gains in net benefits from rice production of VND 14,021 million. It would lead to a total gain in benefits from aquaculture of VND 2.5 billion. This gain would be due to a reduction in the cost of dam reinforcement work and a reduction in the amount of water pumping necessary to reduce aquaculture pond salinity levels. These benefits would take place because upgrading the An Xuan tributary dike system would increase the water level of the Tam Giang lagoon, which would, in turn, benefit aquaculture practices.

Table 24. Difference in net return in rice and aquaculture production with and without the project

STT	Rice crop	Total area of rice cultivation (ha)	Average net benefits/ha (10^6 VND)	Total net benefits (10^6 VND)
Net benefit of rice production without project				
1	Winter-spring crop	812.5	7,666	62,28.6
2	Summer-autumn crop	812.5	5,820	47,28.8
	Total net return			**10,957.4**
Net benefit with project				
1	Winter-spring crop	812.5	16,996	13,809.3
2	Summer-autumn crop	812.5	13,746	11,168.6
	Total net return			**24,977.9**
	Changes in net benefit of rice production/year			***14,020.5***
	Changes in net benefit of aquaculture/year			***2,500***
	Total benefit increase/year			***16,520.5***

Source: Surveyed in 2013 and the calculation of authors

Total avoided damages and losses for communities

It is obvious that, every year, the commune government and communities suffer huge damages due to floods and must spend significant amounts of money to repair public infrastructure and private homes. The difference in the cost of flood damage "with" and "without" the chosen adaptation project is equal to the total value of avoided damages and losses for communities (i.e., the benefit of the project). As shown in Table 25, the value of avoided damages and losses is about VND 1,734.9 million.

Table 25. Difference in the cost of flooding damages with and without the proposed adaptation project

Cost items	Units	Tieu man	Early Floods	Main Floods	Late floods	Total
Costs to the community due to flood						
Labor-days mobilized to remediate flood damage	person-day	5,600	8,755	18,790	7,805	40,950
Relief goods and necessities	Mill VND	40	87	318	120.0	565.0
Damages to infrastructure	Mill VND	78	234	421	237.0	970.0
Rehabilitation of An Xuan and in-field canal	Mill VND	310	467	792	631.0	2,200.0
Total cost	Mill VND	512.0	919.3	1812.9	1105.1	4,349.3
Probability of floods recurrent without the project	%	0.4	0.25	1	0.75	
Total damage value WITHOUT project	Mill VND	204.8	229.8	1812.9	828.8	3,076.3
Probability of floods recurrent with project	%	0.1	0.1	0.6	0.1	0.9
Total damage value WITH project	Mill VND	51.2	91.9	1087.7	110.5	1,341.4
Total avoided damage per year	**Mil VND**	**153.6**	**137.9**	**725.1**	**718.3**	**1,734.9**

3.2.3 Cost and benefit analysis

The total benefit of the project is the sum of changes in the net benefit of rice production plus the value of the damages avoided by communities and the value of the costs avoided by households. As shown in Table 26, the total cost of the project is VND 97,819 million and the total benefit of the project is VND 176,740 million; in this assessment the economic internal rate of return (EIRR) reached 19.4% and the benefit/cost ratio was 1.81.

Estimating the household WTP for the implementation of the chosen adaptation project shows that the mean WTP (using the lower-bound estimated method) is VND 496.1 thousand/quarter per household. Using this WTP estimate the total benefit of the project would be VND 204,481 million. While the total of the project remains unchanged, the IRR reached 25.3% and the benefit/cost ratio was 2.09.

The above findings confirm that upgrading the entire An Xuan tributary dike system will generate significant economic benefits for local communities in the long-term. In addition, it will also make a significant contribution to sustainable water management. It will help farmers and commune government agencies to actively manage water for over 812 ha of farmland and over 4,100 households living inside the An Xuan tributary. In other words, when the entire An Xuan tributary is upgraded, flood water will be pumped out; thus, water levels will be controlled so as to stop floods from damaging rice production, aquaculture and communities. Moreover, in the drought season, river water will be pumped into the rice fields more effectively.

In terms of sanitation conditions and gender issues, upgrading the entire An Xuan tributary dike system will significantly improve community sanitation conditions, particularly for women. It is reported that, as An Xuan tributary is the lowest-lying areas in Quang Dien district, it is often inundated by flood to a greater degree and for longer periods of time than other places in the district. This causes serious health problems for local people, particularly for women, children and the elderly. The gender imbalance is caused by the fact that women are often more exposed to flood water than men, as they have to take care of house work, harvests and their children. Epidemic diseases, such as marsh fever, dengue fever, diarrhea and water-related diseases often emerge during the flooding season due to poor sanitation conditions and environmental pollution. Accordingly, upgrading the entire An Xuan tributary will help communities, particularly women and children by significantly reducing environmental health problems.

Table 26. Costs and benefits of upgrading the entire An Xuan tributary dike system

Year	Total cost (VND 10^6)	Total benefit (VND 10^6)	Discount factor r = 10%	PV of cost (VND 10^6)	PV of benefit (VND 10^6)
1	40000.00	0.00	0.9091	36364.00	0.00
2	61177.50	6008.40	0.8264	50557.10	4965.30
3	1417.00	15320.80	0.7513	1064.60	11510.50
4	1417.00	18624.80	0.6830	967.80	12720.70
5	1417.00	23581.30	0.6209	879.80	14641.60
6	1417.00	23581.30	0.5645	799.90	13311.60
7	1417.00	23581.30	0.5132	727.20	12101.90
8	1417.00	23581.30	0.4665	661.00	11000.70
9	1417.00	23581.30	0.4241	600.90	10000.80
10	1417.00	23581.30	0.3855	546.30	9090.60
11	1417.00	23581.30	0.3505	496.70	8265.20
12	1417.00	23581.30	0.3186	451.50	7513.00
13	1417.00	23581.30	0.2897	410.50	6831.50
14	1417.00	23581.30	0.2633	373.10	6209.00
15	1417.00	23581.30	0.2394	339.20	5645.40
16	1417.00	23581.30	0.2176	308.30	5131.30
17	1417.00	23581.30	0.1978	280.30	4664.40
18	1417.00	23581.30	0.1799	254.90	4242.30
19	1417.00	23581.30	0.1635	231.70	3855.50
20	1417.00	23581.30	0.1486	210.60	3504.20
21	1417.00	23581.30	0.1351	191.40	3185.80
22	1417.00	23581.30	0.1228	174.00	2895.80
23	1417.00	23581.30	0.1117	158.30	2634.00
24	1417.00	23581.30	0.1015	143.80	2393.50
25	1417.00	23581.30	0.0923	130.80	2176.60
26	1417.00	23581.30	0.0839	118.90	1978.50
27	1417.00	23581.30	0.0763	108.10	1799.30
28	1417.00	23581.30	0.0693	98.20	1634.20
29	1417.00	23581.30	0.0630	89.30	1485.60
30	1417.00	23581.30	0.0573	81.20	1351.20
			Total	**97,819.0**	**176,740.0**
EIRR				**19.4%**	
B/C ratio				**1.81**	
B-C				**78,924**	

Source: Survey and calculation by authors

3.3 Sensitivity Analysis

It is important to analyze the sensitivity of the NPV of the project over its 30-year lifetime. The project is not sensitive to changes in the discount rate. There is an ongoing debate about using the discount rate to conduct an analysis of sensitivity of the CBA of a project. The choice of a discount rate is mainly dependent on researchers and the predictions about the impact and nature of the project under scrutiny, but it is agreed that the range of discount rates should be from zero to 20%. In this study, in order to confirm the economic feasibility of the project, discount rates of between 5% and 20% were used. As shown in Figure 6, the NPV does not become negative at a 15% discount rate and just goes below the zero line when the discount rate is at 20%.

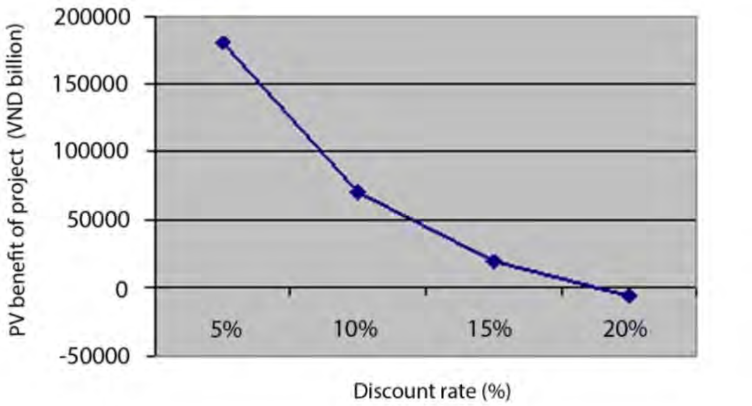


Figure 6. Sensitivity analysis of An Xuan Project with discount rate changes from 5% and 20%

The sensitivity analysis of the CBA of the chosen adaptation project also took into account the impact of climate change on the frequency and severity of future floods. Using the B2 climate change scenario[4], it is clear that there will be an increase in both the frequency and intensity of floods and droughts in Thua Thien Hue in general and in the An Xuan tributary in particular. It is projected that floods will increase its severity and that the sea level will rise, particularly during the rainy season from November to December. This means that the flood situation in the An Xuan will increase in both its frequency and severity and have an even greater impact on local communities than it has in recent decades. This means that the chosen adaptation project will possibly create even greater benefits for households than has been calculated.

4.0 CONCLUSION AND RECOMMENDATION

Floods are the most frequently occurring natural disasters in Vietnam, particularly in Thua Thien Hue and the An Xuan tributary. There has been an increase in both the frequency and intensity of floods in the last 30 years. Floods annually cause serious damage to both communities and households. They therefore push many households into a vicious cycle of poverty and increased flood risk. The situation is set to get worse as the national climate change scenario projects that there will be an increase in rainfall. To deal with this situation, various adaptation measures have been adopted at both the government and household level. However, most of these measures tend to just be responses to the impact of floods rather than adaptation and mitigation measures that will reduce the impact that floods have. This is mainly due to a lack of resources.

The study identified an adaptation project to reduce the impacts of floods in one of the most flood-prone areas in Vietnam. This project involves upgrading the entire An Xuan tributary dike system. The study conducted a cost-benefit analysis of this project. The An Xuan tributary is the lowest-lying area in its district and is home to about 4,197 households who farm 812 ha of rice fields. The An Xuan tributary is also known as one of the poorest communities in the region. Its fields, properties and infrastructure are all seriously damaged by various types of floods throughout the year.

It is important to understand that households living in the An Xuan tributary have diversified their livelihoods in a number of ways. However, agricultural production (e.g., rice production, livestock and aquaculture) is still their dominant source of income. Alternatives sources of income are very limited, while agricultural production is becoming more vulnerable to floods due to the impact of climate change.

The study's cost-benefit analysis shows that adopting the chosen adaptation project will deliver significant benefits at both the community and household level. Upgrading the entire An Xuan tributary dike system will help communities and households avoid damages to livelihoods, houses and assets; it will

[4] Medium greenhouse gas emission levels leading to an increase in rainfall of about 11% and a 23% decrease in drought seasons over the next 100 years.

also reduce damages to infrastructure, increase the net benefit of rice production and reduce the cost of the social disruption caused by floods.

The study found that the investment cost of the project would be about VND 97,819 million over 20 years, in which over 90% of the costs would be investment costs incurred in the first two years. This means that the project would be relative expensive for government to finance. However, when the costs of the project are compared with its benefits, they are seen to be very low.

Overall, it is clear that upgrading the entire An Xuan tributary dike system would bring great benefits to households and the government and would make good policy sense in light of the potential impact of climate change on rainfall and sea levels. In other words, because the frequency and intensity of floods is set to increase (along with expected sea level rises), they will cause even more damage to communities than they do now, if the An Xuan tributary dike system is not upgraded. This means that it is really worthwhile for the government to invest in this project, as it will increase the sustainability of both agricultural production and socio-economic development.

Besides the potential economic benefits that it will bring to communities, upgrading the entire An Xuan tributary dike system will also make a significant contribution to sustainable agricultural water management and improve sanitation conditions and gender equality across the region’s communities.

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