Measuring direct losses to rice production from extreme flood events in Quang Nam province, Vietnam

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Abstract

Since the 1990s, Vietnam has made the transformation from being a net rice importer to becoming one of the world's largest exporters of rice. In fact, Vietnamese farmers have been highly successful at increasing food production since the reformation (Doi moi) in 1986 so that by 2010, rice yields had more than doubled (General Statistics Office of Vietnam, 2012). However, Vietnam, because of its geographical location and characteristics, is highly vulnerable to natural disasters, with a World Bank report (2010) estimating that 59% of Vietnam's total area and 71% of its population are susceptible to the impacts of tropical cyclones and floods. Furthermore, the regularity of extreme flood events during the last decade in central Vietnam has raised concern, with three flood classes, 1:10, 1:20 and 1:100-year floods occurring in Quang Nam province in 2004, 2009 and 2007, respectively (Institute of Geography, 2012; Institute of Water Resources Planning, 2011).

In this study we use a three-stage approach to estimate the direct losses to rice production caused by 1:10, 1:20 and 1:100-year flood events in Quang Nam, central Vietnam. Firstly, utilising information from geo-spatial inundation maps together with the timing of the floods with respect to crop rotation, we calculate flood-depth susceptibility rates for rice crops. Secondly, we calculate the loss to rice production experienced under the three flood classes. Thirdly, using 2010 prices, cost-benefit analyses were conducted for rice production when impacted by the three flood classes. These include scenario (pessimistic, optimistic and likely) and sensitivity analyses. The estimated value of direct losses to rice production for 1:10, 1:20, and 1:100-year flood events were VND11billion, VND100 billion and VND121 billion, respectively. Benefit-cost ratios, already very low for subsistence rice farmers, are further eroded in years of extreme floods.

Key words: Flood damage, cost benefit analysis, inundation mapping.

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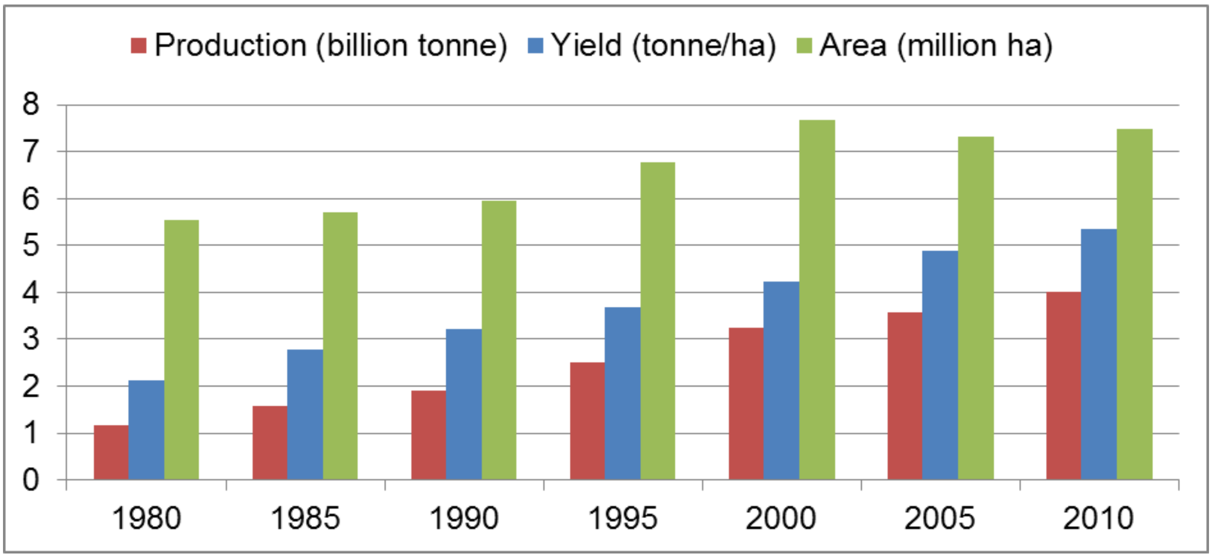
Introduction

There is no doubt that natural disasters are being reported with increasing frequency across the globe (CRED, 2013). Records from the International Disaster Database show that for the 32-year period to 2011, the average annual global cost of flood damage was US$90 billion. The Stockholm Environment Institute, the International Union for Conservation of Nature and the International Institute for Sustainable Development all predict that the cost of natural disasters worldwide will exceed US$300 billion annually by 2050 (UNISDR, 2002) and indeed, this figure was exceeded in 2011 when the cost was more than US$360 billion, one-quarter of which was attributed to floods alone. Such disasters leave developing countries like Vietnam particularly vulnerable, as their capacity to respond is so much less than more developed countries (Mechler, 2003). And, although capital losses in the developing world might be on a lesser scale than those in developed countries, their relative loss and the overall impact tends to be severe (ECLAC, 2003).

Since the 1990s, Vietnam has made the transformation from being a net rice importer to becoming one of the world's largest exporters of rice. In fact, Vietnamese farmers have been highly successful at increasing food production since the reformation (Doi moi) in 1986. The yield per hectare of crops in general, and rice in particular, more than doubled during the 30-year period to 2010, as shown in Figure 1. In addition, it can be seen that the amount of land used for rice production has also increased since the 1980s.



Note: Data was sourced from the General Statistics Office of Vietnam (2012) & Pham (2011).

Figure 1: Trends in total rice production, yield/ha and total rice-growing area for Vietnam (1980-2010).

However, this increased productivity is threatened by factors such as urbanization, environmental degradation and, more particularly, natural disasters. Though flooding is not a new phenomenon, the regularity of extreme flood events during the last decade has raised concerns about flood damage in Vietnam. Subsistence farmers, who rely upon agriculture as their main source of income, are the most vulnerable to natural disasters and extreme floods in particular, which have the potential to significantly reduce their production, exacerbating their poverty (Biltonen, 2001).

Various systems and measures have been developed to reduce the damage caused by extreme floods, for example, early warning systems and flood protection structures. Increasingly, however, flood damage has been reduced through flood risk management (Li, Wu, Dai & Xu, 2012), which was defined by Simonović and Carson (2003) as a broad spectrum of water resource activities aimed at reducing the potentially harmful impact of floods on people, economic activities and the environment. Simonović (1999) identified three flood management stages: the planning stage, the flood emergency management stage, and the post-flood recovery stage. Activities associated with each stage are reliant upon results of risk assessment, and in particular, on economic assessment of the impact of floods (Duttaa, Herathb & Musiake, 2003; Li et al., 2012). Historically, however, economic assessment has received little attention and it is now widely recognised as being necessary to provide valuable information in the efforts to mitigate the impact of floods and other natural disasters (Okuyama, 2007; Merz, Kreibich, Schwarze & Thieken, 2010; Penning-Rowsell, Yanyan, Watkinson, Jiang & Thorne, 2013).

Estimation of potential flood damage provides critical information for the assessment of support needed in the short-term, and policy development in the long-term for flood control planning, land use planning, and allocation of resources for recovery and reconstruction (Duttaa et al., 2003; Downton and Pielke, 2005; Merz et al., 2010). Changnon (2003) highlighted problems resulting from poor estimates of losses and from a lack of understanding of data uncertainties, from which controversies have arisen over government relief payments for natural disasters.

The full cost of natural disasters include both tangible and intangible costs (Changnon, 2003; Downton and Pielke, 2005; Penning-Rowsell and Parker, 1987). These, however, are difficult to both identify and quantify, due to lack of data availability. Downton and Pielke (2005) identified three reasons that made accounting for the cost of disasters inherently complicated. First, disasters have both direct and indirect costs and benefits. Direct flood costs may include the destruction of crops and livestock, while floodwater inundation may result in indirect costs, such as interruptions in transportation, trading activities and consumption, and a temporary increase in unemployment (Okuyama, 2007). Indirect benefits may be, for example, the supply of nutrients resulting in an increase in soil fertility. Second, “disaster’s losses are a function of the spatial and temporal scale that the analyst chooses as the focus of a particular loss analysis” (Downton and Pielke, 2005, 212) and as a result may influence, for example, information used by a government to enact legislation. Third, many losses incurred as a result of natural disasters are intangible, such as psychological damage and impacts on health (Duttaa et al., 2003). With respect to agriculture, widespread damage causes a decrease in food supply, inflating commodity prices and compounding the problem of estimating the economic loss associated with crops that never went to market.

A number of methods have been developed to estimate the cost of flood damage. Duttaa et al. (2003) developed an integrated model that combines a hydrologic model with a flood loss estimation model. The model’s loss estimation component was “based on stage-damage relationships between different flood inundation parameters and land use features” (Duttaa et al., 2003, 24). They tested their model for a frequently flooded river basin in Japan and found that it performed satisfactorily when compared with damage estimated from post flood parameters. Messner, et al. (2007) developed a set of recommended principles and methods for flood damage evaluation that included formulae to calculate total flood damage from a single event. Their formulae used an approach for 'what-if' analyses which estimated the flood damage when inundation and susceptibility data were available.

A number of case studies have been conducted to assess agricultural yield losses resulting from flood inundation (Banerjee, 2010; Gilbert, Rainbolt, Morris & McCray, 2008; Kotera & Nawata, 2007; Penning-Rowsell et al., 2013). Banerjee (2010) used rice and jute productivity data to estimate the short-term and long-term impacts of extreme floods on agricultural productivity in Bangladesh. The short-term impact was assessed by comparing average annual yield rates in 'normal' flood years with those in 'extreme' flood years. The long-term impact was analysed by comparing the area under cultivation and the agricultural productivity in 'more' and 'less' flood-prone districts over a 20-year period. Penning-Rowsell et al. (2013) used a depth-loss relationship to assess flood damage to the Taihu Basin, China (including damage to agricultural production). They established the depth-loss rate by asset categories and flood depth based on an existing 'flood loss rate', which is a percentage of the pre-flood property value at varying flood depths, and its associated flood damage data from past floods. They tested their model using 1999 flood data and found that their damage loss differed slightly from the widely accepted records of loss issued by the Taihu Basin Authority.

Flood damage estimation methodologies are helpful to determine the economic feasibility of flood control measures. Frequently, however, flood damage evaluation in rural areas, particularly flood damage assessments of agricultural production, are either neglected or accounted for using over-simplified approaches and rough estimates because the expected losses are typically much lower than those in urban areas (Förster, Kuhlmann, Lindenschmidt & Bronstert, 2008).

This study aims to fill that gap by conducting an economic assessment of flood damage to rice production in rural Vietnam. This assessment is conducted in Quang Nam province and estimates the direct tangible economic losses to rice production resulting from extreme flood events associated with three flood classes: 1:10, 1:20 and 1:100-year floods. The analysis utilises geo-spatial inundation maps developed by Chau, Holland, Cassells and Tuohy (2013) that portray the extent of damage to rice crops affected by the three flood classes. Using this information, and the timing of the floods with respect to crop rotation, we estimate the resulting economic losses due to extreme flood events.

Study area and data used

Figure 2 shows the location of Quang Nam province in the coastal region of central Vietnam. The province is approximately 10,408km^2 in area and around 72% of the province is mountainous or hilly.

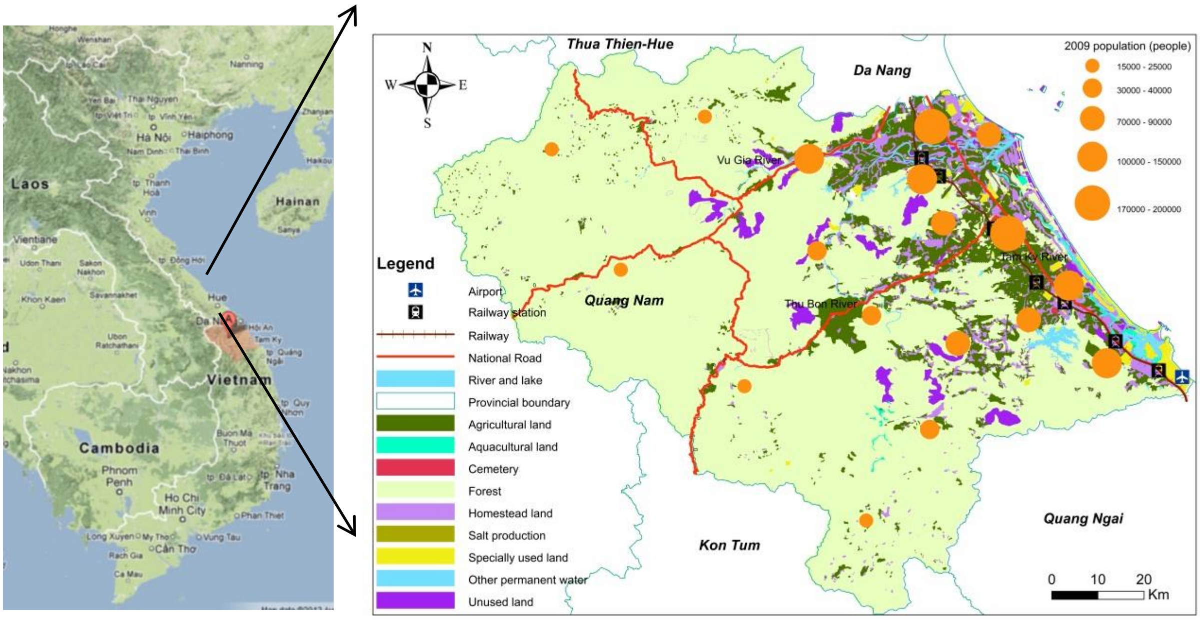


Figure 2: Quang Nam Province, central Vietnam, and the location of its agricultural land

Quang Nam is home to 1.4 million people, more than 80% of whom live in rural areas (Quang Nam Statistics Office, 2011). The main concentrations of people are shown in Figure 2, along with the location of agricultural land, aquaculture, forests and principal infrastructure.

The province is situated within the tropical monsoon and typhoon zone of South-East Asia. Annual rainfall for the province averages 2,600mm, with 2,500mm of this falling during the rainy season from September to December. More recently, exacerbated by global climate change, extreme flood events have increased in both intensity and frequency (Institute of Geography, 2012). The most productive agricultural land, concentrated along the low-lying sections of the river systems, is particularly vulnerable to flooding. In addition, urbanisation in the low lying areas has resulted in a greater number of people being impacted by extreme floods.

The per capita Gross Domestic Product (GDP) of Quang Nam province is low, around VND11.22 million (US$560) in 2010 and ranked 48th out of the 63 provinces in Vietnam (General Statistics Office of Vietnam, 2011). While the annual cost attributed to natural disaster damage averages around 6.3% of the province's GDP, this can be as high as 20% of GDP in years of extreme floods (Institute of Geography, 2012). A number of studies, from both local and international institutions, have been undertaken to study flood hazards in Quang Nam province (Chau et al., 2013; Cologne University of Applied Sciences, 2013; Ho & Umitsu, 2011; Institute of Geography, 2012; Institute of Water Resources Planning, 2011), however, none of these studies have quantified the impact on rice production (the primary agricultural crop) of extreme floods.

This study estimates the flood damage cost to rice production for 1:10, 1:20 and 1:100-year floods. The Institute of Geography (2010) and the Water Resources Planning Institute (2011) analysed the highest annual water levels recorded from 1976 to 2009 at Cau Lau station to simulate flood frequency for the Vu Gia-Thu Bon river system. They concluded that 1:10, 1:20 and 1:100-year floods were compatible with the floods of 2004, 2009 and 2007, respectively. To estimate the flood damage costs to rice production we use the inundation results of the Chau et al. (2013) study in conjunction with 2010 economic data collected during a field trip to Quang Nam province from November 2011 to February 2012.

Chau et al. (2013) used the geographic information system (GIS) technology and flood depth marks from the floods of 2004, 2009 and 2007 respectively, and a digital elevation model (DEM). The flood depth marks were interpolated by the inverse distance weighting (IDW) algorithm to generate the water height surface. Inundated areas were identified by subtracting the DEM from the water height surface to create a map of the inundated areas, which is shown in the insert for Figure 3 for a 1:100-year flood (which occurred in Quang Nam in 2007). The insert for Figure 3 shows the different inundation depths of the flooded land. A little under half (45.6%) of the inundated area is flooded to a depth of more than three metres, and two-thirds to a depth of more than two metres. The flood inundation map was then overlaid on the agricultural land use map for the province and this is shown, for a 1:100-year flood, in Figure 3.

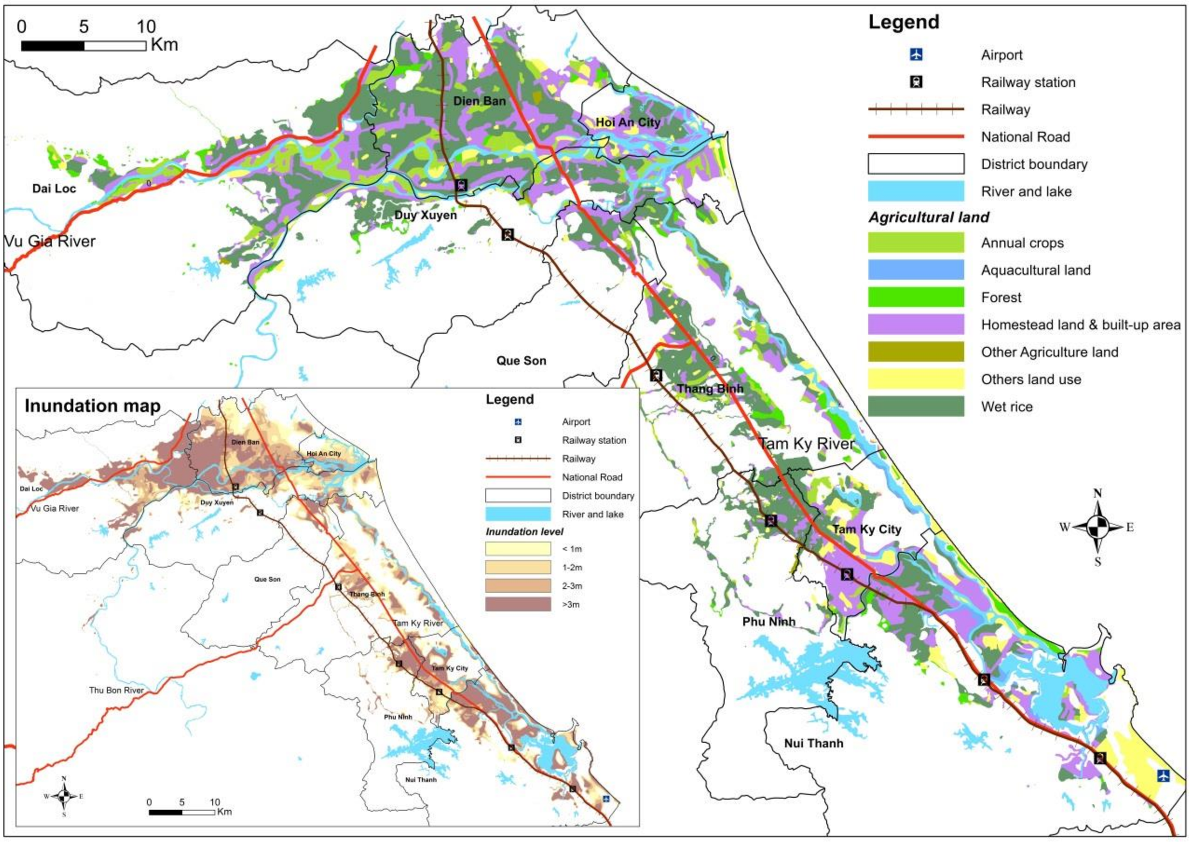


Figure 3: Predicted inundation of rice production (and other production) land in Quang Nam Province resulting from a 1:100-year flood event

Figure 3 shows the predicted areas of wet rice production, other agricultural land, aquaculture, and forest land inundated by a 1:100-year flood. The model estimated that agricultural land would be the land use type most impacted by each of the three flood scenarios.

Rice production (the main crop) was identified as being the most affected by each of the three flood scenarios. The predicted flooded rice crop areas were estimated to be 24,496ha (1:10-year flood), 27,275ha (1:20-year flood), and 29,815ha (1:100-year flood), which account for

43%, 48% and 53% of the total rice production areas in Quang Nam, respectively (Chau et al., 2013).

Nine districts most affected by the floods, namely, Dai Loc, Dien Ban, Duy Xuyen, Hoi An, Thang Binh, Phu Ninh, Que Son, Nui Thanh and Tam Ky are shown in Figure 3. These nine districts were grouped into the 'more' flood-prone group. The remaining administration districts were identified as the 'less' flood-prone group, and in general were not affected by flood water inundation. Therefore, in this study we use the 'more' flood-prone group of districts for our analysis.

In Quang Nam, rice (as well as vegetable) production is carried out on small irrigated family farms, utilising family labour. Farm sizes are typically less than 0.2ha in the low-lying areas. Farming families consume a considerable proportion of the farm output, with the remainder being sold or bartered locally. There is no official classification between skilled and unskilled labour in agricultural production in Quang Nam province, so it is assumed that the same wage rate is paid to all labour.

Crop production costs and revenue data were adapted both from the Quang Nam Statistical Yearbook 2010 (Quang Nam Statistics Office, 2011) and data collected during field work and included seed purchase, seedbed preparation, sowing, agrochemical and fertilizer application, labour costs, weed and pest control, harvesting and post harvesting costs. Farm gate inputs and output prices are used to calculate the costs and benefits of rice production impacted by the three flood classes. Average crop yields were obtained from the Quang Nam Statistic Yearbook for 2010 (Quang Nam Statistics Office, 2011). The average seasonal rice yields per hectare for both the 'more' flood-prone and the 'less' flood-prone districts of Quang Nam province, for the period 2000 to 2011, are shown in Figure 4.

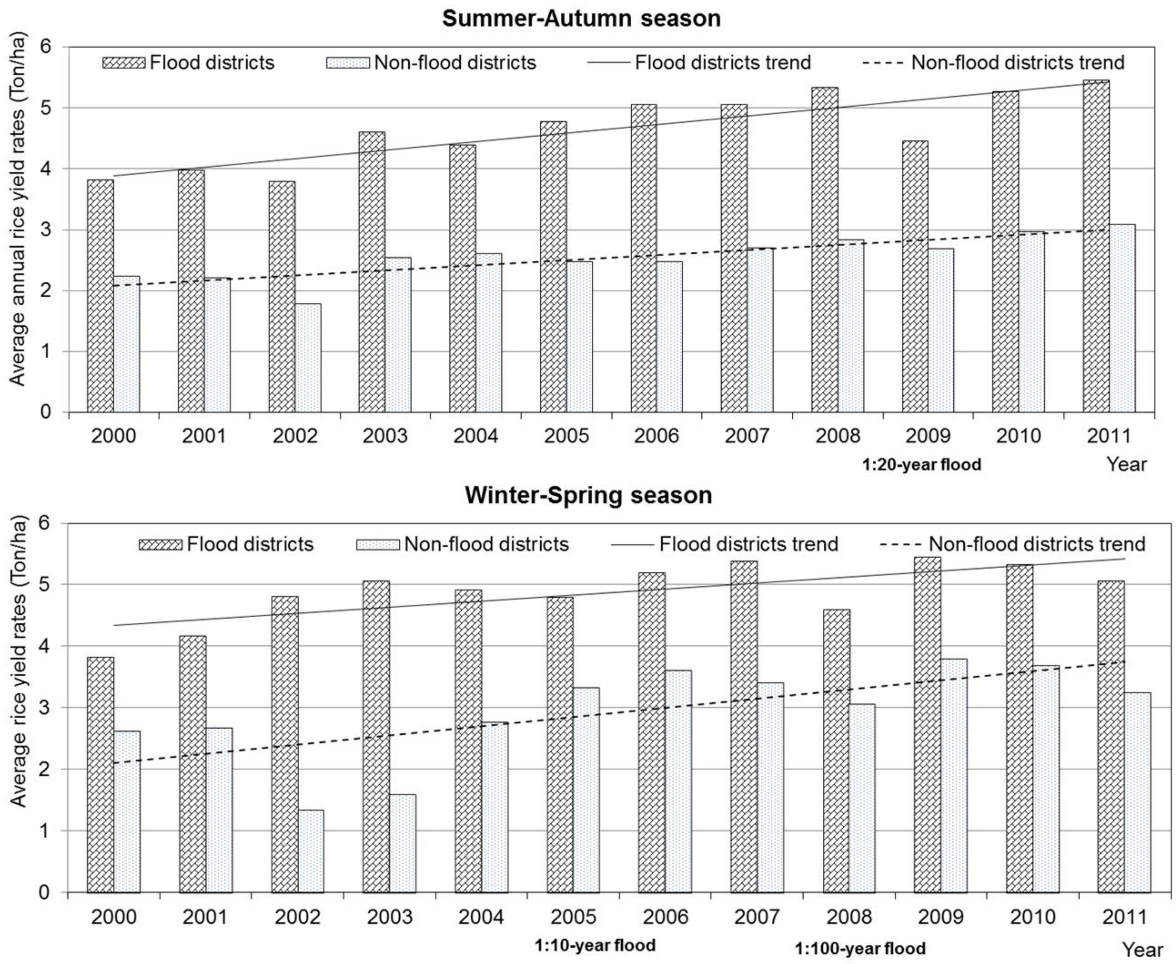


Figure 4: Average annual rice yields/ha and trends in 'more' flood-prone and 'less' flood-prone districts in Quang Nam province, 2000-2011.

Figure 4 shows the average yield (tonne) per hectare of the summer-autumn and the winter-spring rice crops, with differentiation made between the 'more' flood-prone and 'less' flood-prone districts. Trend lines for both crop season yields have been included, showing that the yield trend tends to increase by an average rate of 4% per season for the summer-autumn crop and by 3% for the winter-spring rice rice crop. Rice crop yields per hectare have been increasing for a number of reasons. These include improved varieties of rice which have increased yields, more effective irrigation and also increased use of fertiliser. It is important to note that the 2004 and 2007 floods affected the winter-spring rice crops, which were harvested in April of the following year. Therefore, it is the 2005 and 2008 rice yields which are impacted by the floods, as can be seen in Figure 4.

It is also worth noting that previously there were three annual rice crops grown in Quang Nam, which included a spring-summer rice crop. However, the Government decided that this spring-summer rice crop was to be eliminated completely from 2005 on, since it was the crop most often seriously affected by frequent flooding and so was the one which was least profitable. Since this rice crop rotation is no longer grown in the province, it was not considered in this study.

Method

We use a three-step method to determine the value of lost rice production due to 1:10, 1:20 and 1:100-year flood events. First, we calculate the flood-depth susceptibility rates for rice crops. Second, we calculate the loss to rice production experienced under the three flood classes. Third, we perform a cost-benefit analysis (CBA) for rice production under different scenarios for the three flood classes. Each CBA is a simple one-year analysis since all costs (and benefits) are incurred (and realised) within each crop season, which is less than one year. In addition, there is no capital equipment used, with planting and harvesting done by hand.

Flood damage to rice production is dependent upon a number of variables, such as, the crop's development stage, inundation depth and duration of inundation (Hansen, 1987; Messner et al., 2007; Read Sturgess and Associates, 2000). Where available, damage can be estimated based on historical data from past flood events or, alternatively, by using damage functions. These damage functions estimate the crop damage based on the relationship between inundation depth, duration of inundation and crop development stages (Hansen, 1987; Messner et al., 2007; Penning-Rowsell et al., 2013). Since the required level of historical data is not available for Quang Nam, this study has utilised the damage function method, however, some further assumptions will be made, which will be detailed later.

To calculate total crop flood damage we use the method developed by Messner, et al., (2007) that is estimated according to the following formula:

$$Damage_{total} = \sum_{i=1}^{n}\sum_{j=1}^{m} D_{i,j} = \sum_{i=1}^{n}\sum_{j=1}^{m}\left(value_{i,j} \times susceptibility_{i,j}\right)$$

Where: $susceptibility_{i,j} = f\left(E_{i,j}, F_k\right)$ (measured as a percentage)

i: category of crops at risk (n crops possible. In this study there is only crop, rice);

j: inundation depth (m inundation levels possible. In this study, four inundation levels are used: <1m, 1-2m, 2-3m and >3m);

E_{ij}: characteristic of crop i, under inundation level j, of flood class k;

F_k: Inundation characteristics of flood class k (Here the 3 flood classes are k=1:10, 1:20, 1:100-year flood).

The susceptibility rate (reflecting the loss of rice crop yield) for each flood class was estimated based on the difference between the rice yield in the year of the extreme flood with that of the previous year. For the extreme flood year, average yields from the 'more' flood-prone districts (nine districts in total) were calculated and separated according to four inundation levels, namely <1m, 1-2m, 2-3m and >3m.[2] The crop losses for each district

[2] Once these nine districts were grouped, they naturally populated just three of the four inundation levels, namely 1-2m, 2-3m and >3m. However, the four inundation levels will be included for overall results when calculating total losses, and for use in the scenario analyses.

populating a particular inundation level were collected for each flood class. These yield losses were then averaged to obtain an estimate of the yield loss associated with that inundation level, and expressed as a percentage. These percentages are the susceptibility rates.

Assumptions made

The flood season in Quang Nam province is separated into early (August to September), main (October to November) and late flooding (December to January). The Provincial Committee for Flood and Storm Control note that, in conditions where there is no further rain immediately following a flood, and with normal tides, the receding of the flood waters vary between one and six days, depending upon the level of inundation. An inundation of less than one metre was likely to have receded completely within one and a half days, causing no damage to rice crops. An inundation of one to two metres had receded within two days, two to three metres within three days and more than three metres took between three and six days to recede. No information was available regarding the duration of inundation and the damage impact, therefore, these durations of floodwater inundation are noted here, but are not used when calculating the damage function. The calendar for the flood seasons and the growing months for the two rice crops are presented in Table 1.

Table 1: The calendar for both the rice crops and the flood seasons in Quang Nam (2010)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Winter-Spring Rice												
Summer-Autumn Rice												
Flood season												
Main flood period												

The floods used in this study occurred during 23 – 28 Nov 2004 (1:10-year flood), 27 Sep – 3 Oct 2009 (1:20-year flood) and 9 – 15 November 2007 (1:100-year flood). As can be seen from Table 1, the 1:20-year flood (2009) occurred when the summer-autumn rice crop was ready for harvest. The 1:10-year flood (2004) and 1:100-year flood (2007) both occurred as the winter-spring rice crop was planted (although planting data from 2010, shown in Table 1, begins at the end of November). This meant the damage from the 2004 and 2007 floods was reflected in crop losses for the years following, as the winter-spring rice crop was planted in November 2004 and 2007 but was harvested the following Aprils (2005 and 2008). This is clear to see in the Figure 4 yields of the winter-spring season for the flood-prone districts.

Scenario and sensitivity analyses for the CBAs

Since both the timing and the intensity of flood events are uncertain, scenario analyses were performed to estimate the rice yield losses for the three flood classes. The baseline for both the scenario and sensitivity analyses used was the 2010 rice yields and prices. The most significant impact on the level of loss to rice crops is the timing of the floods. According to Kotera and Nawata (2007) the rice submerged at the end of growth phase is subject to significant yield loss, and rice plants inundated immediately following transplanting in the field, are particularly vulnerable. Three scenarios were developed by varying the timing of the flood event for each flood class, and were identified as likely, pessimistic and optimistic scenarios. These scenarios were created from field observation and expert consultation in Quang Nam province.

The likely scenario for each of the 1:10, 1:20 and 1:100-year floods is that which occurred in 2004, 2009 and 2007, respectively. Therefore, the susceptibility rates calculated from these floods, and presented in the main analysis, will be used on 2010 rice yields for the likely scenarios.

For the pessimistic scenario, it was assumed that the extreme flood event would occur at the end of September, destroying the summer-autumn rice crop just as it is ready for harvest. The susceptibility rates for each of the inundation levels will be increased by 30% to reflect the worst-case scenario for each flood class.[3]

The assumption for the optimistic scenario is that flooding will occur during the main flood period, after the summer-autumn rice has been harvested. In this scenario, with no rice crop planted at this time, there is no loss to rice production.

Sensitivity analyses are performed to estimate the impact on the loss to rice production as a result of changes in the product price, the yield and the labour costs. Variation in product prices are considered from -30% (where the quality of the output is degraded by the flood) to +50% (where food shortages during the flood season have pushed the prices up). Variations in yield from -30% (impact of disease) to +30% were considered.[4] Changes in labour costs (which are most often returned to the farmers themselves as income) were also considered since this is the most significant cost to the small scale farmer, where all work is done manually. A range of between -30% (where farmers help each other (and any employees) out, for no payment, in difficult periods or periods of unemployment) and +50% (the actual cost observed in 2012 during data collection in the field) of the labour cost, per person per day, was considered in this sensitivity analysis.

Results

Flood-depth susceptibility

Based on the inundation mapping and data collected during field work, estimation was made of the area of inundation of rice crops at each of the four inundation levels. These results are presented in Table 2, for each of the flood classes**.**

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[3] It will be shown in the results (Table 3) that for an inundation depth of >3m for the 2009 flood (which occurred just prior to harvest of the summer-autumn crop), the susceptibility rate was 28.69%, therefore, a 30% increase in total loss at each inundation level will be assumed as worst-case.

[4] In 2010 the rice yield for the US was roughly 7.5 tonne/ha (FAO, 2012), some 40% higher than Vietnam's rice yield. Since the US is one of the most technologically advanced rice producing countries, we have assumed that a 30% increase in yield would be possible.

Table 2: The predicted area (ha) of rice crops affected at each of the four inundation levels for the three flood classes

Flood	Area affected by inundation level				Total area
	< 1m	*1-2m*	*2-3m*	*>3m*	
1:10 YR	6,620	7,586	4,929	5,361	24,496
1:20 YR	5,367	6,808	6,628	8,472	27,275
1:100 YR	4,021	5,778	6,159	13,857	29,815

Table 2 shows that for a 1:20-year flood, 31% of the flooded rice growing area is inundated by more than three metres of water. For a 1:100-year flood this increases to close to half (46.5%) of the flooded rice crops being inundated by more than three metres of water, with the water not receding for some days.

The susceptibility rate of the rice crop to floods, for each inundation depth, was determined (as outlined in section 3) based on the reduction in rice yield in the year of the extreme flood from the previous year. The results, expressed as a percentage, are shown in Table 3.

Table 3: Susceptibility rate (decrease in rice yield) as a result of flooding (%)

Inundation depth (m)	1:10 YR (2004)	1:20 YR (2009)	1:100 YR (2007)
<1	0	0	0
1-2	0	7.32	7.06
2-3	2.96	14.66	16.36
>3	6.16	28.69	23.44

As shown in Table 3, the highest rate of loss of rice yield, from the previous year, was for an inundation of more than three metres in 2009 when the summer-autumn crop was inundated prior to harvest. It is worth noting that this is for a 1:20-year flood, evidence that it is the timing of the flood that is the critical factor.

Costs, benefits and CBAs to estimate flood damage to crops

The per hectare yields and total costs and benefits (for 2010 yields and 2010 prices) for rice production in the 'without' extreme flood events are calculated and are presented in Table 4. Costs are separated into labour costs and non-labour costs.

Table 4: Yields, economic benefits and costs and benefit-cost ratios for rice production in the 'without' flood scenario (VND mill in 2010 prices)

Crops	Yield	Benefits	Costs per ha			B/C
	(ton/ha)	*(per ha)*	*total costs*	*labour costs*	*non-labour costs*	
Winter-Spring Rice	5.33	25.63	21.30	10.50	10.80	1.20
Summer-Autumn Rice	5.26	25.31	21.30	10.50	10.80	1.19

Note: Non-labour costs include seed/planting materials, fertilisers, agrochemicals, transportation, tractor, bags and packaging, cooperative charge and irrigation maintenance.

Labour costs are roughly half the rice grower's total costs. It can be seen from Table 4 that benefit-cost ratios for rice production in 'normal' years is not particularly high, with an approximate 1.2 VND benefit for every 1 VND spent.

Next, the rice per hectare yields, and the costs and benefits (in 2010 prices) are calculated for the 'with' flood scenario for each of the three flood classes. These are presented in Table 5.

Table 5: The total damage (loss) to rice production (VND billion in 2010 prices) and the benefit-cost ratios for the three flood classes

Flood	**Depth level** (m)	**Area** (ha)	**Total cost**	**Total benefit**	**Total damage**	**B/C**
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
1:10-year (2004)	< 1	6620	141	157	0.00	1.11
	1-2	7586	162	179	0.00	1.11
	2-3	4929	105	113	3.45	1.08
	>3	5361	114	119	7.81	1.04
	Total	*24496*	*522*	*568*	*11.26*	*1.09*
1:20-year (2009)	< 1	5367	114	138	0.00	1.20
	1-2	6808	145	162	12.77	1.12
	2-3	6628	141	145	24.89	1.03
	>3	8472	180	155	62.29	0.86
	Total	*27275*	*581*	*599*	*99.94*	*1.03*
1:100-year (2007)	< 1	4021	86	104	0.00	1.22
	1-2	5778	123	139	10.56	1.13
	2-3	6159	131	133	26.08	1.02
	>3	13857	295	275	84.08	0.93
	Total	*29815*	*635*	*651*	*120.73*	*1.03*

Note: Total damage = susceptibility rate x previous year's yield/ha x area inundated (at that level) x price (2010)

As expected, the 1:100-year (2007) flood caused the greatest total damage (loss) to rice production in Quang Nam province at VND120.7 billion, since it inundated the greatest area and it impacted the larger yielding winter-spring rice crop which had to be replanted for inundations over three metres[5]. This compares with losses of VND99.9 billion and VND11.3 billion for the 1:20 (2009) and 1:10-year (2004) floods, respectively. However, the B/C is equally low for the 1:20 and 1:100-year floods.[6] The reason for this is due to the timing of the 1:20-year flood (occurring in 2009) which came at a worse time, affecting the summer-autumn rice crop just prior to harvest so that the crop was seriously damaged. For individual

[5] Hence the much higher total cost of VND295 bill.

[6] For the province as a whole, benefits just outweigh costs for both these floods as well as for the 1:10-year flood.

rice producers, however, whose rice crop is inundated by more than three metres during a 1:20 or 1:100-year flood event, their costs outweigh their benefits (B/C is less than one).

Scenario and sensitivity analyses

Scenario and sensitivity analyses were used to further estimate the total damage (loss) to rice production under the three flood classes. These are presented in Table 6.

Table 6: Estimation of the total rice crop loss (using 2010 yields) due to extreme flood events under pessimistic, likely and optimistic scenarios (VND billion in 2010 prices).

Flood	Total loss	B/C
Pessimistic scenario		
1:10-year	15.9	1.17
1:20-year	128.3	0.97
1:100-year	155.4	0.96
Likely scenario		
1:10-year	12.20	1.18
1:20-year	99.96	1.03
1:100-year	118.00	1.00
Optimistic scenario		
1:10-year	0.0	1.20
1:20-year	0.0	1.20
1:100-year	0.0	1.19

The likely scenario for the 1:10, 1:20 and 1:100-year floods are losses of VND12.2 billion, VND100.0 billion and VND118.0 billion, respectively, with B/C ratios equal to, or just above one. However, it can be seen in Table 6 that under a pessimistic scenario, where the flood events occur in late September, destroying the summer-autumn rice crop, the losses could be as high as VND15.9 billion, VND128.3 billion and VND155.4 billion, respectively. Under the pessimistic scenario, the B/Cs for 1:20 and 1:100-year flood classes are less than one, meaning the costs outweigh the benefits.

The sensitivity analyses involved varying the product price, the yield, and the labour cost. These results are presented in Table 7.

Table 7: B/Cs resulting from percentage changes to the rice price, labour cost or, crop yields.

Percentage change	Resulting B/C for each flood class due to percentage changes in:								
	Product price			Labour cost			Crop yield		
	1:10 YR	*1:20 YR*	*1:100 YR*	*1:10 YR*	*1:20 YR*	*1:100 YR*	*1:10 YR*	*1:20 YR*	*1:100 YR*
-30	0.83	0.72	0.70	1.38	1.21	1.18	0.83	0.72	0.70
-20	0.94	0.83	0.80	1.31	1.14	1.11	0.94	0.83	0.80
-10	1.06	0.93	0.90	1.24	1.08	1.05	1.06	0.93	0.90
0	**1.18**	**1.03**	**1.00**	**1.18**	**1.03**	**1.00**	**1.18**	**1.03**	**1.00**
10	1.30	1.13	1.10	1.12	0.98	0.96	1.30	1.13	1.10
20	1.42	1.24	1.20	1.07	0.94	0.91	1.42	1.24	1.20
30	1.53	1.34	1.30	1.03	0.90	0.87	1.53	1.34	1.30
40	1.65	1.44	1.40	0.99	0.86	0.84			
50	1.77	1.55	1.50	0.95	0.83	0.80			

Table 7 shows that while a 10% fall in the price of rice will still yield a B/C over one for a 1:10-year flood; this would not be the case for any year experiencing a 1:20 or 1:100-year flood, where almost any fall in price would result in costs outweighing the benefits.[7] A similar trend also occurs for the crop yields.[8] With regard to labour cost, for any year experiencing a 1:100-year flood, if there is an increase in labour cost of even 1%, costs would outweigh benefits. However, for a 1:20-year flood this increase would need to be more than 7% and for a 1:10-year flood, labour costs could increase by more than 37% before resulting in a B/C of less than one.

Finally, B/C ratios are calculated when there is simultaneously a change in the price of rice and labour costs and also the price of rice and crop yields. The results for a 1:100-year flood are presented in Table 8.

[7] A fall in the price of rice of more than 14%, 2% and 0% would result in a B/C < 1.0 for a 1:10, 1:20 and 1:100-year flood, respectively.

[8] A reduction in crop yield of more than 15%, 3% and 0% would result in a B/C < 1.0 for a 1:10, 1:20 and 1:100-year flood, respectively

Table 8: B/C ratios for a 1:100-year flood as a result of simultaneous changes in the price of rice and either the labour cost or, the crop yield.

1:100 YR		Percentage change in product prices								
		-30	-20	-10	**0**	10	20	30	40	50
Percentage change in labour cost	-30	0.82	0.94	1.06	1.18	1.29	1.41	1.53	1.65	1.76
	-20	0.78	0.89	1.00	1.11	1.22	1.33	1.45	1.56	1.67
	-10	0.74	0.84	0.95	1.05	1.16	1.27	1.37	1.48	1.58
	0	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50
	10	0.67	0.76	0.86	0.96	1.05	1.15	1.24	1.34	1.43
	20	0.64	0.73	0.82	0.91	1.00	1.09	1.19	1.28	1.37
	30	0.61	0.70	0.79	0.87	0.96	1.05	1.14	1.22	1.31
	40	0.59	0.67	0.75	0.84	0.92	1.00	1.09	1.17	1.26
	50	0.56	0.64	0.72	0.80	0.88	0.97	1.05	1.13	1.21
Percentage change in crop yield	-30	0.49	0.56	0.63	0.70	0.77	0.84	0.91	0.98	1.05
	-20	0.56	0.64	0.72	0.80	0.88	0.96	1.04	1.12	1.20
	-10	0.63	0.72	0.81	0.90	0.99	1.08	1.17	1.26	1.35
	0	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50
	10	0.77	0.88	0.99	1.10	1.21	1.32	1.43	1.54	1.65
	20	0.84	0.96	1.08	1.20	1.32	1.44	1.56	1.68	1.80
	30	0.91	1.04	1.17	1.30	1.43	1.56	1.69	1.82	1.95

It can be seen from Table 8**,** that for a 1:100-year flood, the impact of a fall in the price of rice is dominant over impacts from changes in yield or labour cost. With a 20% decrease in the price of rice, only an increase of almost 30% in rice yield (or a fall in labour costs of more than 30%) will see benefits outweigh costs (B/C > 1). Similarly, a 10% fall in the price of rice would require either a yield increase of more than 10% or a decrease in labour costs of at least 20% for benefits to outweigh costs. These results are for the Quang Nam rice production sector as a whole, individual rice producers could be affected to a greater (or lesser) degree depending on the level of inundation on their land, under each flood scenario.

Discussion

When comparing the results of this study (based on 2010 prices) with the actual reported losses to rice production in Quang Nam province for the corresponding years, the comparisons for two flood classes are favourable. In this study, the estimated loss from flood damage for a 1:10-year flood (like that occurring in 2004, where the loss is realised in 2005) was VND11.3 billion as compared with the reported damage bill of VND8.5 billion from the Quang Nam People's Committee (2005) and the Central Committee for Flood and Storm Control's (CCFSC) disaster database (2012). The likely estimated loss (in this study) for a 100-year flood (occurring in 2007, with the loss realised in 2008) was VND120.7 billion, which was approximately 5% of the total rice production output for the province. The total damage of the 2007 flood was reported at VND120 billion (for crops), 70% of which was damage to rice crops. This means that the reported estimate for loss to rice production in 2007 was approximately VND84 billion (Quang Nam People's Committee, 2008).

The total reported damage for the 2009 flood by the Quang Nam People's Committee (2010) and recorded in the CCFSC disaster database (2012) was VND3,500 billion, of which, VND300 billion was damage to rice production (our estimate is VND100 billion). However, the Vietnamese Prime Minister (2012) stated that the 2009 natural disaster damage reports were deliberately excessive in order to claim higher relief payments from the central government. Therefore, direct comparison with estimates from this study cannot easily be made. To provide a more realistic estimate of rice production loss, the results of the pessimistic scenario in this study (with the estimation of damage at VND128.3 billion) could be used as a 'maximum' flood damage estimate for a 1:20-year flood. In the same report, the Prime Minister (2012) also revealed that there were no natural disaster damage assessment criteria in Vietnam, which highlights a gap in the knowledge of post- natural disaster recovery.

Whilst return on investment for rice is less than for other crops (with a B/C of around 1.2 in the 'without' flood scenario), rice remains the most important crop in Quang Nam province. This is because rice is the staple crop and, as such, does not experience the fluctuation in demand experienced by other crops, therefore, farmers are extremely reliant on this crop.

The estimated cost of flood damage to rice production used in this study is a function of the inundation depth, land use type and timing of the floods. However, no consideration was given to potential loss incurred indirectly, for example, through traffic interruptions, delayed crop planting and intangible costs.

With all three flood classes having occurred in central Vietnam in the last decade, attention is being given to flood prevention measures. Current proposals, such as upgrading dykes and improving drainage by removing excess sedimentation in the river basins, aim to reduce the susceptibility of rice production to loss as a consequence of extreme flood events. A further risk to flood damage loss to rice is as a consequence of flood discharge from upstream hydro-power stations. With increasing demand for renewable power, more hydro-power stations are being planned and developed, therefore, this needs to be included in future analyses.

Conclusion

This study estimated the direct damage caused by 1:10, 1:20 and 1:100-year floods on rice production in Quang Nam province, Vietnam. Prior to evaluation of the flood damage, a CBA was conducted on rice production for a typical year, without an extreme flood event, using 2010 rice yields and prices. The B/C for rice production was found to be around 1.2, indicating that the return to subsistence farmers is not high, making them very vulnerable when extreme floods occur. This study estimates that the total direct losses to rice production in Quang Nam for a 1:10 (in 2004), a 1:20 (in 2009) and a 1:100-year (in 2007) flood were approximately VND11 billion, VND100 billion and VND121 billion, respectively. These figures are comparable to those recorded by the local government in the corresponding years for both 1:10 and 1:100-year floods, verifying the method used in this study. The corresponding B/C ratios were calculated to be 1.09 for a 1:10-year flood and 1.03 for both 1:20 and 1:100-year floods. Whilst the B/Cs are a little higher than one for the three flood classes, what little returns subsistence farmers receive are significantly eroded, and for many individual farmers, net losses will occur. In addition, if a 1:100-year flood occurs at the end of September when the summer-autumn rice crops are ready to harvest, the returns will be devastating.

The analysis highlights shortcomings in the data, with no account taken for duration of the floodwaters in the damage calculations. This would improve findings in future estimations. Further research could also incorporate the additional impact from both the release of hydropower floodwaters to downstream agricultural land and the many indirect losses (to agriculture) incurred as a result of the extreme flood events.

This study utilises a method of analysis that can be replicated elsewhere. By using flood inundation maps and the likely timing of the flood event relative to the crop rotation, the extent of devastation to specific crop types (measured by their susceptibility) can be quantified and an economic assessment conducted. The results can provide further evidence to support future flood mitigation measures being directed to where they are most needed. In addition, results may give a better estimate of direct losses, when deciding on levels of relief payments. The focus of this study was flood damage impacts on rice production sustained by subsistence farmers in central Vietnam.

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