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Socioeconomic Vulnerability and Adaptation to Environmental Risk: A Case Study of Climate Change and Flooding in Bangladesh

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In this article we investigate the complex relationship between environmental risk, poverty, and vulnerability in a case study carried out in one of the poorest and most flood-prone countries in the world, focusing on household and community vulnerability and adaptive coping mechanisms. Based upon the steadily growing amount of literature in this field we develop and test our own analytical model. In a large-scale household survey carried out in southeast Bangladesh, we ask almost 700 floodplain residents living without any flood protection along the River Meghna about their flood risk exposure, flood problems, flood damage, and coping mechanisms. Novel in our study is the explicit testing of the effectiveness of adaptive coping strategies to reduce flood damage costs. We show that, households with lower income and less access to productive natural assets face higher exposure to risk of flooding. Disparity in income and asset distribution at community level furthermore tends to be higher at higher risk exposure levels, implying that individually vulnerable households are also collectively more vulnerable. Regarding the identification of coping mechanisms to deal with flood events, we look at both the *ex ante* household level preparedness for flood events and the *ex post* availability of community-level support and disaster relief. We find somewhat paradoxically that the people that face the highest risk of flooding are the least well prepared, both in terms of household-level *ex ante* preparedness and community-level *ex post* flood relief.

KEY WORDS: Bangladesh; climate change; flood risks; social vulnerability

1. INTRODUCTION

Bangladesh is a highly flood prone country. Eighty percent of the country consists of floodplains of the Ganges, Brahmaputra, Meghna, and several other minor rivers. These floodplains sustain a predominantly poor rural population. Approximately 75% of the total population of 132 million people (in 2001) live in these rural areas, earning on average US$325 per capita per year (Bangladesh Bureau of Statistics, 2005). Once every 10 years roughly one-third of the country gets severely affected by floods, while in catastrophic years such as 1988, 1998, and 2004 more than 60% of the country was inundated, i.e., an area of approximately 100,000 km^2 for a duration of nearly 3 months (CEGIS, 2002). Floods cause social disruptions and result in scarcity of drinking water as surface water gets contaminated by organic and inorganic

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substances. Cases of diarrhea, cholera, and other intestine diseases increase remarkably during and after floods.

The increased volume of rainfall caused by climate change during the past decades has intensified the flood problem in this part of the world. The population expected to be hardest hit by flood disaster is the poor people who lack adequate means to take protective measures and who also have very little capacity to cope with the loss of property and income (IPPC, 2001). A range of studies have recently focused on understanding how different groups of people and communities perceive and respond to flooding risks, especially in flood-prone countries in Asia, including Bangladesh (e.g., Schmuck-Widmann, 1996; Rashid, 2000; Rasid & Haider, 2003). Since the mid 1990s, the concept of social vulnerability is used to describe and analyze the exposure and coping mechanisms of groups and individuals to environmental risks, primarily in the context of climate change and flooding hazards in developing countries (e.g., Blaikie *et al*., 1994; Few, 2003).

In this article, we build upon the steadily growing number of theoretical and empirical studies in the domain of social and economic vulnerability to environmental risk and assess household and community vulnerability and coping strategies to flood hazards in one of the poorest and most flood-prone countries in the world: Bangladesh. In a large-scale household survey carried out in 2005 in southeast Bangladesh, we ask almost 700 floodplain residents living without any flood protection along the river Meghna about their flood risk exposure, flood problems, flood damage, and coping mechanisms. In addition, we carried out almost 50 semistructured interviews with key informants at the community level to address and assess community vulnerability to flooding.

The main objective of this article is to investigate and provide further empirical evidence of the complex relationship between poverty and social and economic vulnerability in a concrete case study, focusing on individual household and community vulnerability and adaptive coping mechanisms. We show that, as expected, households with lower income and less access to productive assets face higher exposure to risk of flooding. Income inequality also plays a role in determining sources of collective vulnerability. Disparity in income and asset distribution at the community level tends to be higher at higher risk exposure levels, implying that individually vulnerable households are also collectively more vulnerable. Regarding the identification of coping mechanisms to deal with flood events, we look at both the *ex ante* household-level preparedness for flood events and the *ex post* availability of community-level support and disaster relief.

The remainder of this article is organized as follows. Section 2 provides an overview of the theoretical concepts underlying social and economic vulnerability to environmental risk based upon the relevant literature in this field and presents our "analytical model." Section 3 introduces the case study, while Section 4 discusses the set-up of the household survey and the key informant interviews. Section 5 presents the general floodplain resident characteristics and Section 6 the flood-related problems in the case study area. In Section 7 we examine the relationship between risk exposure, socioeconomic vulnerability, and poverty, while Section 8 looks further into the impacts of flood risks measured through flood damage in relation to poverty. Section 9 follows with the presentation and discussion of the effectiveness of *ex ante* and *ex post* coping strategies at household and community levels in terms of their impact on flood damage. Finally, Section 10 concludes.

2. THEORETICAL PERSPECTIVES ON VULNERABILITY AND ADAPTIVE CAPACITY

There exists an increasing amount of literature about the operationalization of the concept of social and economic vulnerability to environmental risk. Generally, vulnerability is seen as the outcome of a mixture of environmental, social, cultural, institutional, and economic structures, and processes related to poverty and (health) risk, not a phenomenon related to environmental risk only. An extensive overview and discussion of recent theoretical and applied research on vulnerability and adaptive capacity in flood-prone areas is provided by Few (2003). Definitions of vulnerability focus on risk and risk exposure on the one hand, and coping and adaptation mechanisms on the other (e.g., Pelling, 1999). Besides risk exposure, adaptive capacity is seen as a key component of the concept of vulnerability (e.g., Adger, 2000; IPPC, 2001). Empirical studies focus more and more on variations in both exposure to natural hazards and people's capacity to cope with these hazards (Few, 2003). Adaptive capacity is considered a process of adaptation (over time) to structural and/or incidental sources of environmental stress (e.g., Nishat *et al*., 2000), consisting of distinct social, economic, technological, institutional, and cultural adaptive mechanisms (e.g., Cardona, 2001). Social mechanisms refer,

for example, to social networks of relatives and neighbors, economic mechanisms to livelihood diversification or savings, technological mechanisms to technical measures to prevent flooding such as embankments or terps (mounds of earth), institutional mechanisms to (in)formal political-organizational structures and associated collective action to ameliorate vulnerability (including, for instance, access to productive assets or community microcredit systems), and cultural mechanisms to perceptions and beliefs about the nature and avoidance of flooding.

Another distinctive feature of the concept of vulnerability is the level or scale of analysis. Variation in social and economic vulnerability to environmental risk can, for example, be explained at the level of the individual household or the community. In some studies, even national indicators are compiled and used (Vincent, 2004). Adger (1999) argues that individual vulnerability is determined by other factors than collective (community) vulnerability, but uses similar indicators for both levels of analysis (e.g., income either measured at individual household level or at the level of a region or country). In this article, we also distinguish explicitly between individual (household) and collective (community) vulnerability and we use similar indicators as the ones proposed by Adger (1999) in order to establish associations between risk exposure, poverty, and what we label as *ex ante* and *ex post* adaptive coping mechanisms. We will show that the relationship between vulnerability and poverty is not as straightforward as expected. The poor are indeed more exposed to risks of flooding, but the claim that they are therefore also more likely than the wealthy to suffer when flooding strikes (e.g., Few, 2003) is rejected in our study.

The analytical "model" of socioeconomic vulnerability to flood risk exposure in our case study is shown in Fig. 1. Central to the concept of vulnerability are, as mentioned, the exposure to risk and the adaptive capacity to risk.

According to conventional risk theory (e.g., Shogren & Crocker, 1991; Smith, 1992), risk exposure consists of an exogenous and endogenous component as people are—to some extent—able to protect themselves against (the negative impacts of) environmental risks, by avoiding the risk involved or by taking protective (preventive) measures before being exposed to the risk or afterward (e.g., insurance). Here, we subsume the endogenous component of risk under adaptation, and distinguish explicitly between *ex ante* and *ex post* coping mechanisms at individual household and collective community levels. Following the seminal work by Knight (1921) and more recent expositions by, for example, Faber and Proops (1990) and Funtowicz and Ravetz (1992), we furthermore distinguish explicitly between the likelihood of being struck by flooding (probability of exposure) and the impact of flooding (measured through damage cost). These are considered two separate dimensions of the concept of risk, where risk is defined as the (objective or subjective) probability of reaching a future state or outcome and the expected consequences of this state or outcome (e.g., Costanza, 1994). Here, we refrain from attaching probabilities to flooding (flooding being an annual event) and simply measure (1) the probability of risk exposure through the distance (in kilometers) people live to the river at the community level (the closer to the river, the higher the probability of flooding), (2) the state or condition of risk exposure through inundation depth (in feet) at the individual household level, and (3) the consequence of risk exposure through economic damage cost (local currency converted to US$) when the flooding occurs at the individual household level.

Poverty is both an important determinant of (endogenous) environmental risk—and hence (in)directly of socioeconomic vulnerability—and an important constraint of adaptive capacity. Poorer people tend to be more (often) exposed to environmental risk than wealthy people. The latter are furthermore able to take protective measures or are able to avoid certain environmental (health) risks, i.e., the endogenous component of risk. Conventional poverty indicators (e.g., Blackwood & Lynch, 1994) used in this study include annual household income compared to the official poverty threshold value calculated by the Bangladesh Bureau of Statistics, income distribution at the community level (measured through Gini coefficients[5]), and household access to and ownership of natural resources, most importantly in this case study land for crop cultivation.

3. THE CASE STUDY AREA

The case study is carried out in a low-lying, severely flood-prone fluvial delta located in the southeast of Bangladesh in the district of Homna, approximately 70 km from Dhaka. The floodplain delta

[5] The Gini coefficient is a measure of the inequality of a distribution and is often used to measure income or wealth inequality. The Gini coefficient takes values between 0 and 1, with 0 representing perfect equality and 1 representing perfect inequality. Hence, the higher the coefficient, the less equal the income distribution.

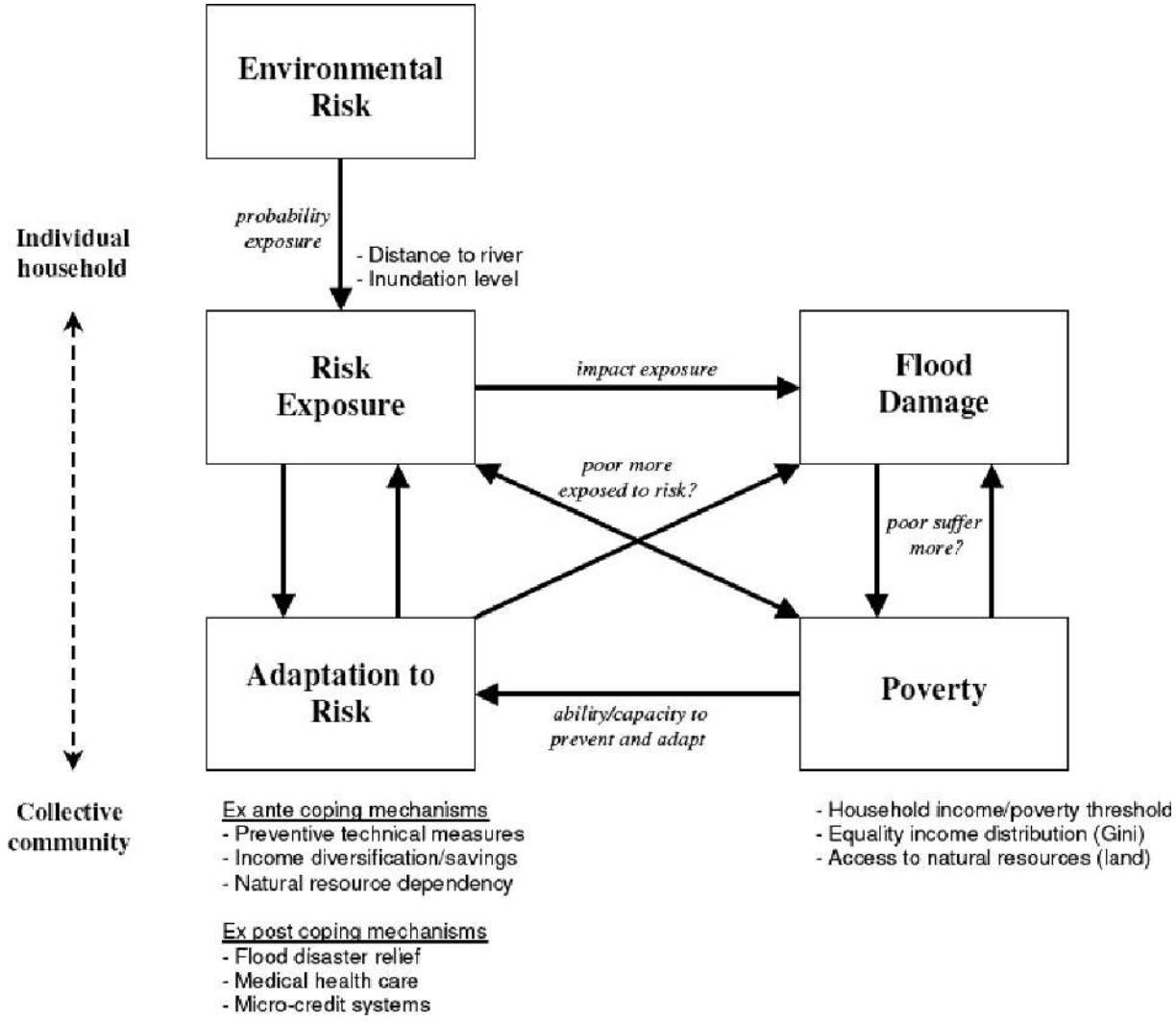

Fig. 1. Analytical framework underlying the case study.

covers an area of approximately 10,000 hectares and is bordered in the northwest by the Meghna River, its tributaries the Titas River in the north and south and the Kathalia River in the west (Fig. 2).

More than 400,000 people live in the area (2001 population census). Most of them are farmers. Almost three-quarters of the land is used for farming, mainly rice. Other crops include wheat, vegetables, pulses, oil seeds, and maize. Some livestock farming is also present, but on a very small scale. Communities of fishermen are found along the rivers. Furthermore, many creeks and canals are found in the area, which are also utilized for fishing.

The area's topography varies between 1.5 and 4.0 meters above sea level. Average annual rainfall is 2,025 mm, of which 75% falls during the monsoon from June to October. Heavy monsoon rainfall generates excessive flows in the rivers and thereby causes floods almost every year. These floods cause damage to houses, agricultural crops, and the infrastructure in the area. For more than half of the rain season around two-thirds of the area remains under six feet water. As a result, employment opportunities decrease dramatically. Around 80% of the labor force is unemployed during the flood season.

In addition to regular seasonal flooding, the area suffered from devastating floods over the past 20 years in 1988, 1996, 1998, and 2004. During the 2004 flood, Homna was identified in the Rapid Flood Assessment as one of the most severely affected areas in

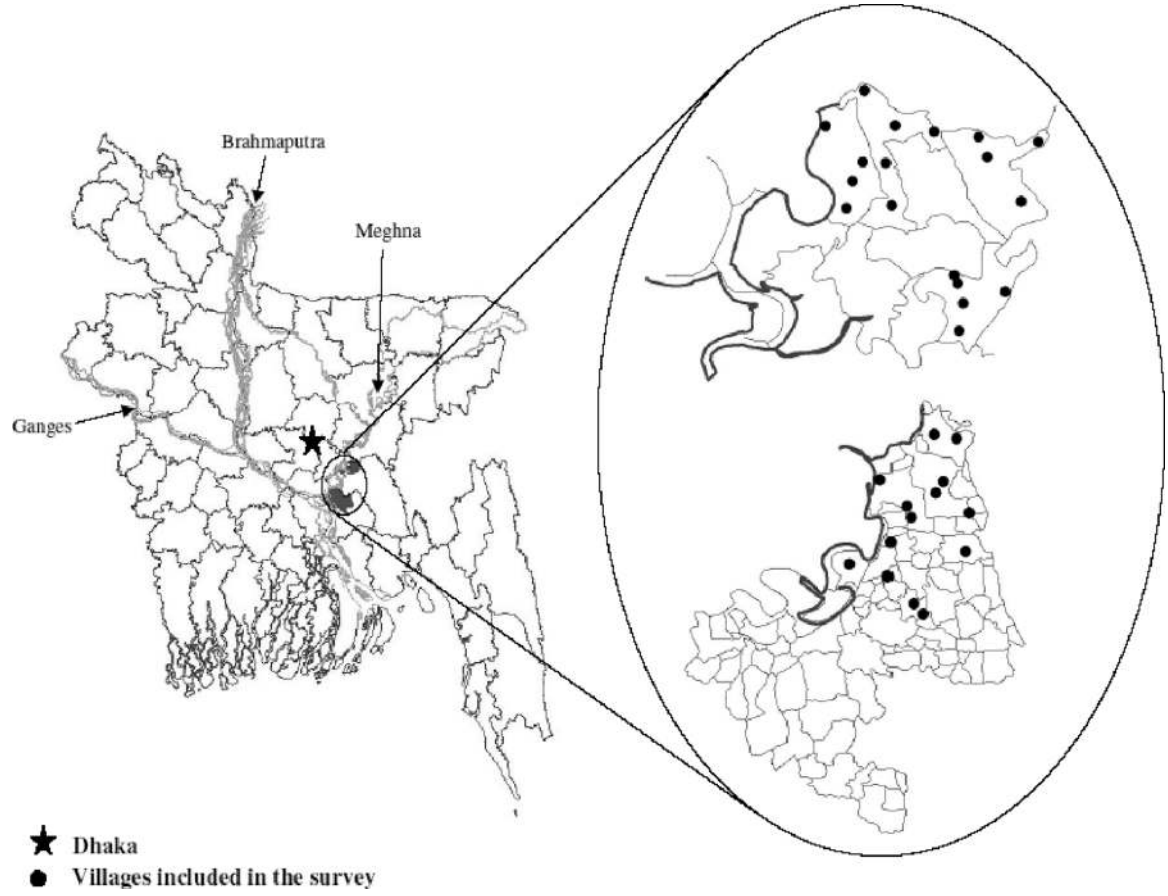

Fig. 2. Location of the case study area in Bangladesh.

Bangladesh in terms of percentage of area inundated, inundation depth (≥2 m), and percentage of people affected (Centre for Policy Dialogue, 2004).

4. SURVEY SET-UP AND SAMPLING PROCEDURE

The study presented here was part of a wider, extensive rural household survey looking at agricultural and fish production systems in flood plains, general demographic, socioeconomic characteristics of floodplain residents, and flood problems in one of the most severely flood-prone areas in Bangladesh.

A total of 672 people were interviewed face-to-face from the last week of March until and including the second week of May 2005 by local (male and female) interviewers.[6] Each interview lasted on average 30 minutes. A stratified sampling procedure was used where 32 villages were chosen based on their distance from the river Meghna (Fig. 2). In each of these 32 villages every fifth house along one side of the main village road was selected in the sample.

The questionnaire consists of five sections, two general sections and three sections designed for specific occupational activities (including household production and consumption patterns). Hence, each respondent answered three sections: a general introductory section including questions about respondent demographic and socioeconomic characteristics, a section specifically dealing with flood and flood control issues, and an occupational section. For a more detailed description of the survey design, the interested reader is referred to Haque *et al*. (forthcoming). The flood-related questions are aimed at examining the extent and nature of the impacts of flooding on life

[6] The interviewers were carefully selected and thoroughly trained in view of the low education level of respondents and the high illiteracy rate in the area. The same interviewers were also used for the pretesting of the questionnaire. Three pretest rounds were used to finalize the household questionnaire over a period of two and a half months, including a one-day workshop with local experts and stakeholders.

and livelihood (including inundation frequency and depth, health-related impacts, and damage costs) and floodplain residents' perceptions regarding the management and funding of a proposed flood alleviation scheme in the area.

In addition to the household survey, 45 semistructured key informant interviews were carried out from the second week of April to the second week of May 2005. On average, each key informant interview lasted one and a half hours. The semistructured questionnaire covered the impact of flooding on different occupational groups, coping mechanisms during and after a flood, and information regarding household activities during normal and extreme flood years. Besides some quantitative information, the key informant interviews were primarily qualitative in nature. Where necessary, interviews were adapted to different professional backgrounds of the interviewee. Local primary school teachers, leaders from fishing communities, agricultural extension officials, health and nongovernment organization (NGO) workers were interviewed. The interviews were conducted by local college teachers, who were very knowledgeable about and familiar with the specific local situation and circumstances, and well informed and trained about the main objectives of the interviews.

Finally, to test the reliability of responses in the original survey and collect additional information, a small-scale follow-up survey was carried out 6 months after the original survey (in November 2005). Face-to-face interviews were conducted with 89 randomly selected respondents who also participated in the original rural household survey (13% of the original sample population). In this unannounced follow-up survey, respondents were asked additional questions about, for example, the type of preventive measures they take to protect themselves against flooding and the reasons why a large proportion of the sample population does not take any preventive measures. These results will also be reported here and are used in the overall analysis.

5. GENERAL FLOODPLAIN RESIDENT CHARACTERISTICS

Table I summarizes the general demographic and socioeconomic characteristics of the 672 households included in our sample. Most of the floodplain respondents are Muslim men, who are the head of their household (75%). Most people interviewed (97%) were furthermore born and raised in the region. The average age of respondents is around 40–45 years. About half of the interviewed respondents were unable to read and write. Just over a quarter finished primary school and just over 10% finished high school. The households consist, on average, of six people, of which two (usually men) earn income. The household size found in our sample corresponds with the national household situation in Bangladesh.

Most households are involved in agricultural activities to support their livelihood. Approximately 20% of the sample population consists of day laborers.[7] Almost all households own the house they live in, and 60% owns the land they grow their crops on. Almost all houses are made of tin (both roof and walls) and a water-sealed latrine is the most important sanitary facility in dwellings. About one in every third household has electricity. Most households get their drinking water from a private or collective tube well and use leaves and cow dung as their main source of energy.

There is a wide spread in annual household income, as can be seen from the standard deviation in Table I and the Gini coefficient calculated for the sample population. Average annual household income (related to the past 12 months) is about US$950, while half of the sample population earns US$585 per year. Average annual per capita income is US$175, which is substantially lower than the national average (US$325). Using the Basic Cost Need (BCN) calculated by the Bangladesh Bureau of Statistics as the poverty threshold (US$105 per capita per year), almost 50% of the floodplain residents included in the sample appear to live below this poverty line. A further distinction can be made between natural resource dependent and nonnatural resource dependent income. A quarter of the interviewed floodplain residents are fully dependent for their income on (access to) natural resources such as agriculture and fishery (including aquaculture).

6. FLOOD PROBLEMS AND FLOOD DAMAGE

A majority of 96% of the interviewed floodplain residents are exposed every year during the rainy season to flooding, and a quarter of the population

[7] The distribution of respondents across occupational groups is not representative. Relatively more fishermen were interviewed in the rural household survey for the estimation of fishery production functions. However, when taken together, the group of fishermen and farmers in the sample is more or less representative for the whole rural population in Bangladesh (60% of the rural population is full-time farmer or fisherman).

Table I. Summary Statistics of Respondent (Household) Demographic and Socioeconomic Characteristics

Respondent (Household) Characteristic		Value
Percentage male respondents in sample		85.4
Respondent average age (median value)		42 (40)
Respondent religion (%)	Muslim	89.0
	Hindu	11.0
Literacy rate respondent (%)	Illiterate	51.9
	Primary school	27.9
	High school	12.6
Respondent occupation (%)	Self-employed farmer	43.0
	Self-employed fisherman	19.0
	Day laborer	19.0
	Ferry/taxi worker	14.2
Average number of family members (min–max)		6.3 (2–20)
Average number of adults (min–max)		4.1 (2–13)
Average number of children (min–max)		2.2 (0–11)
Average household income (US$/year) (st. dev.)		954 (1245)
Average per capita income (US$/month) (st. dev.)		14.5 (20.3)
Percentage households dependent on NRDI*		25.1
Percentage households under poverty threshold**		48.5
Income inequality (Gini coefficient)		0.466
Percentage households owning agricultural land		59.4
Average size land owned by household (ha)		0.33
Percentage households owning fish pond		18.7
Percentage with pacca latrine sanitary facility		71.3
Percentage with electricity connection		37.8
Percentage with telephone connection		5.4
Percentage tubewell as main drinking water source		97.8
Main sources of household energy (%)		58.8
	Twigs/leaves/straw/ dung Coal	38.2
Percentage of which house area gets inundated		95.5
Average annual flood damage (US$) (st. dev.)		198 (672)
Percentage of annual household income		20.8

*Natural Resource Dependent Income (NRDI) is defined as income originating from agriculture (crop cultivation), fishery, or aquaculture.
**The Bangladesh Bureau of Statistics calculates the so-called Basic Cost Need as a poverty threshold value. This threshold value was US$105/capita/year in 2004.

mentions flooding as the main problem faced by the region, followed by other important problems such as bad roads (23%), unemployment (20%), and lack of electricity (17%). In more than one-third of the cases the water comes waist high during the rain season (approximately 1.5 feet) and in another one-third of the cases even shoulder high (approximately 3 feet). Almost half of the population (46%) indicates that they suffer each year from diarrhea during the rain season. Ninety-nine percent seek medical treatment for this.

Average flood damage costs are almost US$200 per household per year. This amounts to approximately 20% of average household income. Median damage costs are half of this amount (US$95). Dividing this by the median value for household income, the share of damage in household income is slightly lower, namely, 16%. The minimum damage costs are zero and the maximum US$16,000. Trimming off the 5% lowest and highest values, the average damage cost estimate is US$140 per household per year. Most flood damage is caused by house property damage (27%) and crop damage (27%), followed by damage to fishponds (loss of fish stock) (19%). Other damage categories include damage to fruit trees (11%), medical expenses (7%), loss of livestock (5%), and income losses from day labor and trade (4%).

7. RISK EXPOSURE AND SOCIOECONOMIC VULNERABILITY

As expected, there exists a significant positive relationship between the distance people live from the river Meghna as an indicator of (collective) risk exposure and household income ($r = 0.113$; $p < 0.003$).

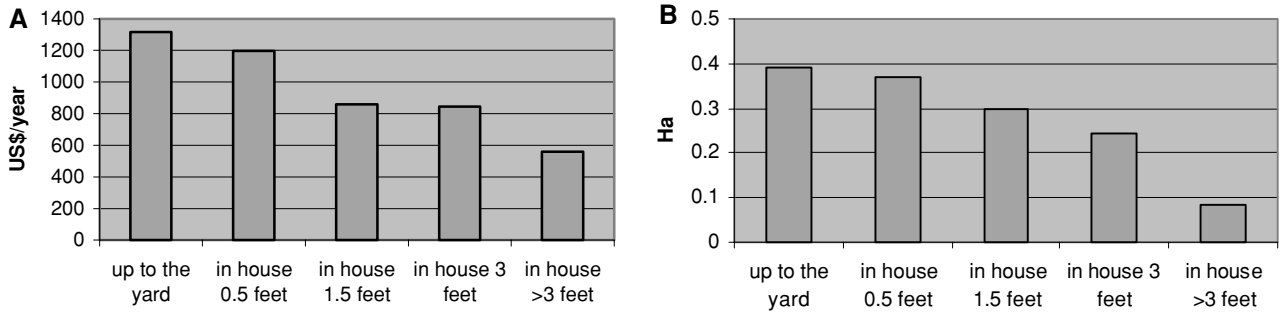

Fig. 3. Relationship between inundation depth (horizontal axis) and household income (US$/year) (Fig. 3A) and inundation depth and landownership (ha) (Fig. 3B).

Floodplain residents living in villages that are situated closer to the river have lower income levels. Interestingly, a significant negative relationship is found between distance and income distribution as measured through Gini coefficients at the village level ($r = -0.246; p < 0.001$). Villages situated further away from the river have more equal income distributions.

Relating inundation depth as another indicator of risk exposure at the individual household level to household income, we find a small, but significant negative relationship ($r = -0.181$; $p < 0.001$), suggesting that lower incomes suffer higher inundation levels and are hence indeed more exposed to flood risks. The same significant negative relationship is also found between inundation depth and land ownership ($r = -0.167$; $p < 0.001$). Those respondents who own more land suffer lower inundation levels. This is visualized in Fig. 3. As expected, land ownership is significantly and positively correlated to household income ($r = 0.331$; $p < 0.001$). People with higher income own more land.

These results are confirmed when comparing the same risk exposure indicator for respondents living under and above the poverty threshold value (see Section 5). Floodplain residents living under the poverty threshold value face significantly higher inundation levels than floodplain residents living above the poverty threshold value (Table II). At the same time, floodplain residents living under the poverty threshold depend for their livelihood significantly more on natural resources such as land for crop cultivation and fishery than floodplain residents living above the poverty line (Table III) ($\chi^2 = 9.162$; $p < 0.002$), even though they own, for instance, significantly less land, as shown in Table II.

8. RISK EXPOSURE AND FLOOD DAMAGE

As expected, the consequences of risk exposure, measured through economic damage costs, are negatively correlated with the distance from the river. However, this correlation is not statistically significant at the conventional 5 or 10% level ($r = -0.055$; $p < 0.17$). Comparing the damage costs across different inundation levels, we find that the damage costs are more or less the same at lower inundation levels, but increase as inundation depth increases (Fig. 4). The outcome of the Kruskal-Wallis test confirms that

	Below Poverty Threshold	Above Poverty Threshold	MW Test Z-Statistic (2-Tailed Sig.)
Inundation level (0–5)	3.19 (0.949)	2.82 (1.103)	−4.540 ($p < 0.001$)
Landownership (ha)	0.29 (1.20)	0.36 (0.49)	−3.606 ($p < 0.001$)
Average flood damage (US$/year)	191 (928)	204 (242)	−4.791 ($p < 0.001$)
Average flood damage as share of household income (%)	41.6 (103.1)	16.6 (18.9)	−6.399 ($p < 0.001$)

Table II. Differences Between Floodplain Residents Living Under and Above the Poverty Threshold Value in Terms of Inundation Level, Landownership, and Absolute and Relative Flood Damage Costs

Explanatory notes:
Mean values (standard deviations in parentheses).
MW: Mann-Whitney test.

	Below Poverty Threshold (%)	Above Poverty Threshold (%)	Total
Household income fully dependent on natural resources	14.7 ($n = 99$)	10.4 ($n = 70$)	25.1 ($n = 169$)
Household income not fully dependent on natural resources	33.8 ($n = 227$)	41.1 ($n = 276$)	74.9 ($n = 503$)
Total	48.5 ($n = 326$)	51.5 ($n = 346$)	100 ($n = 672$)

Table III. Cross Tabulation of the Number of Floodplain Residents Living Under and Above the Poverty Threshold and the Number of Floodplain Residents Whose Income Depends Fully on Natural Resources (Land for Crop Cultivation and Fishery)

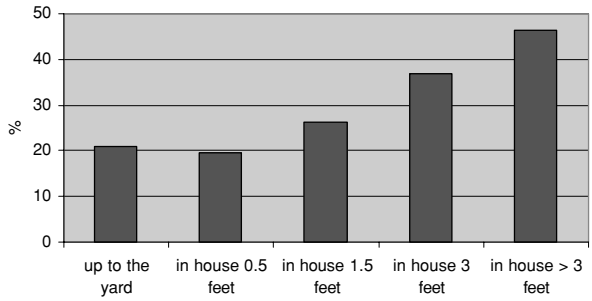

Fig. 4. Relationship between average annual damage costs as a percentage of annual household income and inundation level.

this increase is statistically significant ($\chi^2 = 9.626$; $p < 0.05$).

The relationship between poverty and the consequences of the environmental risk involved proves rather complex. We test the hypothesis that the poor suffer most from being exposed to environmental risk by further examining the relationship between flood damage and income, income distribution, income dependency on natural resources, and access to these natural resources. Damage costs appear to be significantly and positively correlated with household income ($r = 0.412$; $p < 0.001$) at individual household and village levels, suggesting that floodplain residents who are better off in economic terms also are most sensitive and vulnerable to suffer economic damage. Although this finding rejects the hypothesis that the poor usually suffer most when faced with a natural disaster, the result seems perfectly plausible. The more one has, the more can be lost or is at stake to be lost.

The results are confirmed when examining average damage costs between floodplain residents living under and above the poverty threshold. Although the former face significantly higher inundation levels, they have slightly, but significantly lower (absolute) average damage costs (Table II). However, in relative terms compared to annual household income, the share of annual damage costs is significantly higher for floodplain residents living under the poverty threshold than for floodplain residents living above this threshold. This latter finding confirms the hypothesis.

Average annual flood damage costs vary significantly across different occupational groups (Kruskal-Wallis $\chi^2 = 72.250$; $p < 0.001$). Fish cultivators suffer most damage (US$307) as a result of flood damage to artificial ponds and loss of fish stock, followed by farmers (US$227) and tradesmen (US$209). Although still substantial, the damage suffered by other occupational groups (ferrymen, taxi drivers, and day laborers) is significantly less (US$95). This finding corresponds more or less with the results presented earlier in Section 6, with crop damage, house property damage, and fish loss being the most important damage cost categories. The distribution of flood damage across occupational groups slightly changes when we examine relative damage costs. The share of flood damage relative to household income appears to be highest for farmers (35%), followed by fishermen (32%). This percentage is more or less the same for the other occupational groups (20%).[8]

At the community level, greater income inequality appears to result in higher flood damage costs ($r = 0.176$; $p < 0.001$), suggesting that a policy pursuing income equality may also have important economic benefits in terms of avoided damage costs in a flood-prone country such as Bangladesh. This finding furthermore confirms the hypothesis that vulnerability is determined—*inter alia*—by income inequality (e.g., Adger, 2000). The assumption behind this hypothesis is that inequality is linked to the extent to which resources are allocated communally.

[8] The different occupational groups earn significantly different incomes (Kruskal-Wallis $\chi^2 = 39.108$; $p < 0.001$). Tradesmen have the highest annual household income (US$1,490), followed by farmers and fishermen, who have more or less the same household income (respectively, US$1,095 and US$1,060 per year), and ferrymen, taxi drivers, and day laborers, who also earn more or less the same (respectively, US$670, US$640, and US$645 per year).

	Fully NRDI	Not Fully NRDI	MW Test Z-Statistic (2-Tailed Sig.)
Average inundation level (0–5)	3.23 (0.98)	2.93 (1.05)	−3.159 ($p < 0.002$)
Average flood damage (US$/year)	94.9 (139.8)	231.9 (770.5)	−6.244 ($p < 0.001$)
Average flood damage as share of household income (%)	20.7 (29.0)	31.6 (84.0)	−2.159 ($p < 0.03$)

Table IV. Differences Between Floodplain Households Fully Dependent on and Floodplain Residents Not Fully Dependent on Natural Resources in Terms of Absolute and Relative Flood Damage Costs

Explanatory notes:
NRDI: National resource dependent income (agriculture and fishery).
Mean values (standard deviations in parentheses).
MW: Mann-Whitney test.

Communities with a more equal distribution of income and wealth are more likely to spend resources on collective projects such as flood protection than if resources are concentrated in the hands of a small section of the population. This will be true for poor communities as well as richer communities. Higher levels of income equality tend to produce more cohesive communities that are able to collectively support each other.

Corresponding with the result found for damage and income, the more assets someone owns (i.e., land for crop cultivation) and the higher the share of natural resources in income generation (agriculture and fishery), the higher the damage costs involved as a result of flooding ($r = 0.409$ and $r = 0.430$, respectively, at $p < 0.001$).[9]

However, for floodplain households that fully depend on natural resources (the poorer segment in the floodplain sample) we find on the other hand that their absolute and relative damage costs are significantly lower than those for households who do not fully depend on natural resources (Table IV). Whether this suggests that income diversification is not an effective vulnerability-coping strategy will be discussed in the next section.

9. COPING STRATEGIES AND SOCIOECONOMIC VULNERABILITY

Flood damage costs can be mitigated by measures aimed at preventing, avoiding, or alleviating the physical and socioeconomic impacts of flooding. As mentioned in Section 2 (Fig. 1), we distinguish between *ex ante* and *ex post* coping mechanisms at individual and collective levels. Following the results presented at the end of the previous section, we start with the *ex ante* adaptation strategy of income diversification (e.g., Few, 2003). This will be followed by a discussion of *ex ante* prevention measures at the individual household level and we will end this section with a presentation of *ex post* coping mechanisms at the community level.

When relating flood damage costs to the number of income sources, we find an interesting trend where an increase in income sources seems to go hand in hand with lower average damage costs (Fig. 5). The observed trend is furthermore statistically significant at the 1% level (Kruskal-Wallis $\chi^2 = 14.325$; $p < 0.006$). The flood damage costs increase significantly from one to two income sources, but decrease gradually from there onward, suggesting that income diversification is indeed an effective coping strategy.

At the village level income diversity appears to be significant and positively correlated with the distance people live from the river Meghna ($r = 0.209$; $p < 0.001$). Households living further away from the river not only have more income (and income is more

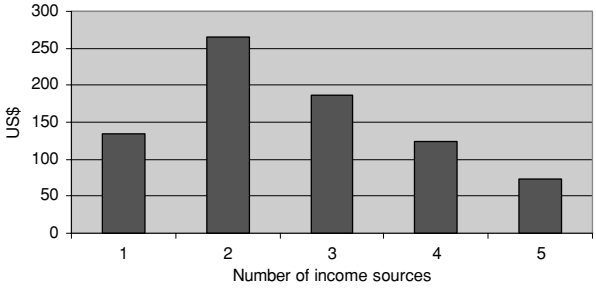

Fig. 5. Relationship between average flood damage cost (vertical axis) and number of income sources.

[9] The hypothesis that asset erosion results in more insecurity and hence vulnerability (Moser, 1998) cannot be tested here as this requires a more thorough time series analysis.

	Preventive Measures Taken	No Preventive Measures Taken	MW Test Z-Statistic (2-Tailed Sig.)
Average household income (US$/year)	1,513.8 (1,094.3)	976.3 (926.3)	−2.343 ($p < 0.02$)
Average flood damage (US$/year)	245.6 (122.2)	391.3 (1,831.4)	−2.030 ($p < 0.05$

Table V. Differences Between Floodplain Residents Who Take Preventive Measures and Floodplain Residents Who Do Not in Terms of Household Income and Flood Damage Costs

Explanatory notes:
Mean values (standard deviations in parentheses).
MW: Mann-Whitney test.

equally distributed), they also have significantly more sources of income. Hence, at the household level the relationship between flood damage and income diversity suggests that the latter is an effective coping mechanism for environmental risk, but at the village level communities that face the highest risk of flooding seem to be the least well prepared.

Turning to preventive (*ex ante*) measures, a majority of 86% of the floodplain residents interviewed in the follow-up survey (see Section 3) take no preventive measures for a variety of reasons; most importantly because they have insufficient financial means to protect themselves against flooding (45%), followed by not knowing which type of measures to take (30%), and the belief that flooding is a natural process that cannot be prevented (21%).[10] Floodplain residents in the follow-up survey taking preventive measures, primarily through land elevation works, earn significantly higher incomes and have significantly lower damage costs (also in relative terms) (Table V). Hence, taking preventive measures pays off as it significantly reduces annual flood damage costs, but implementation seems to be significantly constrained by limited income resources.

When asking floodplain residents in the original sample about their attitudes toward flood protection, 80% of all respondents say that they consider flood protection (very) important. Thirteen percent believe this is not important. Interestingly, comparing floodplain residents who consider flood protection not important with those who believe this is (very) important, the latter live significantly further away from the river than the former and earn significantly more income.[11] However, in the case of inundation depth during floods and annual flood damage the relationships are as expected, i.e., those who believe flood protection is (very) important face significantly higher inundation depths during the rainy season and suffer significantly more damage.[12]

In the follow-up sample, floodplain residents were also asked which type of embankment they prefer. A majority of 53% prefers controlled flooding, i.e., a submerged embankment in the river, which allows the whole area to flood regularly, but protects the area from extreme floods (flood disasters). About one in every fifth floodplain resident (22%) prefers a completely closed embankment (no flooding at all) and an equal number of floodplain residents (21%) have a preference for a partly closed embankment, which allows only certain parts of the area to be flooded every year. No large differences were found here between floodplain residents who already take preventive measures and those who do not.[13] Similar results have been found by Rashid (2000), who showed that a majority of floodplain residents—mainly farmers—prefer regulated flood levels instead of total flood prevention, where the preferred level of inundation corresponds with the ideal flood depth for the cultivation of floodplain rice.

From the key informant interviews, it appears that the existence of social networks or an institutional set-up in the area for a more collective *ex ante* or *ex post* coping strategy to flooding is very thin. Moreover, no differences between villages in this poor and severely flood-struck area can be detected in terms of formal or informal institutional arrangements to

[10] The remaining 4% indicated not suffering from flooding.

[11] The Mann-Whitney Z statistic equals −1.881 ($p < 0.06$) in the case of household income and −3.462 ($p < 0.01$) in the case of distance from the river.

[12] The Mann-Whitney Z statistic equals −6.436 ($p < 0.01$) in the case of inundation depth and −4.255 ($p < 0.01$) in the case of annual flood damage.

[13] When asking respondents who they believe is responsible for flood control in their area and who should pay if an embankment was to be constructed to protect the area from flooding, a majority of 82% refers to the central government, followed by foreign aid agencies (12%). Less than 5% believe that the local residents should pay.

cope with flood hazards within the community.[14] Poor flood-affected families are allowed to take shelter in village schools or higher local government buildings, where they can stay as long as the area remains flooded (weeks/months). Families who lose their home and livelihood and remain without savings or other sources of income can move to flood relief camps in the district (upazilla) headquarters, which are usually set up and managed by local government. Most of the flood-affected people barely have any savings or food stocks. Based on the 2004 regional flood report (LCG Bangladesh, 2004), it was estimated that flood-affected floodplain residents required food aid for between 150 and 180 days as they did not have any possibilities of income generation until the next harvesting season.

Also the existence of formal credit institutions to help rehabilitate flood-struck households in the study area is rare. Flood-affected families mainly cope with a flood crisis with the help of informal credit. Relatives, neighbors, and family friends help flood-affected families by providing loans and other assistance, or flood-affected families buy food from local shops on a credit basis. Sometimes, richer, well-off families in a village lend money to flood-affected local residents. A number of leading NGOs that deal with microcredit also operate in the study area. Although existing literature suggests that these NGOs play an important role in *ex post* coping response to flood disasters by distributing flood relief, agricultural inputs and subsidized microcredits in flood-affected regions in Bangladesh (Zaman, 1999), most key informants in this particular area stated that they play almost no role at all. Most flood-affected families depend on relatives, neighbors, and informal microcredit systems to cope with floods.

A study based upon survey data collected after the 1988 flood disaster (Haque & Zaman, 1994) shows that around 70% of the affected farmers in Bangladesh mitigated their income and asset losses by selling land, livestock, and other belongings. This was not observed in our case study, or mentioned by the key informants as an effective common coping strategy, possibly because of the fact that many floodplain residents in this specific case study area are so poor (half of the sample lives under the poverty threshold) that they have no assets to sell.

[14] In certain protected parts of Bangladesh, the existing flood protection schemes are operated and managed by local stakeholders who are organized in cooperatives (Quassem, 2001).

Finally, we also investigated possible migration patterns as a result of flood-related problems in the case study area. About a quarter of the sample have relatives that moved outside the area in the past 15 years, mainly because of economic considerations (e.g., work in Dhaka or abroad). When asked, only 2% said that the main reason for moving is directly related to the flood problems experienced in the area. This seems to imply that migration is not considered a direct coping mechanism. However, given the negative relationship between the physical conditions in the area (severely flood prone) and the area's economic development (one of the poorest regions in Bangladesh) and the substantial share of remittances in total household income (16%), it is our opinion that migration does seem to play a role as a flood coping mechanism in combination with income diversification.

10. DISCUSSION AND CONCLUSIONS

In this article, we investigated the complex relationship between environmental risk, poverty, and vulnerability in a concrete case study carried out in one of the poorest and most flood-prone countries in the world, focusing on household and community vulnerability and adaptive coping mechanisms. Building upon the growing theory and empirical evidence regarding these relationships, we produced our own simple analytical model and tested relationships between the model's core variables in (as far as possible) a systematic way, using data and conventional indicators from a large-scale survey of households in rural Bangladesh. Although a number of studies have been carried out in Bangladesh looking at poverty and flood coping strategies, such a systematic examination of the concept of socioeconomic vulnerability is currently lacking. The case study area is situated in one of the poorest and most flood-prone areas of Bangladesh, making it an ideal case for further testing of the mentioned relationships. Novel in our study is the explicit testing of the effectiveness of existing preventive and adaptive coping strategies in terms of their impact on flood damage costs.

Our results confirm the positive relationship between environmental risk, poverty, and vulnerability. Poorer segments of society live closer to the river, and therefore face a higher risk of flooding and are thus more vulnerable. We were able to show that actual inundation levels are indeed significantly higher for poorer households. At the same time, environmental risk exposure also goes hand in hand with income

inequality and access to natural resources: higher exposure levels are associated with higher inequality and less access to land. Inequality also results in higher flood damage, confirming the hypothesis found in the literature that an unequal income distribution contributes to socioeconomic vulnerability. However, the relationship between poverty and damage costs (and hence vulnerability) appears to be more complex than the literature suggests. The poor suffer more in relative terms, but not in absolute terms. Average damage costs in absolute terms are significantly higher for wealthier households. Their coping capacity is, as expected, also greater than poorer households, reflected by the fact that the relative proportion of the flood damage costs in total household income is significantly lower for wealthier families. Farmers and fish cultivators suffer most damage, both in absolute and relative terms. Approximately one-third of their annual household income is lost due to flooding.

Floodplain households that fully depend on natural resources for their livelihood (the poorer segments in society) suffer significantly less damage, but from our analysis we conclude that this does not exclude income diversification as an effective flood coping strategy. On the contrary, more income sources appear to result in lower average damage costs, suggesting that spreading the environmental risk across multiple economic activities pays off. However, we find that income diversification is primarily a strategy followed by wealthier families and communities living further away from the river. Families living nearer to the river seem to have fewer opportunities to engage in multiple economic activities, which makes them more vulnerable to natural disasters, and may keep them trapped in a poverty cycle (see, for example, Chambers, 1995). The latter conclusion cannot be further substantiated in this study as the study merely provides a snapshot of the current situation. A more detailed time series analysis is required to test the hypothesis that poorer segments in society depending on just one or two natural sources of income are trapped in a downward poverty spiral due to asset erosion. A similar situation is observed for preventive measures. Floodplain households taking preventive measures earn higher incomes and have significantly lower damage costs in absolute and relative terms. Also, the implementation of preventive measures is constrained by limited financial resources, although a substantial proportion of floodplain residents do not take any preventive measures because they believe that flooding is a natural process, which cannot be prevented.

Regarding the availability of *ex post* disaster relief, we used information from semistructured key informant interviews to assess the existence of social networks and institutional arrangements to support flood victims. It appears that the availability of such community-level support is generally rather low, although some degree of flood relief exists in the form of loans to flood victims from family members, neighbors, rich members of the community and credit for food from local shops. Using the assumption that communities with a more equal income and wealth distribution are more likely to have social networks to provide flood relief, we find that villages with higher risk exposure also have more unequal income distributions, suggesting that they have a lower provision of community-level organization to cope with flooding. We therefore find, somewhat paradoxically, that the people who face the highest risk of flooding are the least well prepared, both in terms of household-level *ex ante* preparedness and community-level *ex post* flood relief. There is clearly a need for more government involvement to either provide further flood protection and flood relief directly, or to stimulate household- and community-level efforts to protect and support flood victims. Moreover, policies that pursue income equality may also be effective in that they will have important economic benefits in terms of avoided damage costs.

In terms of *ex ante* flood protection, controlled flooding is the preferred option among floodplain residents interviewed in our survey. One possibility is the construction of submerged embankments in the river, which allow regular flooding and the cultivation of floodplain rice, but protect the area from disaster floods. Such a preventive structure furthermore avoids damage costs as a result of water logging, in the case of a fully enclosed embankment, or erosion of floodplain soils.

Regarding the provision of *ex post* flood relief, NGOs operating in Bangladesh could potentially facilitate health care, microcredit, and insurance services. Insurance schemes in particular appear to be a promising option for providing support to even the poorest sections in the community. Such schemes could be targeted at different occupational groups and provide cover for flood-related material damage, health care, and unemployment.

As a final methodological note we want to emphasize that the analysis presented in this article is primarily based on observed associations and relationships, using linear correlations and nonparametric testing procedures. An important question remains how

much the observed relationships actually tell us about underlying (nonlinear) causal relationships and in which direction these causal relationships act. We believe that a more extended deterministic model is needed to further test these underlying causal relationships and their direction in future research in this domain.

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